FIRST BOOK

IN

PHYSIOLOGY.

FOR THE USE OF

SCHOOLS AND FAMILIES.

INTENDED AS INTRODUCTORY TO THE LARGER WORK
BY THE SAME AUTHOR.

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PREFACE.

THIS book is intended for *beginners* in the study of Physiology, of whatever age they may be. It is a "First Book" for the adult as well as for the child. There is more in common between young and adult minds, in regard to a subject which is new to them, than is commonly supposed. There is for both the same need of simple, clear, and precise statement, with familiar illustration. A book intended to instruct a child in any science should be so written, that it will be just as instructive to an adult unacquainted with the subject. Not only so, but it should be so written, that it will interest and please a mind that has a full knowledge of the subject, by its logical and clear development of simple fundamental facts and principles.

It is a common error to suppose, that there need not to be as logical a presentation of a subject in teaching children as in teaching adults. A correct logic, in the true sense of that word, is necessary in either case. In teaching any science, no matter what the age of the scholar may be, a natural, that is, a logical, arrangement of the facts and principles, is essential to success. Indeed, it is more essential at the outset than it is subsequently, for the beginner lays the very foundations of his knowledge, upon which in his course of learning afterwards he builds up the superstructure. It is the *simple* facts and principles of science, such as should be taught to the beginner, that are *fundamental*. In order that he may begin right, he must acquire a clear idea of these.

This, it is obvious, cannot be done by a loose, partial, and ill-arranged presentation of them, but only by a presentation that is strictly logical. Commonly, this foundation-work, as it may be termed, has to be done over and over again, bringing much unnecessary labor to both teacher and scholar, simply because it is not done right at the outset.

There is another consideration bearing upon this point, which is of great importance. It is essential to the successful study of science that good habits of mind be formed, and the earlier they are formed the better. I need not stop to show that clear logical presentations of facts and principles tend to form such habits, and that a loose, confused mode of presenting them tends to form habits of an opposite character.

Let me not be understood to advocate that prominence of logical framework, as it may be called, which is so common in books for instruction. With all this show of logical arrangement, there is often much that is really very illogical. With the beginner, at least, the less there is of the formalities of arrangement the better. And yet there should in reality be a strict regard to the proper logical order in introducing facts and principles to the mind of the learner. If this natural order be observed, every page that the student learns serves to prepare his mind for what comes after. There is no point in which books for instruction so often fail as in this.

Most books for the instruction of beginners in science, present a strange mixture of child's talk, and language that the child cannot understand, but can only learn by rote. Even the hard technical terms of science often enter abundantly into the compound. It seems to be forgotten that *great simplicity of language may be the vehicle of even a deep philosophy, and is consistent with an elevated style.* Clear, precise statement, logical order of arrangement, and felicitous illustration, are the elements of such a style. And these elements cannot exist, unless there be an appreciation in the writer's mind of the attitude of the minds that he addresses. He must not only see clearly the facts and principles of science himself, but he must know how to make others see them clearly also.

It is obvious that in a "First Book" there must be a less number of points introduced than in a book intended for instruction afterward. The field of vision should be gradually enlarged as the learner advances. At first there must be a selection of such points as he can most readily understand, reserving the more difficult ones for another book. And while the second book should be much more complete than that which is designed for beginners, yet in the latter the really essential and fundamental parts of the science should be clearly presented.

The principles thus advanced I have endeavored to follow in the construction of this little work. It is intended principally for the use of common schools, and yet, like my larger work on Physiology, it is adapted for general reading. It will prepare the reader and the scholar for the more full examination of the subject in the larger work.

I need hardly say, that in order to teach from this book satisfactorily, it is necessary for the teacher to read both books. By doing so, he will see clearly in every case the reason of the selection that I have made in this work from the facts that are presented so fully in the other, and will therefore be better prepared to teach according to the plan that I have in view. The questions that I have placed at the bottom of each page can be altered as the teacher thinks best, to suit the different capacities of his scholars. For certain general directions in teaching Physiology, I refer him to the Appendix of my larger work.

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FIRST BOOK IN PHYSIOLOGY.

CHAPTER I.

THE MACHINERY OF THE BODY.

1. When you look at any machine made by man, you inquire what it is intended to do. You find, commonly, that it is for some one purpose. Thus, a nail-machine makes nails, and does nothing else ; a paper-machine makes paper ; a locomotive draws cars on a track ; and so of other machines.

2. But the human body is not a single machine for a single purpose. It is a complicated machine, and serves many purposes. It differs very much in this respect from the machines that man makes. While for example, it is a machine that walks, walking is not the only thing that it does. It is not like the locomotive, that does nothing but draw cars. It can perform a great variety of motions besides walking. It can run, jump, leap, climb, &c.

3. You see the same difference, if instead of looking at the body as a whole, you look at any particular part of it. Look, for example, at the hand, and com-

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What is said of machines made by man? How does the machinery of the body differ from these?

pare it with the most ingenious machinery that man has ever made. The variety of things that it can do is almost endless. So, too, if you open your mouth before a looking-glass, and move about that busy little machine, the tongue, you will get some idea of the great variety of motion that it can perform.

4. But besides being a locomotive machine, capable of all this variety of motion, the human body is also a machine in which many things are made. Blood is made in it. This red fluid is made out of the food which this machine puts into its mouth and eats. And then from the blood are made all the various parts of the body.

5. In order that the blood may be used to construct all parts of the body, it must be carried everywhere. There is a wonderful set of machinery to do this. The heart is pumping night and day, sending out the blood through the pipes that branch out from it all over the body.

6. Then the blood, when it has been used, is not fit to be used again until it is changed. There is, therefore, a set of machinery in the chest for the purpose of changing the blood. The blood is carried to the lungs, and there it is exposed to the air that we breathe into the lungs every time that we draw a breath. By being *aired* in this way, it is fitted to be used again, and it goes back to the heart that it may be pumped out again all over the body.

7. But the most wonderful machinery in the body

Mention some particular parts of the body in which this difference is seen. What is made by the machinery of the body? By what machinery is the blood circulated? How is the blood changed after it has been used?

is that which we find in the nervous system. The brain is the great central organ of this system. From it branch out white cords, called nerves, which are found in every part of the body. This nervous system is somewhat like a telegraph, though it is much more perfect and mysterious. The brain may be considered as the central office, where the mind has its seat. The nerves may be called the wires, by which messages are sent forth and received by the mind.

8. Messages are sent by means of the nerves to the muscles, whenever the mind wills that any part of the body move. Thus, when you wish to move your hand, messages are sent from the brain to the muscles that move this part. When the mind wills that the whole body shall move, a great number of these messages are sent in all directions at once.

9. The mind too receives messages through the nerves. It receives them from the senses. When we see, something is sent by means of the nerves of the eyes to the brain, and thus reaches the mind, just as electricity goes along the wires of a telegraph. And the same may be said of the other senses.

10. Observe now how great a variety of machinery there is in the body. The digestive machinery grinds up the food with its teeth and mixes it with juices in such a way that blood is made out of it. Then the machinery of the circulation moves the blood about everywhere in the body, so that all the parts may be made out of it and be kept in repair. The breathing

What is the most wonderful machinery in the body? What is it like? And how? Describe what is done when the muscles act. How and from what does the mind receive messages? Give what is stated in ¶ 10 about the variety of the machinery in the body.

machinery continually purifies the blood after it has been used, and so fits it again for use. Then by means of the nervous machinery the mind uses the parts that are thus constructed from the blood—viz., the muscles, the bones, and the organs of the senses.

11. You see that some of the machinery of the body is for the purpose of making other machinery. This is the business of the machinery of the digestion, the circulation, and the respiration. This machinery makes nerves, and muscles, and bones, and the brain, and the eye, and the other organs of the senses. The object then of eating and drinking and breathing and having the blood circulate, is to make machinery for the mind to use.

12. There is one difference between the machinery of the body and the machines constructed by man, that I have not yet mentioned. When man makes a machine he cannot use it till it is completed. If he wishes to alter it or repair it, he cannot use it at all while he is doing this. But the machinery of the body is *constantly altered while it is in use.* I will illustrate this difference.

13. The machinery of the child's body is small machinery, but every part of it gradually becomes larger, and in manhood it is of its full size. But no machine made by man can grow to be a larger one. Now, the machinery of the body not only grows, but it is kept in use while it is growing. A small telescope never grows to be a large one, but the little eye of the infant

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Can the machinery that man makes be kept in use while he is altering or repairing it? How is it with the machinery of the body? What is said of the growing of the machinery of the body?

grows to be the large eye of a man, and is used every day while this is done. A cord does not grow to be a rope, but the muscles grow as we use them.

14. The machines that man constructs cannot be repaired while they are in use; they have to *lie by for repair*, as it is expressed. It is not so with the machinery of the body; repairing is going on while it is in use. In the machinery made by man it is done only now and then, but in the machinery of the body it is done all the time, every day, every hour, every moment.

15. One thing is to be noticed, however, about this repairing of the body. Some of its machinery must have seasons of rest, in order that the repairing may be thoroughly done. This is the case with the brain, the nerves, and the muscles. When the mind has worked these parts of the machinery during the day, the rest of night is needed to repair fully the wear and tear. Though the business of repairing them is going on all the time, more of it is done while they are at rest in the hours of sleep than when we are awake.

16. Another thing to be remarked is, that when the machinery is much deranged by disease, more rest than is commonly taken at night is needed. There must be some lying by for repair now. Thus, if a limb be inflamed, it must be kept still. An inflamed eye needs to have the light shut out from it. If the brain be diseased, the mind must be kept from using

Does the machinery of the body lie by for repair? What parts of the machinery of the body must have seasons of rest to have the repairing well done? What is said of the need of rest for repairing in disease?

it as much as is possible; that is, it must be kept from thinking. And what is true of particular parts of the machinery is true of it as a whole. When the whole body is disordered, as in fever, all the machinery must be kept as quiet as possible.

17. There is some of the machinery that never stops, either when we are sick or when we are asleep; it is the breathing and the circulating machinery. The heart is always beating, and the chest is always heaving; they never rest from their work, and they are stopped only by death.

18. In this chapter I have given you some general views of the machinery of the body. In the following chapters I shall describe particular parts of it, and shall explain to you how they operate. I shall speak of the machinery of digestion, of circulation, of respiration, the nervous machinery, &c., each of them separately.

CHAPTER II.

THE DIFFERENT STRUCTURES OF THE BODY.

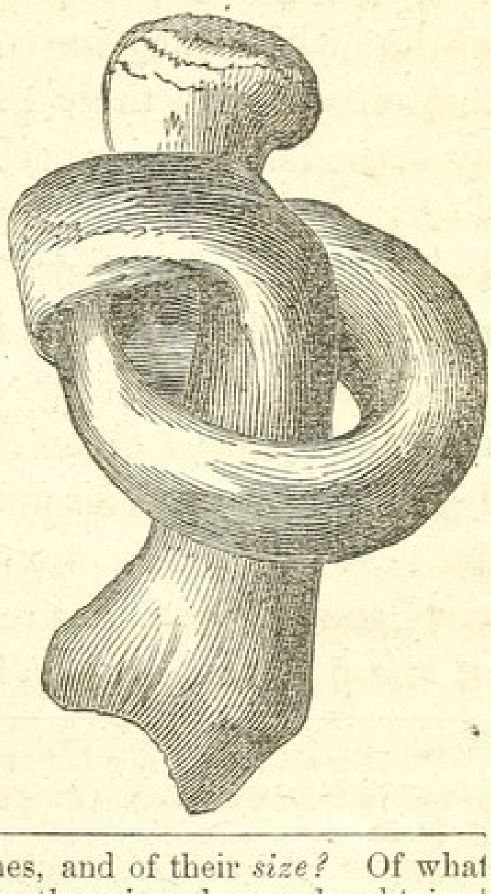
1. Before considering each subject particularly, let us look in this chapter at some of the various things or structures that make up the machinery of the body. By doing this, these subjects will be more clear to you. For, as I shall mention different parts of the body, as I proceed, you will understand me better, if you have some knowledge of these parts at the beginning.

What parts of the machinery of the body never rest?

2. Notice first, the hard bones which are the framework of the body. These are very different in their *shapes* in different parts of the frame. For example, in the leg and arm they are long and slender, while in the head they make a box to hold the brain. They vary much in *size* also.

3. The bones are composed partly of mineral and partly of animal substance. When you see a pile of bones near a slaughter-house, which have been a long time exposed to the air, you see only the mineral part of them. The animal or soft part has been taken away by the heat of the sun and the washing of the rain. The same thing can be done, very quickly, by exposing a bone to a very hot fire. A bone thus deprived of its animal part is very brittle, and breaks easily.

FIG. 1.



4. The animal part of a bone can be obtained also separate from the mineral part. This can be done by putting it into a mixture of an acid, called muriatic acid, and water. The acid takes the mineral part away, and leaves the animal part in perfect shape. While the mineral part is brittle, this soft animal part can be bent so as

What is said of the *shapes* of the bones, and of their *size?* Of what two parts is bone composed? How can the mineral part be obtained separate from the other part? How can the animal part be obtained by itself?

to be tied into a knot, if the bone be one of the long ones. Fig. 1 represents a thigh-bone thus tied, after being deprived of its mineral part.

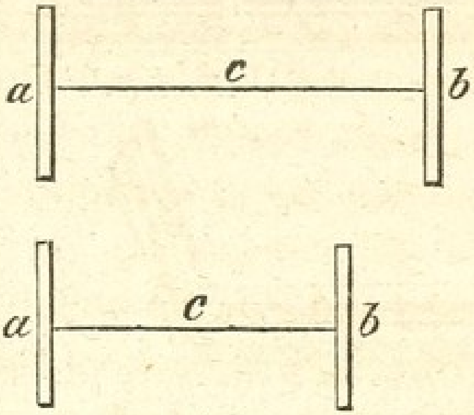
5. In the child, when the bones are growing, they do not have as much of the mineral part as the bones of old persons do. It is well that they do not; for if they did, the frequent falls of the child would often give him a broken bone. If an old person should have as many falls as children commonly do, his brittle bones would very often snap asunder. A fall down stairs, which in the child is generally followed only by a momentary fright, a short crying-spell, and perhaps a bruise, is apt to break some bone in the old, and may even destroy life.

6. The bones are bound together by firm *ligaments*, so that while they move on each other at the joints, they are held in their places. The bones are moved by *muscles*. The muscles make up the bulk of the fleshy part of the body. Their color is red. The *tendons* are white and shining cords, by which the muscles pull the bones, in moving them.

7. As I must refer occasionally to the action of muscles before I come to the chapter on the muscles, I will explain to you now the manner in which they act. A muscle is composed of a great number of very small fibres or threads. When it acts, each one of these fibres shortens itself.

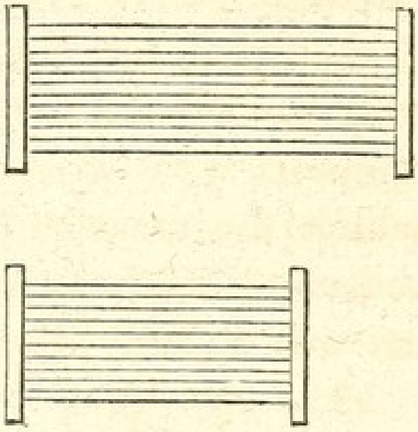
What is the difference between the bones of the old and those of the young in regard to these two parts? What would happen to the child if there were not this difference? By what are the bones bound together? By what are they moved? What are the tendons? What is a muscle composed of?

FIG. 2.

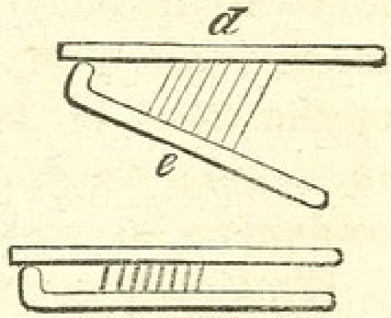


8. I will show how this shortening of the fibres moves the bones, by means of some figures. Suppose *a*, in Fig. 2, is a bone that is fixed so that it cannot be moved, and that *b* can be moved. Let *c* be a fibre that extends from the one bone to the other. If the fibre *c* shorten itself, it will draw the bone *b* towards *a*, as represented in the lower figure. The same thing is true of a number of fibres, as represented in Fig. 3. You see, then, how it is true of a multitude of fibres, as they are bound together in a muscle.

FIG. 3.



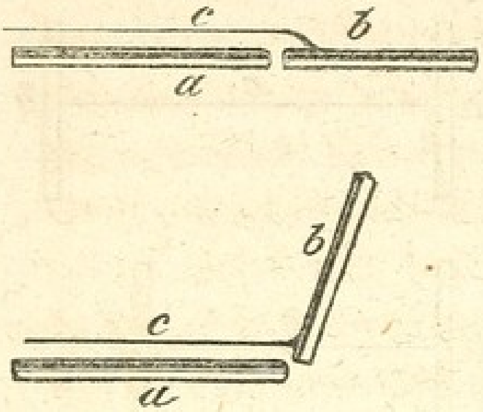
FIGS. 4, 5.



9. Let *d*, in Fig. 4, represent a bone that is fixed, and *e* a bone that moves on *d*, with a hinge-like joint. If the fibres are relaxed, the bone *e* will be as in Fig. 4; but if the fibres contract, the bone will be as in Fig. 5. These two figures show the action of the lower jaw, as it is moved up and down by the muscles, in eating. In Fig. 4, *e* is like the lower jaw when it is down; and in Fig. 5 it is like it when it is up, so that its teeth press against those of the fixed upper jaw.

Explain by figures 2 and 3, how the fibres of a muscle act. Illustrate the manner in which the muscles move the lower jaw in eating.

Figs. 6, 7.



10. Figs. 6 and 7 show you how the muscle that bends the elbow acts. In Fig. 6 the bones *a* and *b* are represented as they are when the arm is extended out straight. The muscle which is represented by the line *c*, is relaxed. When it contracts or shortens itself, the bone *b* will be bent upon *a*, as seen in Fig. 7.

11. These two examples of muscular action will be sufficient for the present. In some of the succeeding chapters you will see examples of other ways in which the muscles operate; and, in the chapter on the muscles, the many various ways in which they act will be fully illustrated.

12. I have thus spoken of the *bones* with their *ligaments*, and the *muscles* with their *tendons*. The limbs of the body are made up of these four structures. They compose also all the outer parts or walls of the trunk of the body and of the head. Within these walls are the three great cavities of the body, containing its most important organs.

13. In the cavity of the *head* is the brain. This delicate and soft organ is shut in very securely by that round box of bones, called the cranium or skull. The cavity of the *chest* contains the heart and the lungs. The walls of this cavity are the spinal column, or back-bone, as it called, the ribs, and the breast-

Illustrate the manner in which the muscles bend the arm at the elbow. Of what four structures are the limbs of the body composed? What other parts do they compose?

bone. These are strongly bound together by muscles and ligaments. In the cavity of the *abdomen* are the stomach, liver, &c. Its walls are the spine behind, and at the sides and in front, broad flat muscles and tendons. The organs contained in these three cavities I shall speak of in other parts of this book.

14. In all the different structures of the body of which I have spoken, there are blood-vessels, large and small, circulating the blood everywhere. Nerves too go everywhere, branching out from the brain and spinal marrow. They are whitish cords, which by dividing continually are distributed to all parts of the body. The blood-vessels and nerves are everywhere mingled together. For if you prick any part, the nerves feel the pain, and the blood-vessels at the same time let out their blood.

15. All the parts and organs of the body are well packed together. They are so arranged that there is no loss of room. And there is a kind of *packing material* made use of everywhere between all the parts. It is a very fine and nice material. You can see it if you look at a piece of meat from any animal. If you pull the fibres of the meat a little apart, you will see a delicate white substance between them. You will also see different portions of the meat separated from each other by considerable layers of this substance. These are the different muscles with the packing material between them.

16. This packing material, which is called the *cel-*

What are the three great cavities of the body? What are their walls? What do they contain? What is said of blood-vessels and nerves in the different structures of the body? What is said of the packing of the parts of the body?

lular membrane, is not only around all the muscles and between their fibres, but it is around everything and in almost everything in the body. It is full of little cells or spaces; and hence comes its name. In some parts these cells are larger than in others. The fat of the body is in cells of this substance, mostly just under the skin. When the cells contain fat they are larger than they usually are.

17. This cellular substance is very yielding, so that the motions of the body are not made less free by their being thus bound together by this packing material. When the muscles are performing some of their motions this substance is very much moved and stretched, but it always yields easily and is not torn.

18. The cells of this substance are kept moist by a very little watery fluid. When this fluid is in greater quantity than it should be, the disease called dropsy is present; and it is because the cells everywhere open into each other, that the water in this disease is so apt to accumulate in the lowest parts of the lower limbs.

19. Over all the parts of the body is the skin covering them up from our view. It also defends them from injury. While for this purpose it is very firm, it is at the same time quite yielding, so that it may not restrain the motions of the body. Underneath the skin the cellular substance is very abundant, connecting the skin with the muscles and other parts.

20. There is a kind of skin, called the *mucous*

Describe the appearance of the common packing material. What is said of the fat? What is said of the yielding character of the cellular membrane? What is said of its cells? What is said of the skin?

membrane, that begins in the mouth and nose, and lines all the passages to the lungs, the stomach, and other organs. It may be called the interior skin of the body. It is termed the mucous membrane, because it is moistened by mucus, a glairy fluid which constantly oozes from it. The red covering of the lips does not seem to be either skin or mucous membrane, but a texture somewhat like both of them.

21. The *serous* membranes are so called because they are moistened with a watery fluid called serum. They line the outside of some of the great organs of the body, and also the inside of the walls of the cavities that hold them. Thus the lungs are covered with a serous membrane, and the inside of the walls of the chest is lined with it. You can see what the object of this is: as the chest moves in breathing, the lungs rub a little against the walls of the chest; but the smooth shining serous membrane that lines them prevents the rubbing from doing any harm. The same thing is true of the organs in the abdomen. The rubbing of the stomach and the intestines against each other and against the walls of the abdomen, would make them sore and inflamed, if they were not all lined with this smooth and moistened membrane.

22. I have not described to you all the structures in the body, but only those that it is well for you to understand in the beginning. You will know more in relation to these as I proceed, and I shall also describe to you in the succeeding chapters some other structures.

What is said of the mucous membrane? What is said of the red skin of the lips? What are the serous membranes? What do they line? Of what use are they in the chest, and in the abdomen?

CHAPTER III.

DIGESTION.

1. I HAVE already told you in the first chapter that the blood, which is the common building material of the body, is made out of the food that we eat. That this may be done, the food must be *digested*, as it is termed.

2. Digestion is not a single and simple process; several things are done. First, the food is cut and ground by a sort of mill in the mouth; and while this is going on the food is thoroughly moistened by a liquid called the saliva. As fast as it is ground and moistened it is passed through a tube that extends from the back part of the throat down into the stomach. There the food is mixed with another liquid called the gastric juice. It is then passed on into the intestines. There all that part of the food that can be used to make blood is sucked up by a multitude of little vessels. These vessels join together to form a tube which empties itself into the blood. Having thus described in a general way the manner in which the nourishing part of our food is separated and extracted from it, let us look at the different parts of the process more particularly.

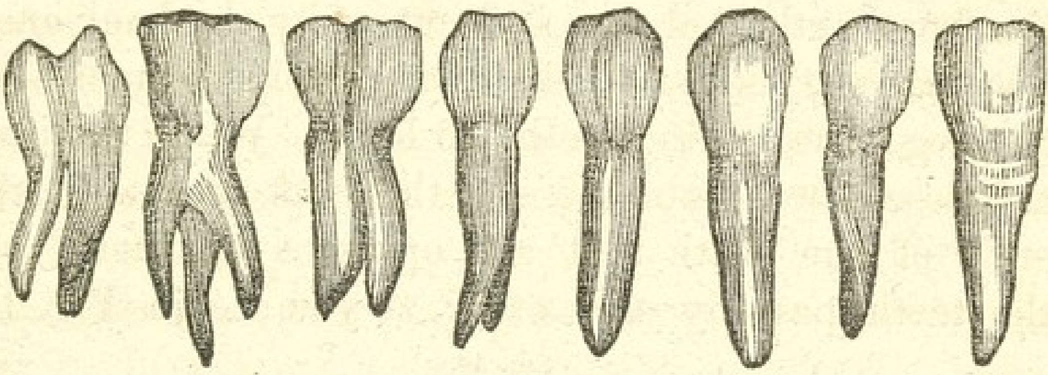
3. First, the food is cut and ground up by the teeth. The teeth, in order to be fitted for this work,

From what is the blood made? Is digestion one simple process? What is first done to the food? By what is the food moistened? What is done with it after it is ground and moistened? What is mixed with the food in the stomach? Into what does it pass from the stomach? What is done with it in the intestines?

are made very hard. They are the hardest substances in the body. None of the bones are as hard as they are. Their hardness is owing to the *enamel*. This forms a thick coat over all the body of the tooth down to the gum. It does not extend down on the roots, for it is not wanted there. The roots and all the inner part of the teeth are like common bone. The roots are fitted into sockets in the jaws so firmly that, as every one knows, it is very hard to pull them out.

4. In Fig. 8 you see a representation of half of the teeth of the upper jaw. Notice the difference in their

FIG. 8.

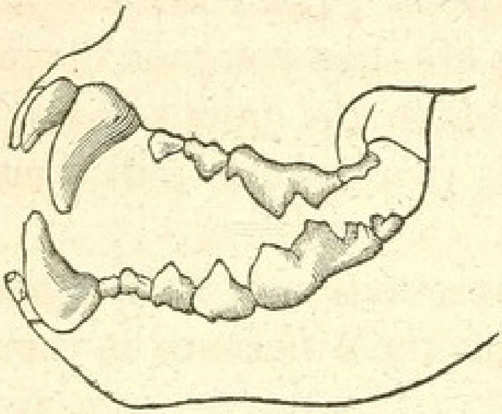


shape. At *a a* are the two front cutting teeth. They have sharp edges. At *d d d* are the three large back teeth. These have, instead of cutting edges, broad irregular surfaces, so that they can grind the food between them and the same teeth in the lower jaw. At *c c* are two smaller grinders. At *b* is what is commonly called the eye-tooth. It is so shaped that it neither cuts nor grinds, but tears. The tooth in the

What is said of the teeth? What is the enamel, and how is it arranged on the teeth? Describe the different kinds of teeth in man?

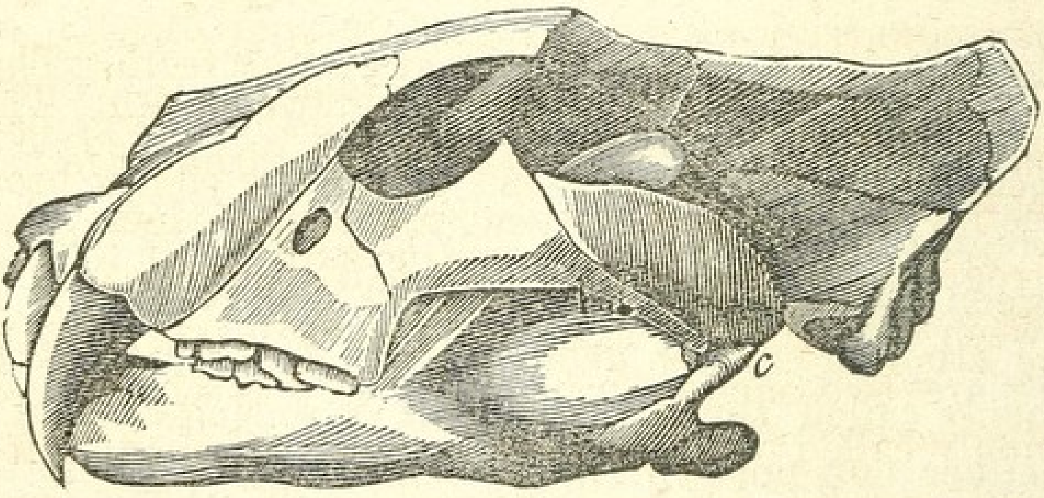
lower jaw that is like it is called the stomach-tooth. You see then that man has three kinds of teeth for eating his different kinds of food, viz., cutting, tearing and grinding teeth.

Fig. 9.



5. Different animals have different kinds of teeth, according to the kinds of food which they eat. In Fig. 9 you see the teeth of an animal that lives on flesh alone, called a *carnivorous* animal. The front teeth are tearing ones, while the back teeth have sharp edges for cutting. The flesh is first torn by the front teeth, and then it is cut up by the back ones. You can see these two kinds of teeth in the mouth of the dog. The tearing teeth are long. When the jaws are closed the ends of these teeth do not press upon the ends of the teeth that are opposite to them, but the teeth pass by each other, as you see in Fig. 10,

Fig. 10.

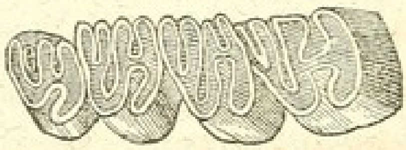


Describe the teeth of *carnivorous* animals. What arrangement of their tearing teeth gives them great power?

which is a representation of the jaws of a tiger. You see at once that this arrangement of these long tearing teeth gives them great power in tearing flesh to pieces.

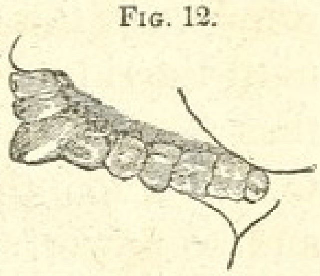
6. Animals that live on vegetable food, called *herbivorous* animals, have no tearing teeth. The horse and the cow are of this class. They have two kinds of teeth. There are cutting teeth in front, by which they crop the grass or draw the hay from the rack. There are also grinding teeth by which they grind up the food before they swallow it. In Fig. 11 you see the rough surface of some of these teeth. There is a peculiar arrangement of the enamel, which admirably fits them to grind up the fibres of the grass. The enamel is not merely on the outside as it is in our teeth, but there are ridges of it, as you see, standing up in the middle of each tooth.

Fig. 11.



7. Those animals that live on soft fruits do not need such grinders as the grass-eating animals do. They therefore have rounded teeth which serve to crush their food as represented in Fig. 12.

Fig. 12.



8. In the cutting, and tearing, and grinding of our food the lower jaw is moved against the upper one by means of muscles. They are the workmen of the mill, as we may say. These muscles work differently

Describe the teeth of *herbivorous* animals. What peculiar arrangement of the enamel do they have? What are the teeth of animals that eat soft fruits?

in different animals, according to the kind of food and according to the character of the teeth. Thus, when an animal eats vegetable food and has grinding teeth, the muscles have the power of making the grinding motion. If it were not so, the grinding teeth could not grind, but could only crush. You can see the difference between the grinding and tearing motion of the jaws, if you watch a dog and a cow while they are eating. The dog, as he tears his food, moves his lower jaw up and down against the upper jaw like a hinge. But the cow, as she chews her cud, gives to her jaw a sidewise motion, together with the hinge-like motion, and thus grinds the food. The dog does not need to grind his food as the cow does, and therefore he has no grinding teeth and no muscles that can perform the grinding motion.

9. Man eats all kinds of food, or is omnivorous; he therefore has the various kinds of teeth. But observe, that his grinding teeth are not such thorough grinders as the cow and the horse have. He does not need the ridges of enamel to grind the vegetable food that he eats, most of which he softens by cooking it. Observe, too, that his tearing teeth are not so long and so powerful as those that you see in the mouth of the dog and the tiger. The reason is, that he knows how to invent and use cutting instruments, and therefore divides his food very much before he eats it.

10. As the food is cut and ground by the teeth, it

Illustrate the difference in the working of the muscles in the carnivorous and herbivorous. Why is man called *omnivorous?* Why are his grinding teeth less powerful than they are in animals?

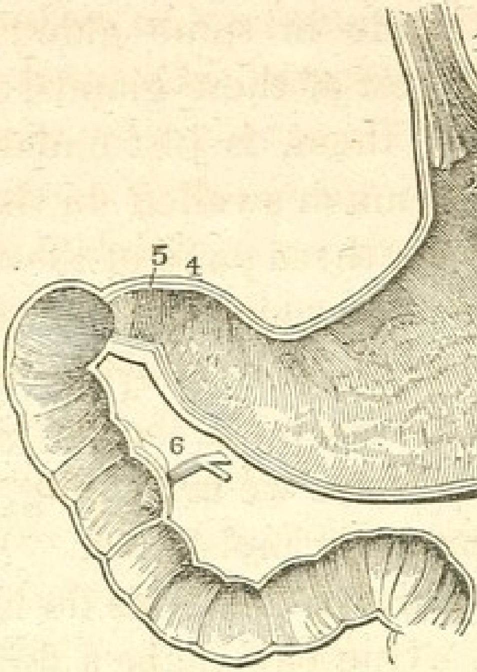
is well moistened by the fluid in the mouth called the *saliva*. This fluid is made in some glands in the neighborhood. The largest of these glands, or saliva-factories, as we may call them, is just under the ear. It is this gland that is so much swelled in the disease called mumps. There are three pairs of these glands, and they have ducts or pipes going from them, which open on the inside of the mouth. They are always at work making the saliva to keep the mouth moist, but they are especially busy while we are eating, in order that the food may be properly moistened.

11. All these three pairs of factories do not make the same kind of fluid. One pair make a fluid which is a little thicker than that which is made by the other two pairs. It is curious to see the reason of this difference. The thin fluid is mixed with the food while the mill is grinding it. The thick fluid is not poured out at all while this is going on; but the moment that we stop chewing, and the food is thrust back into the throat to be swallowed, the thick fluid is poured out and covers the food, so that it may slip down easily into the stomach.

12. The tube through which the food passes down into the stomach is called the œsophagus, or gullet. In Fig. 13 is represented the inside of the stomach with the beginning of the intestines. At 3 is the left end and at 4 is the right end. At 1 is the opening of the gullet into the stomach. At 5 is a valve which is sometimes shut, so as to prevent anything from pass-

By what is the saliva made? Where is the largest of these glands situated? How many of these glands are there? Are they equally at work all the time? Do they all secrete the same kind of fluid? What is the use of the thicker fluid made by one pair of these glands?

Fig. 13.



ing from the stomach into the intestine. This valve is called the *pylorus.*

13. While the food is in the stomach the gastric juice oozes out from all the inside lining, marked 8, and mixes up with the food. The mixture is very thoroughly made, because the stomach keeps up a sort of churning motion. After awhile the food, although it is sometimes of so many different kinds, is all changed into a greyish cream-like substance, called *chyme.*

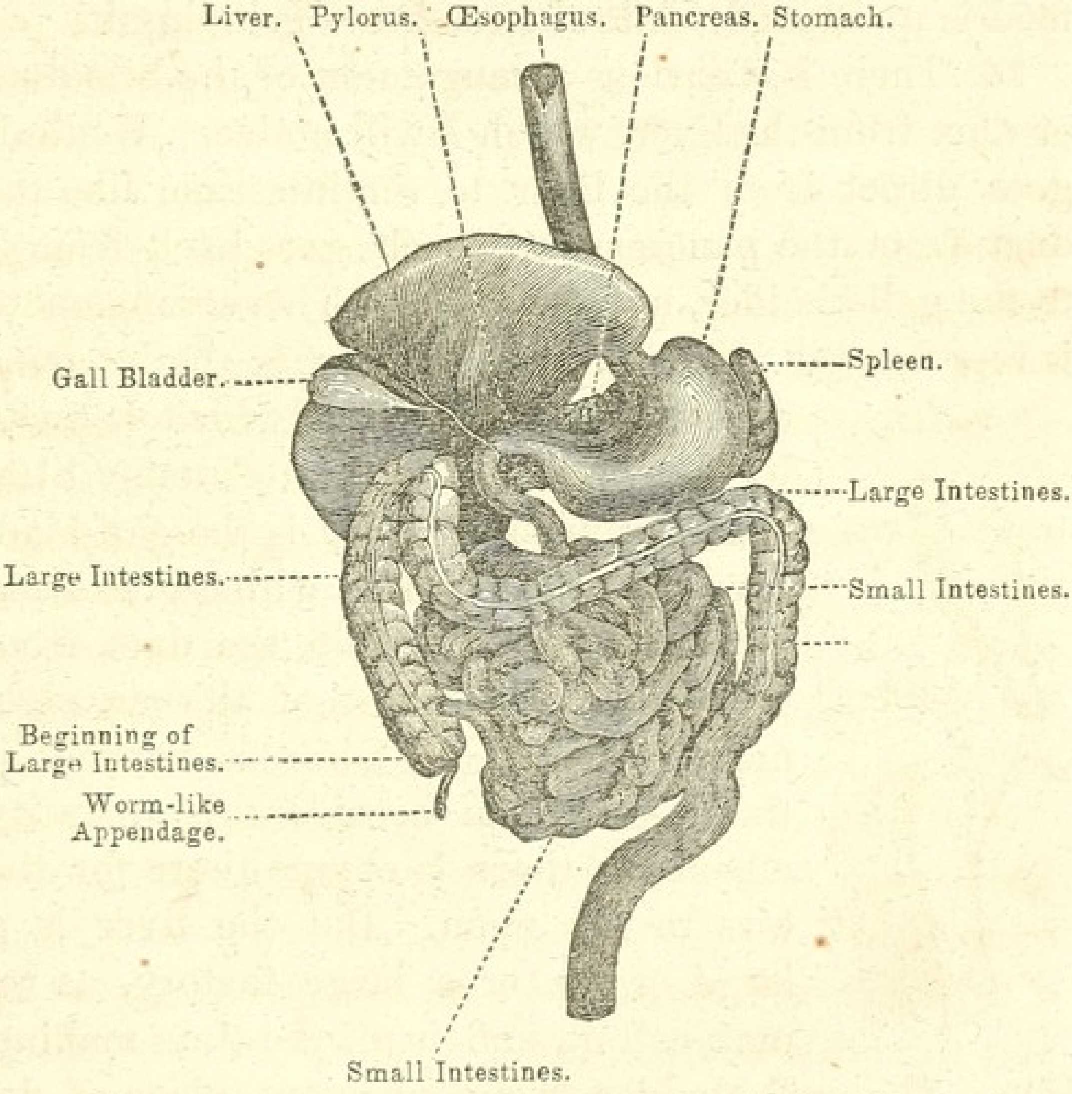
14. None of the food can pass by the valve into the intestines till the gastric juice has acted upon it enough and changed it into chyme. As the stomach churns the food, some of it continually comes in contact with the valve. But the valve will not open till some of it comes along that is fit to pass. If the food

Describe the stomach as shown in Fig. 13. Where does the gastric juice come from? How is it mixed thoroughly with the food? What is the *chyme?* Describe the operation of the valve called the *pylorus.*

is not digested, as sometimes happens, then commonly this sentinel after awhile gives up its resistance, and lets the undigested food pass on. Or, if it holds out in its resistance, the food is got rid of by being thrown back by the stomach through the œsophagus or gullet.

15. When the chyme passes through the valve of the stomach it goes into the intestine, the beginning of which you see in Fig. 13. There two other juices

Fig. 14.



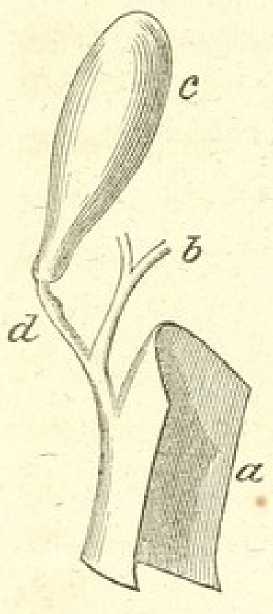
are poured in and mingled with it. The duct from the liver is represented in the figure at 6, and the duct

Into what does the chyme pass from the stomach? What two juices are here mingled with it?

from the pancreas opens near it. These fluids come from two glands. One of these glands is a very large one, the liver. You see this gland in Fig. 14, which gives a general view of the digestive organs. The juice from this gland is called bile. It is of a yellow color and is very bitter. The other juice comes from a gland called the pancreas, which you see in the figure, lying behind the end of the stomach. This is very mild and is much like the saliva with which the food is moistened while the teeth are grinding it.

16. There is a curious arrangement of the bile duct or duct from the liver, which I will notice. While it goes direct from the liver to the intestine, like the duct from the pancreas, a branch goes back from it to the gall-bladder, as it is called. This arrangement is represented in Fig. 15, in which *a* is the intestine cut open, *b* is the duct which is made by the joining together of many little ducts from the liver, *c* is the gall-bladder, and *d* is the duct which goes from the gall-bladder to join the duct from the liver. The object of this arrangement is plain. The bile is needed in the intestine in considerable quantity whenever there is chyme there for the bile to act upon. But the liver is a large organ, or a large factory, as we may call it, and is all the time making bile. The gall-bladder is a convenient place of deposit, or reservoir, where the bile is stored up until it

FIG. 15.



From what glands do these juices come? Describe the arrangement of the gall-bladder and the ducts.

is needed. When there is no chyme in the intestine, the bile, as it flows from the liver in the duct *b*, takes a turn by the branch *d* into the gall-bladder. In what way it is made to take this sharp turn we do not know. After we have eaten a meal, and the chyme begins to be poured from the stomach into the intestine, then much bile is needed, and it comes freely both from the liver and from the gall-bladder.

17. We do not know exactly what the bile and the juice from the pancreas do to the chyme. It is supposed that they separate the nourishing part of the chyme from that which is not nourishing, as the chyme passes along through the intestines. As this chyle (so called) is thus separated, it is sucked up or absorbed by vessels scattered all over the inside of the intestines. These absorbents are called lacteals, from lac, meaning milk, because the fluid which they absorb is a milk-like fluid.

18. The lacteals are exceedingly small, and cannot be counted. They do their work very faithfully. They will commonly take up nothing but the chyle. Anything else that comes along they shut their mouths against and let it pass on.

19. The chyle is that which makes all the blood. It must therefore in some way be poured into the circulation, and I will tell you how this is done. The little vessels that drink it up from the chyme unite together to form a tube about the size of a quill. This tube runs up in front of the back-bone, and at the top

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What is the office of the gall-bladder? What effect do the bile and juice from the pancreas produce upon the chyme? What is the chyle? What are the lacteals?

of the chest empties the chyle into the blood where two large veins unite together. And now this whitish milky fluid becomes blood, and is carried everywhere to nourish the body.

20. In Fig. 14 you see all the complicated apparatus or machinery of digestion, except its mill or grinding part where the process begins. The parts are not closely packed together as they are in the body, but they are represented as a little separated from each other, so that you may see them more clearly and fully. As this is a front view the left side of the figure is the right side of the parts. The large end of the stomach, which is at the right side of the figure, is on the left side in the body. You see that the great bulk of the liver is therefore on the right side. The spleen, which lies against the large end of the stomach, is an organ the use of which we do not understand. Neither does any one know what is the use of the little worm-like appendage at the beginning of the large intestines.

21. The great object of all this apparatus is to extract the chyle, the nutritious part of the food, and pour it into the blood. It is in this way that blood is made out of our food. The blood, the building material of the body, is all the time used in building and repairing. For this reason there must be a constant fresh supply of blood. It is the chyle poured into the blood by its little tube or duct that gives this supply. If this tube should be cut off, or be blocked up,

Describe the way in which the chyle gets into the blood. What does it become? Describe the arrangement of the organs of digestion in Fig. 14. What is the object of all the apparatus of digestion?

the blood would constantly lessen, the body would shrink or become emaciated, as we say, and death would at length result. The same thing would happen if the stomach stopped digesting the food, for then no chyle would be formed, and therefore no new blood would be made.

22. There are many things that are very wonderful in all this process of blood-making, which is executed by this complicated machinery of digestion. It is especially wonderful that a simple milky fluid should be separated from such a great variety of food as we eat from day to day, and then that this whitish fluid should be changed into red blood.

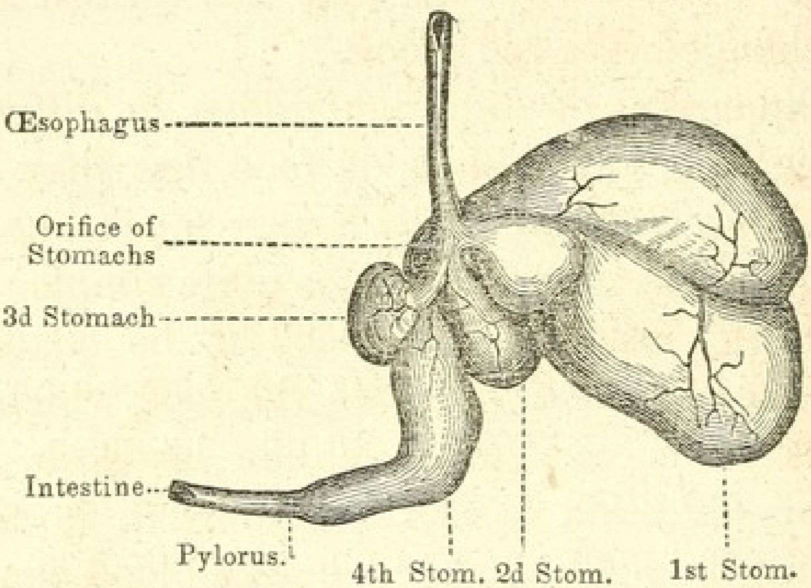
23. The apparatus of digestion differs in different animals according to the kinds of food that they eat. If the food that an animal eats is very much like his body, the apparatus or machinery is quite simple; for the food in this case does not need to be changed much to make his blood. But if the food which an animal lives on is very much unlike his flesh, the apparatus of digestion is very complicated, because the food must be much changed before blood can be made out of it.

24. For these reasons the digestive machinery in such animals as the dog, the tiger, and the lion, is simple, for they live on flesh, which is of course very much like their own flesh. But in such animals as the cow and the sheep, this machinery is complicated.

In what ways can the supply of chyle to the blood be stopped? What things are there in the process of digestion that are especially wonderful? In what animals is the machinery of digestion most simple? In what animals is it complicated? Illustrate by referring to different animals.

The reason is, that the grass which they eat is not at all like their flesh. It must therefore go through a great change to fit it to make the blood and flesh of such animals. And this cannot be done without considerable machinery. The flesh-eating lion has a single stomach, and the length of its intestines is only three times that of its body. But the grass-eating sheep has really four stomachs, and the length of its intestines is twenty-eight times that of its body. Fig. 16 represents the four stomachs of the sheep. In man

FIG. 16.



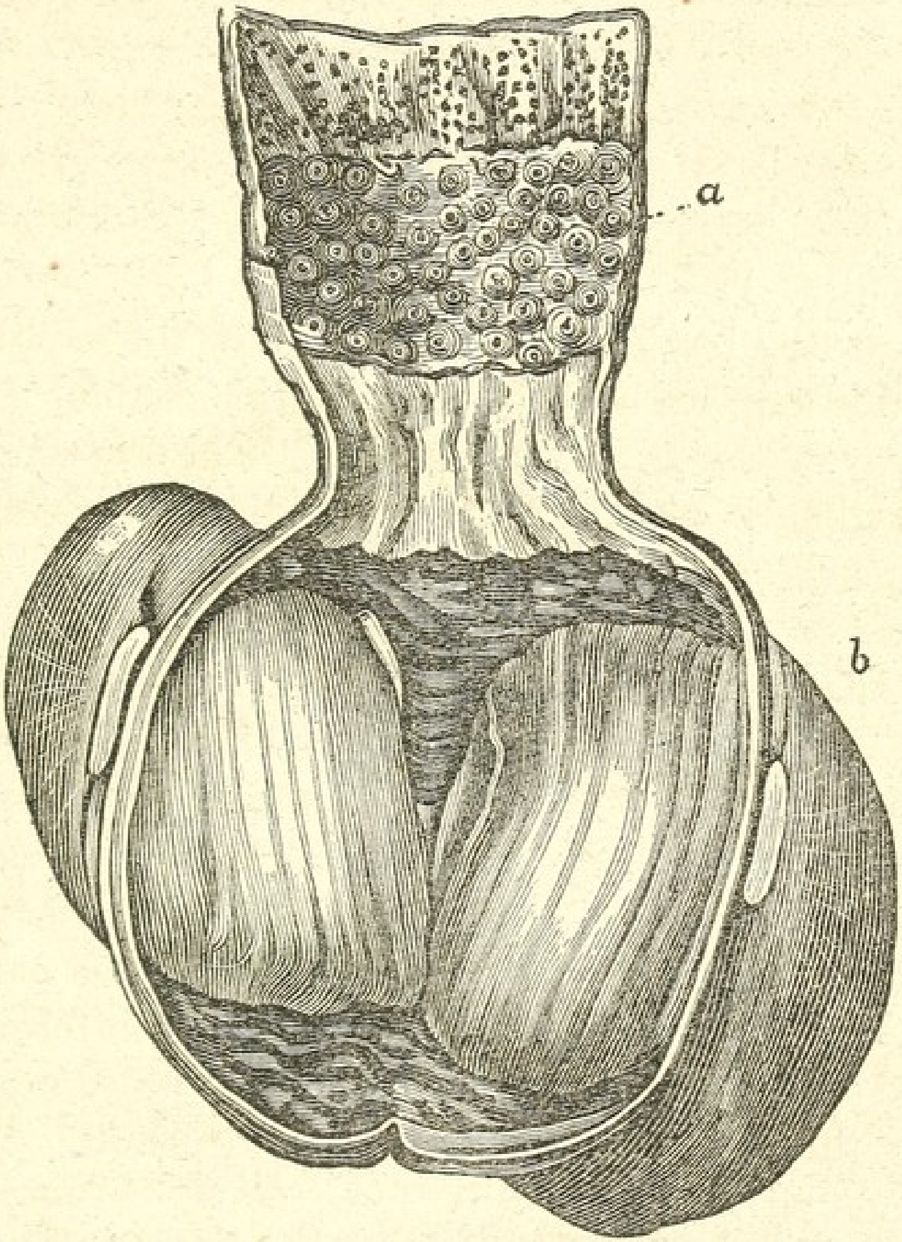
there is but one stomach, and the length of his intestines is about six times the length of the body.

25. In birds that eat grains and seeds there is a peculiar arrangement of the digestive machinery. They have no teeth, and their mill for grinding their food, instead of being in the mouth, is in the stomach. The gizzard, which is the stomach, is truly a mill for crushing the food to pieces. It has on the inside two

How long are the intestines in the lion? In the sheep? In man? How many stomachs has the sheep?

very hard surfaces, which are rubbed and pressed together by stout muscles. The grain is thus broken up just as it is done between two mill stones. While this is going on the gastric juice comes down from above, and dissolves and digests the broken grain.

Fig. 17.



This arrangement is seen in Fig. 17, which represents

What is there peculiar in the digestive machinery of grain-eating birds?

the stomach of a turkey. At *b* is the gizzard cut open, showing the two hard grinding surfaces, and at *a* above is the part from which oozes the gastric juice. In those birds that live on flesh or fish there is no such grinding machinery, but the stomach is a thin bag, just as it is in all animals that live on such food.

CHAPTER IV.

CIRCULATION OF THE BLOOD.

1. In the last chapter you saw how the supply of blood is kept up in the body. In this chapter I shall show you how the blood is circulated everywhere, in order that it may be used in building and repairing. The machinery that thus circulates the blood is called the *circulating system*. It has its pipes everywhere. There is no part of the body where the blood does not go. And this machinery keeps the blood everywhere in motion. It nowhere rests for a single moment.

2. This circulating machinery has a great central organ, the *heart*, situated in the chest. This forces the blood out all over the body through the *arteries*. It receives it back again by the *veins*. It forces the blood out through a large artery, called the aorta, and from this go branches in every direction. These

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Describe the arrangement of the digestive organs in the turkey. What kind of stomach have birds that eat flesh or fish? What is the machinery that circulates the blood called? Is the blood ever still anywhere? What are the different parts of the machinery? Through what does the heart send out the blood? Through what does it receive it back?

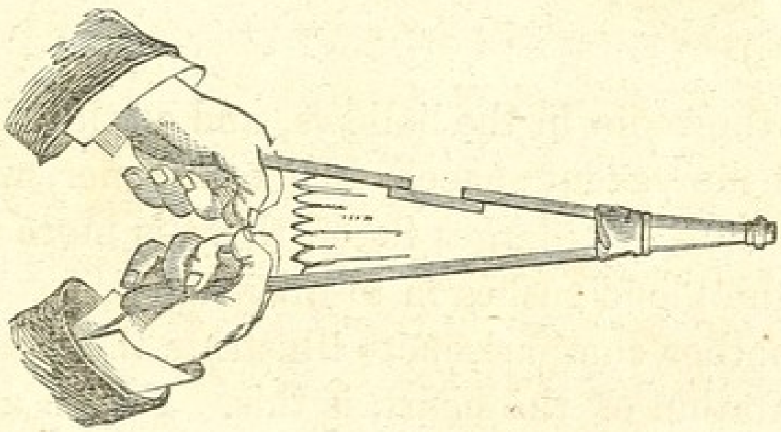
branches divide more and more, just like the branches of a tree, till the extreme branches are exceedingly small.

3. These small arteries end in a network of vessels that are so small that they are called *capillaries*, from the Latin word *capilla*, hair. They are really smaller than any hair. When you prick or cut your finger you wound a large number of these capillaries, and they let out their blood.

4. The heart acts like a forcing and suction pump. It pumps out the blood through the arteries, and by suction it draws the blood back by the veins. It forces out the blood by contracting itself, or making itself smaller. It draws in the blood by dilating itself, or making itself larger.

5. I will make these two actions of the heart plain to you by certain comparisons. When you press the two sides of a pair of bellows together by the handles, as represented in Fig. 18, you contract the bellows—

FIG. 18.

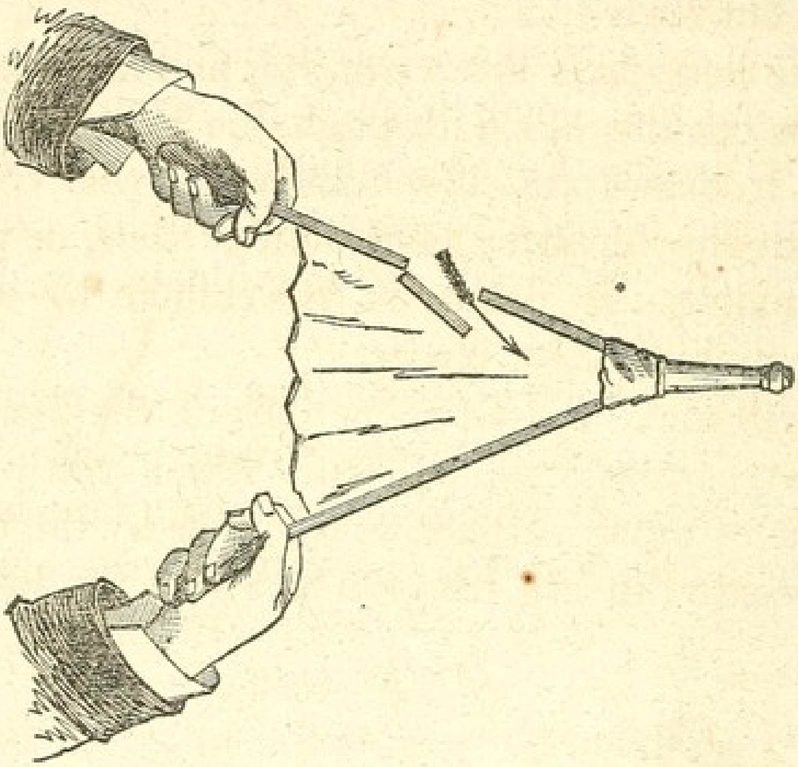


that is, you make the room in it smaller. A part of

What are the *capillaries?* Like what does the heart act? How does it force out the blood? And how does it draw it in? Illustrate by comparison with a pair of bellows.

the air is therefore forced out through the nose of the bellows. It is in the same way that the blood is forced out of the heart through the aorta. The only difference is that the heart contracts itself, instead of having it done, as in the case of the bellows, by hands and handles. Again, when you move the handles of the bellows apart, as represented in Fig. 19, you

FIG. 19.



enlarge the room in the bellows, and so the air rushes in to fill the vacant space. In like manner, when the heart dilates, or enlarges itself, there is more room in it, and the blood rushes in to fill it up.

6. Another comparison, to illustrate the contraction and dilatation of the heart, is this. Fasten a tube to the neck of an india-rubber bottle, and fill it up with water. Put the end of the tube in a vessel of

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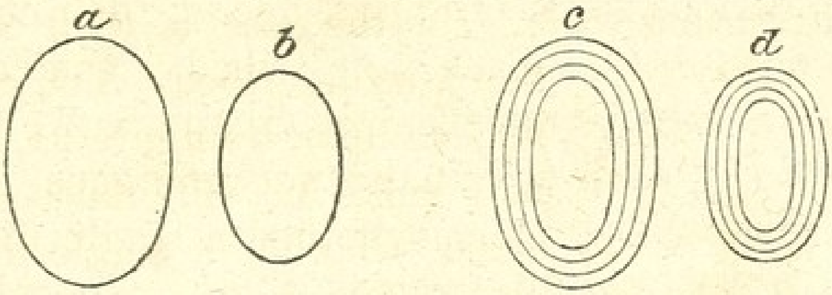
Illustrate the action of the heart by the comparison of the india-rubber bottle.

water. If now you press the sides of the ball together, some of the water in it is forced out into the vessel, just as blood is forced out through the aorta, when the heart contracts. If now you stop pressing the ball, and let it take its round shape again, the water rushes into it from the vessel. For the same reason, when the heart dilates or becomes larger, the blood rushes into it.

7. I will now explain to you the manner in which the heart contracts and dilates. The heart is made up of muscular fibres, which have the power of shortening themselves, as you saw in chapter second, § 7 and § 8. Now suppose one of these fibres, as seen at *a*, in Fig. 20, shortens itself so as to be like *b*, the space that

Fig. 20.



is inclosed in it becomes smaller, just as in the case of the bellows. In *c* and *d* you see the same thing represented when several fibres are together. If the fibres in *c* become shorter, so as to be as in *d*, the space they inclose is smaller. You readily see from this, that when all the fibres of the heart are shortened, the space in it is lessened, and a part of the blood is forced out.

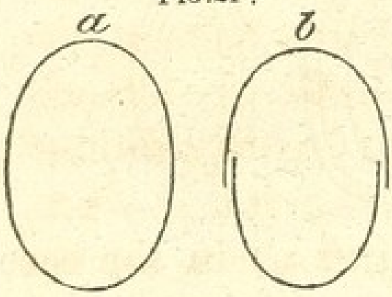
8. You can see by the same figures how the heart

Explain by the Figures the action of the muscular fibres of the heart when it contracts and dilates.

dilates or enlarges itself. If the contracted or shortened fibre *b* lengthens so as to be as *a*, the space enclosed by it becomes larger. And so also of any number of fibres. It is supposed that the enlarged or dilated state of the heart is its natural state of rest, when the fibres are not acting, but are quiet. That is, the heart is really at work only when it contracts. When it dilates it merely ceases to act, and lets itself go back to its natural size by its own elasticity, as it is termed. It is just as the india-rubber ball goes back to its natural roundness when you stop pressing it.

9. The fibres of the heart are not arranged in the regular form in which they are represented in the above figures. They meet each other, and cross each other in various ways. But the effect of their contraction is as described. You can see, for example, by figure 21, that it will make no difference in the effect, whether a single fibre go all around, as in *a*, or whether two fibres lap on to each other, as in *b*, and are fastened together. And the same can be said of any number of fibres.

FIG. 21.



10. When the heart beats, these fibres shorten themselves, and the blood is forced out into the arteries. Then, as the fibres relax, the blood comes into the heart from the veins. And so the heart by turns contracts and enlarges, just as you contract and enlarge the bellows in working them, as you blow the fire.

Is the heart in action, or is it at rest, when it dilates? How are the fibres of the heart arranged? Give the comparison made in §10 between the action of these fibres and the action of the bellows.

11. Let us look now at some things in which the arteries and veins differ from each other. You see veins lying just under the skin in various parts of the body, but you do not see the arteries. They all lie deeper than these veins that you see. The reason is this. It would be dangerous to have the arteries so near the skin as some of the veins are. For the heart is pumping the blood directly into them with great force. And therefore if an artery is cut, it bleeds much more than a vein of the same size, and its bleeding is not as easily stopped. For this reason the Maker of our bodies has, as we may say, laid the arteries deep, so that they cannot often be cut in the accidents that happen to us.

12. You can see that special pains are taken in some cases to guard the arteries. Thus the large artery of the arm, when it comes to the joint at the elbow, does not pass over the bones, where it would be apt to get wounded. It lies deep on the inside of the elbow, under the stout tendon that you feel there. So at the knee, the artery is deep in the ham at the back of the joint, in a space between two jutting parapets of bone, as we may call them.

13. There are only a few places in the body where arteries of any size are very near the surface. In such cases it is because they could not possibly be laid in any better way. One of these is the wrist, where the physician commonly feels the pulse. Another is on the temples. In some persons who are very thin you

How do the arteries and the veins differ from each other in their situation? What is the reason of this difference? Mention some cases in which special pains are taken to guard the arteries.

can see the artery on the temples beating, and can count the pulse there without being obliged to feel it.

14. As the heart pumps the blood into the arteries with so much force, they are made much stronger than the veins are. If they were not, they would often burst, as you have seen the hose of a fire engine do. But the arteries are made so strong that this is a very uncommon accident.

15. What is called the pulse I will explain to you. When the heart contracts it gives a sudden motion or impulse to all the blood in all the firm arteries. The blood all moves at once. The motion is not like a wave, going from the heart in all directions. The blood at a distance from the heart is moved at the same time with the blood near the heart. It is this motion or impulse that you feel when you put your finger upon an artery. The impulse thus felt is called the pulse. You can feel the pulse wherever you can feel an artery. It is everywhere. In a young infant you can both feel and see the pulse in the open space on top of its head, where the bones are not joined together. This is the pulse of the arteries of the brain. When the heart beats very strongly, as it does in a high fever, this pulse in the brain is very manifest.

16. If a vein be cut, the stream from it is a steady one, because the blood flows in the veins back to the heart slowly and steadily. But if an artery be cut, the stream is not steady but spouts out by jerks or

In what places in the body are the arteries very near the surface, and why? How do the arteries and veins differ in strength, and why? Explain what the pulse is. Where can you feel the pulse?

jets. This is owing to the impulse that is given to the blood in the arteries when the heart beats or contracts. There is a jet for every contraction.

17. It is well for every one to know how to stop the bleeding of an artery when it is wounded. It does no good to wind cloths around, as is very commonly done. This only catches the blood, while the artery is left to go on to bleed. If you bear in mind that the blood comes from the heart in the artery, you will see that pressing on the artery on the side of the wound which is towards the heart will stop the bleeding. Firm pressure with the thumb will do it if you put the thumb in the right place. In order to find the right place uncover the wound and press your thumb here and there till you see that the blood stops flowing from the wound. If you find that by pressing in any spot the blood is stopped, hold your thumb there till the surgeon comes to take care of the case. If you cannot find the right spot, tie a slip of cloth or a handkerchief around the limb above the wound, and then twist a stick in it till the bleeding stops. A child with this information may be able to save a life, and yet for want of it many a person has died in such a case, for few even among adults understand the matter.

18. The object of the machinery of the circulation is to get the blood into the network of the capillaries, and then bring it back to the heart. It is when the blood is in these capillaries that it is used for building

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How does the stream of blood from a cut vein differ from the stream from a cut artery? What is the reason of the difference? How would you stop the bleeding of an artery?

and repairing. It is by the arteries, as you have seen, that the blood is brought to the capillaries, and it is by the veins that it is carried back from them to the heart.

19. As the blood comes from the heart by the arteries it has a bright red color. But when it passes from the capillaries into the veins it has a dark color. The cause of this change is the use which is made of the blood while it is in the capillaries. Something has been taken from it for building and repairing, and so it cannot be as good building material as it was before it was used. Not only has there something been taken from it, but there has also been added to it some of the waste matter that comes from the wear and tear of the system. On becoming dark blood, then, it has been changed from good blood to bad blood.

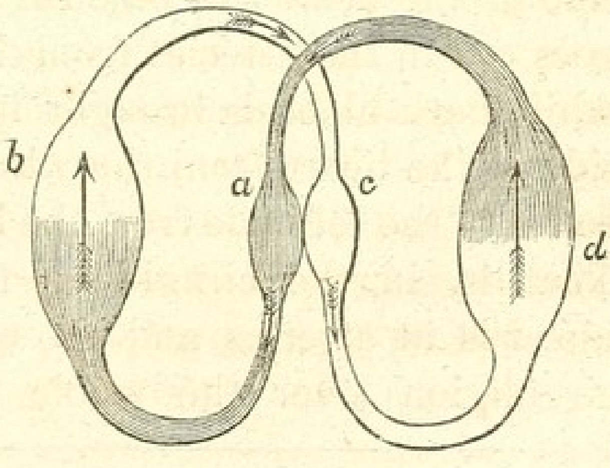
20. This dark blood, then, that goes back by the veins to the heart is not fit to be used so long as it remains dark. When it gets back to the heart it will not do to have it sent all over the body by the arteries. It would destroy life everywhere. The organs of all the machinery of the body would stop their operations. For example, if this dark blood should be sent to the brain, the individual would become insensible and fall down, and he would die very soon if the good red blood could not be sent to his brain. And so, too, would all the organs stop work, as we may say, if dark blood instead of red were sent to them.

What is done with the blood in the capillaries? What is the color of the blood in the arteries? What in the veins? What is the cause of the change? What is done to the blood in the capillaries? What would happen if the dark blood should be sent to the organs of the body instead of red blood?

21. This dark blood then, when it comes back to the heart, must in some way be changed to red blood before the heart sends it again all over the system. For this purpose the heart sends it to the lungs, where, by exposure to the air that we breathe into those organs, it is changed to red blood. After it is thus changed it comes back to the heart, and is then sent all over the body.

22. All this could not be done by the heart if it were a single organ. It is not single. It is double, or rather, there are really two hearts; one for the circulation all over the body, and the other for the circulation through the lungs. The two hearts are so closely united together that they are spoken of as one heart. But they are entirely separate, so far as any communication between them is concerned. None of the blood in one can mingle with that in the other. The blood in them is different. In one heart it is red, and in the other it is dark. I shall speak of them as the two sides of the heart, the right and the left side, as is commonly done.

Fig. 22.



23. That you may understand the course of the blood in the two circulations, I shall describe it by Figure 22. Let *a* represent the right side of the heart, *c* the left side, *b* the

What is done with the dark blood? Why is the heart double? Are the two sides of the heart as separate as if they were two hearts? Is the blood of the same color in the two sides?

lungs, and *d* the general system of the body. The arrows point in the direction in which the blood flows. In all the shaded part the blood is dark, and in the part that is not shaded it is red. Let us now begin at some point, and trace the course of the blood. We will start at *a*, the right side of the heart. The blood received here from the whole body by the veins is of a dark color. It is sent by this right side of the heart to the lungs, *b*. Here it is changed to red blood, and then passes back by veins to the heart —but observe, it is to the *left* side, *c*. It is now sent by this left side of the heart to the whole system, *d*. Here, in the capillaries, it is changed to dark blood, and goes back by veins to the right side of the heart, *a*, where we started. The blood is constantly going the rounds of these two circulations, day and night, as long as life lasts.

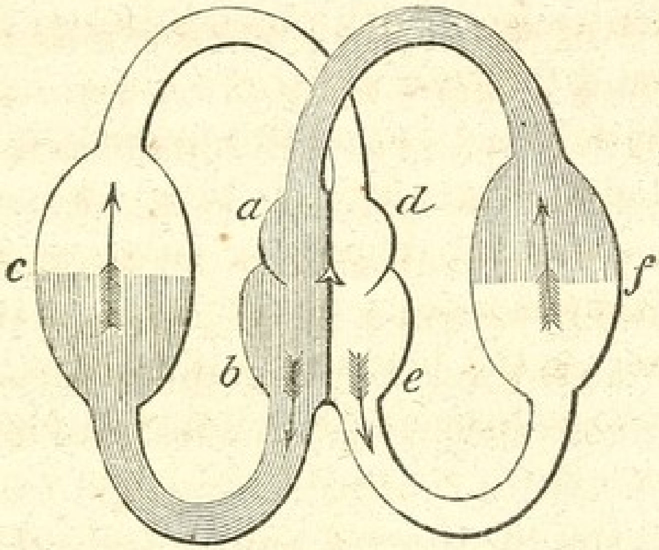
24. The blood in the right side of the heart, or the heart for the lungs, is dark. The blood in the left side of the heart, or the heart for the whole body, is red. So also in the arteries that go out from the *right* side of the heart the blood is dark, while that which goes out in the arteries from the *left* side is red. And while dark blood is brought in the veins to the right side of the heart from the whole body, the veins that come to the left side from the lungs contain red blood. That is, in the circulation for the lungs the dark blood is in arteries and the red in veins, but in the circulation over the whole system it is just the

Describe the course of the circulation as represented in Fig. 22. In which side of the heart is the blood red, and in which dark? How is it in the arteries and veins of the two circulations?

reverse—the dark blood is in veins and the red is in arteries.

25. The heart is not only two separate hearts, but each of these has two apartments in it. One of these apartments is larger than the other. The smaller apartment is called the *auricle* and the larger the *ventricle*. This arrangement is represented in Fig. 23.

FIG. 23.



The middle part of the figure represents the heart with its two sides, that have no communication with each other; *a* being the right auricle, *b* the right ventricle, *d* the left auricle, and *e* the left ventricle. The blood is received in the right auricle, *a*, from the general system, *f*. It then passes into the right ventricle, *b*, and is forced by the contraction of it through arteries to the lungs, *c*. From the lungs it comes back to the heart, to the left side, and enters the left auricle, *d*. From this it passes into the left ventricle, *e*, from which it is sent all over the body, represented by *f*.

Describe the apartments of the heart. Describe the circulation as it takes place through these apartments.

26. In each half or side of the heart the ventricle is the main apartment. It is much larger than the auricle. The auricle is a sort of entrance-chamber to the main apartment, the ventricle. There are valves, or folding doors, as we may call them, between these two apartments. These valves are so arranged, that the blood can pass only one way. Take, for example, the valves between the right auricle, *a*, and the right ventricle, *b*. The blood can go from *a* to *b*, but it cannot go from *b* to *a*.

27. I will describe to you the manner in which the blood is made to go through these two apartments. When the auricle *a* dilates or enlarges, it draws in the blood from the veins of the body. It then contracts and forces the blood into the ventricle *b*. The ventricle now contracts, and sends the blood towards the lungs, *c*. Now, when the ventricle *b* contracts, it would force the blood *back* into the auricle *a*, as well as forward towards the lungs, were it not for the valves. When the ventricle contracts these valves shut, and so none of the blood can go in that direction, but all of it goes towards the lungs.

28. These valves operate just as the valve of the bellows does, as seen in Figures 18 and 19, pp. 37 and 38. In Fig. 19 the hands are drawing the handles apart, and enlarging the space in the bellows. Here the valve is open and the air is rushing in, just as the valves of the ventricle open and the blood rushes in when the ventricle dilates or enlarges. In Fig. 18

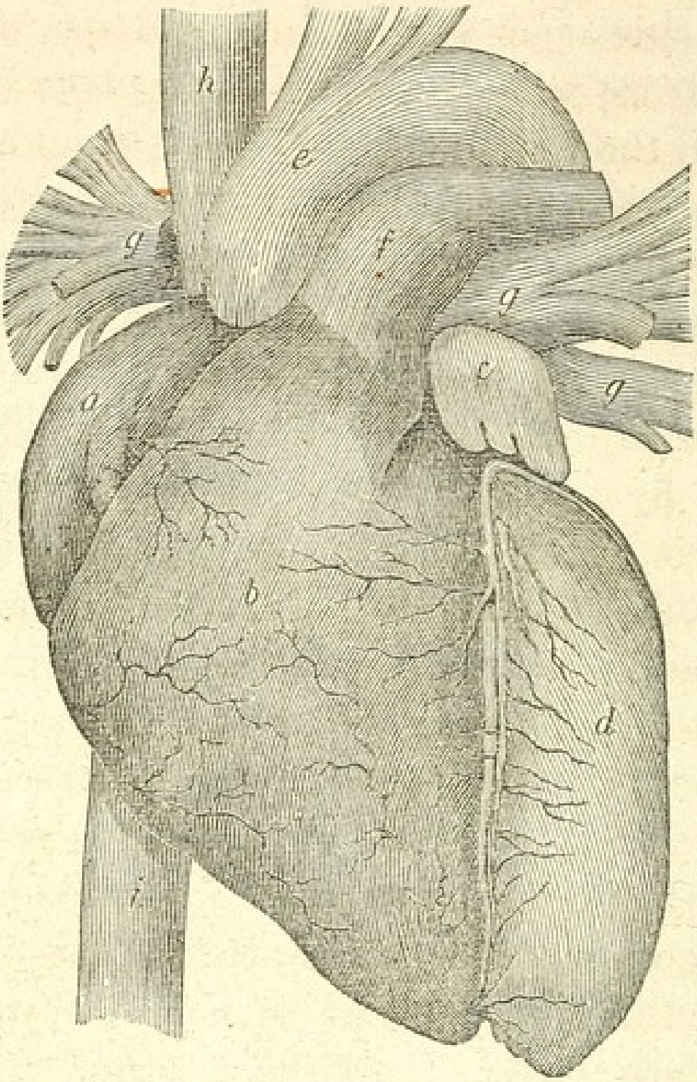
How are the valves between these apartments arranged? Describe the action of the auricles and ventricles. Compare the operation of the valves between them to that of the valve of the bellows as represented in Figs. 18 and 19.

the hands are pressing the handles together, and the valve is shut, and the air is forced out through the nose; just as, when the ventricle contracts, the valves close, and the blood is forced out through the artery that goes from the ventricle. Observe now, in what way the valves are shut in both cases. In the case of the bellows, when the handles are pressed together, the air escapes wherever it can. If the bellows are tight, it escapes only through the nose. If the valve does not fit well some of it escapes there. The air, pressing in all directions, shuts down the valve, and if the valve is tight no air can get out there. Now, the blood does in the ventricle of the heart just as the air does in the bellows. When the ventricle contracts, the blood, in escaping from the pressure, shuts the valves. If the valves fit well, as they commonly do, none of the blood can go back into the auricle, but it will all go out through the artery, just as all the air goes out through the nose of the bellows, when the bellows are tight. There are other valves in the heart, which, with those that I have spoken of, are fully described in my larger work on Physiology.

29. Having thus described to you the manner in which the blood circulates, I now show you in Fig. 24 a representation of the heart as it really appears. It is a *front* view. At *a* is the right auricle. This receives the blood from all parts of the body by two large veins *h* and *i*, *h* bringing the blood from above, and *i* from below. At *b* is the right ventricle, which receives the blood from the auricle, and sends it to

What shuts the valve in the bellows? What shuts the valves in the heart?

Fig. 24.



the lungs by the pulmonary artery *f*. At *c* is the left auricle, which receives the blood from the lungs by the pulmonary veins *g*, *g*, *g*. At *d* is the left ventricle. This receives the blood from the auricle, and forces it out all over the body through the aorta *e*. The aorta, as you see, sends off branches upward to the head and arms, and then bends downward behind the heart to send off branches to all the other parts of the body.

30. You observe much irregularity in the arrangement of the two *sides* of the heart, as they are called.

Describe the heart as it really appears, by Fig. 24.

The auricle *a* and the ventricle *b* make the right side. The auricle *c* and the ventricle *d* make the left side. In this front view of the heart you see only a part of the left side. Much of the left auricle and the left ventricle are hidden behind the right ventricle. The aorta, *e*, the large artery through which the blood is pumped out by the left ventricle, is at first also behind the right ventricle.

31. The heart, with its four apartments and its four sets of valves, is a very complicated machine. Yet commonly it works well and easily. One part does not interfere with another. All the parts do not work at the same time, and there is a time for each part to act. In this way the whole machine works harmoniously.

32. The two auricles act together, and the two ventricles act together also. For example, the two ventricles contract together, the right ventricle pumping the dark blood into the great artery of the lungs at the same time that the left ventricle pumps the red blood into the aorta, the large artery of the body.

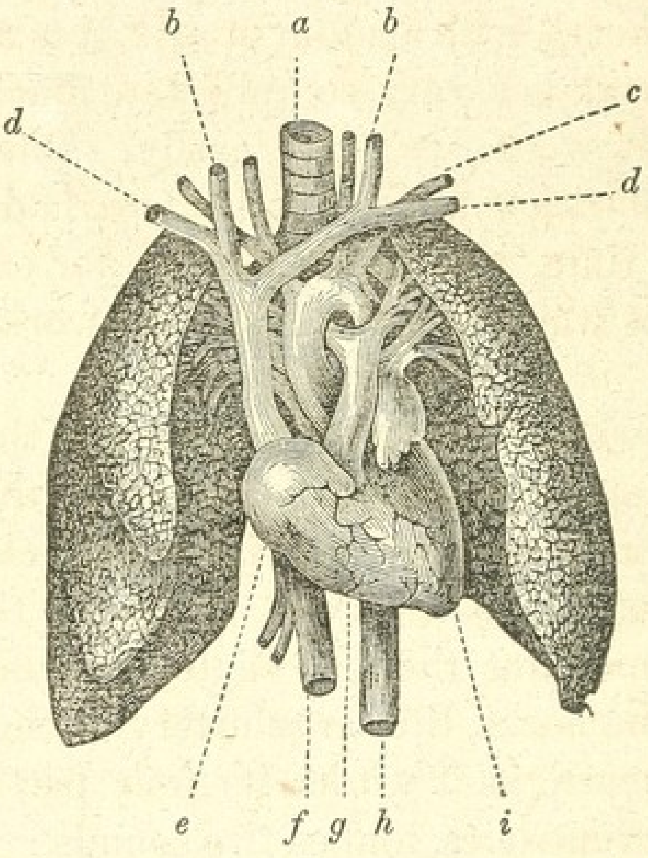
33. The heart, as it works its four parts, the auricles and the ventricles, makes two sounds. These you can hear if you put your ear to any one's chest on the left side at its lower part in front. You hear them better here than at any other spot, because the heart here comes so near to the walls of the chest. You hear a heavy and full sound, followed by a quicker

What is said of the irregularity in the arrangement of the parts of the heart? What is said of the complicated character of the heart, and of its harmony in action? What parts act together? Where can you best hear the sounds of the heart? Why? Describe its two sounds.

and lighter one. The syllables *lub-tup* are a good representation of these sounds.

34. The heart is almost wholly covered up by the lungs. It is encased in a sack or bag, and around this there is considerable of the common packing material of the body, the cellular membrane, spoken of in the second chapter. In Fig. 25 you see the heart between

Fig. 25.



the two lungs. The lungs are represented as drawn apart, so that you may have a full view of the heart with its arteries and veins. The sac of the heart and the packing material are also removed. At *a* is the trachea or windpipe; on each side are the two arteries that go to the head; *c* is the artery that goes to the arm; *b b* are the veins coming from the head, and *d d* the

With what is the heart covered? Describe its situation as represented in Fig. 25.

veins from the arms, all emptying, as you see, into a large vein that goes to the right auricle of the heart, *e*; *f* is the large vein that brings the blood from below to this auricle; *g* is the right ventricle, *i* the left, and *h* is the aorta as it goes down from the heart.

35. The heart is commonly about the size of the closed hand of the individual. It is a very powerful organ for so small a one. It is composed of muscular fibres, and these are so nicely arranged that each fibre contracts exactly as it should to do its part of the work.

36. The amount of work that the heart does in a lifetime is very great. In an adult it beats about seventy times in a minute. This is over one hundred thousand times in twenty-four hours. In the child it beats much faster than this. And it is to be remembered that every time the heart beats each of its four parts contracts and dilates. Each beat of this organ is therefore a complicated movement of a very complicated machine. And this machine is always at work as long as life lasts, alike while we are awake and while we are asleep, keeping the blood in motion in all parts of the body.

What is the size of the heart? Of what is it composed? About how many times does the heart beat in a minute? How many times in twenty-four hours? How is it in children? What is done in the heart in every beat? Does the heart ever rest from its work?

CHAPTER V.

RESPIRATION.

1. You saw in the last chapter that the dark blood is sent to the lungs by the heart in order to be changed into red blood. The great object of the machinery of the respiration is to bring the air and the blood together, so that the air may produce this change. The way in which this machinery operates in doing this I will explain to you in this chapter.

2. The lungs fill up a large part of the chest. They are on each side of the heart, as you have seen in Fig. 25. They are in common language termed the *lights;* and you can see what they are in man by looking at the lights of other animals. They are spongy bodies. They are full of very small air-cells. These give to them their spongy lightness; and as a sponge is much larger when its cells are filled with water than when it is dry, so the lungs swell out when their cells are filled with air. This can be shown to you with the lungs of some animal, as a sheep or a calf. If a tube be fastened to the windpipe, you can make the lungs swell out very much by blowing air into them.

3. It is in these air-cells that the air changes the dark blood to red. But this is not done by mixing up the blood with the air in these cells. The blood is never mixed with the air except when in disease

What is the object of respiration? What is the situation of the lungs? What is the cause of their lightness? Mention the comparison between the lungs and a sponge. Is the blood mixed with the air in the lungs?

blood is raised from the lungs. In such a case the blood gets into the air-cells and air-tubes. But in health this never happens. The thin membrane or skin, that makes each air-cell, does not let the blood come through it. The air acts upon the blood through the pores of the skin, and of the capillaries that branch out upon this skin. It is by the airing that the blood thus takes, that every drop of dark blood that goes to the lungs is changed to red blood.

4. The great object of the machinery of respiration is to keep the air going into and out of these air-cells. In this way fresh air is continually brought to the blood. When you breathe in, the air is forced into all these cells; and when you breathe out, it is forced out of them. It is not all forced out. The lungs are never wholly empty of air. Enough is forced out to keep the air in the lungs constantly changing.

5. Fig. 26 will give you some idea of the structure of the lungs. At *d* is the right lung, and at *c* are represented the main branches of the windpipe that go to the left lung, separated from the lung itself. At the lower part, at *e*, are represented the very minute branches as they go to the air-cells. At *b* is the windpipe, and at *a* is the larynx, or Adam's-apple, as it is commonly called. It is through a chink in this that the air passes in and out as we breathe.

6. I will now show by what machinery the air is forced into the lungs and out of them, and how it operates. You see that as you breathe the chest

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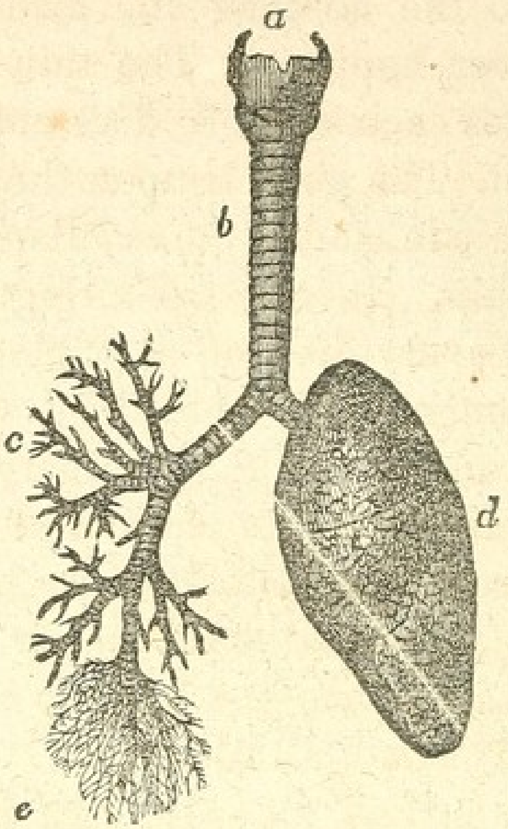
How does the air act upon the blood in changing it? What does the machinery of respiration do? Are the lungs ever wholly without air? Describe the structure of the lungs by Fig. 26.

Fig. 26.



moves. No air would ever enter the lungs if this movement of the chest were not made. If a bank of earth should fall upon a man, and cover his whole body but leave his head free, the pressure of the earth upon his chest would prevent its moving. And so he would die for want of air in his lungs, unless the pressure were removed.

7. When we breathe *in*, or make an *inspiration*, as it is called, the air rushes into the lungs, for the same reason that the air rushes into the bellows when the handles are moved apart. In inspiration the space in the chest is enlarged, just as the space in the bellows is enlarged when the handles are moved apart. And because the space is enlarged air rushes in wherever

What is said of the motion of the chest in breathing? What is *inspiration?* Why does air rush into the lungs in inspiration?

it can get in. In the bellows it comes in through both the nose and the hole in the side. In the chest it comes in only through the trachea or windpipe.

8. In *expiration*, that is, when we breathe *out*, the air is forced out through the trachea, for the same reason that the air is forced out through the nose of the bellows when you press the sides together with the handles. In forcing the air out of the lungs the muscles about the chest do for the chest what your hands do for the bellows.

9. If the bellows had no hole in the side, and the space in them were filled with a soft spongy substance, so that the air coming in through the nose would go into all the spaces in this substance, the bellows would then resemble very much the chest with the lungs. In Figs. 27 and 28 is represented a

FIG. 27.

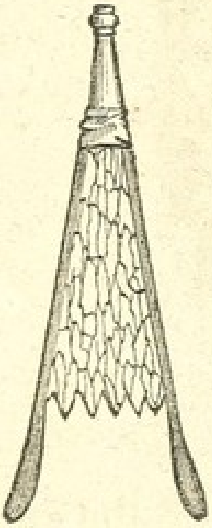
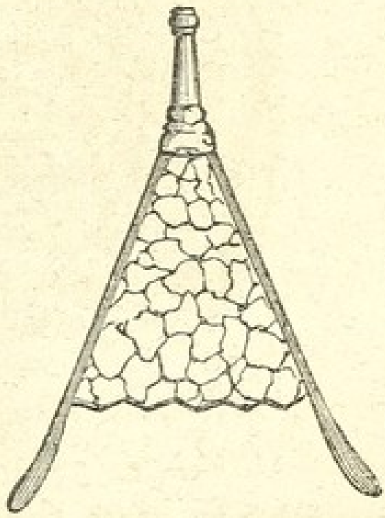


FIG. 28.



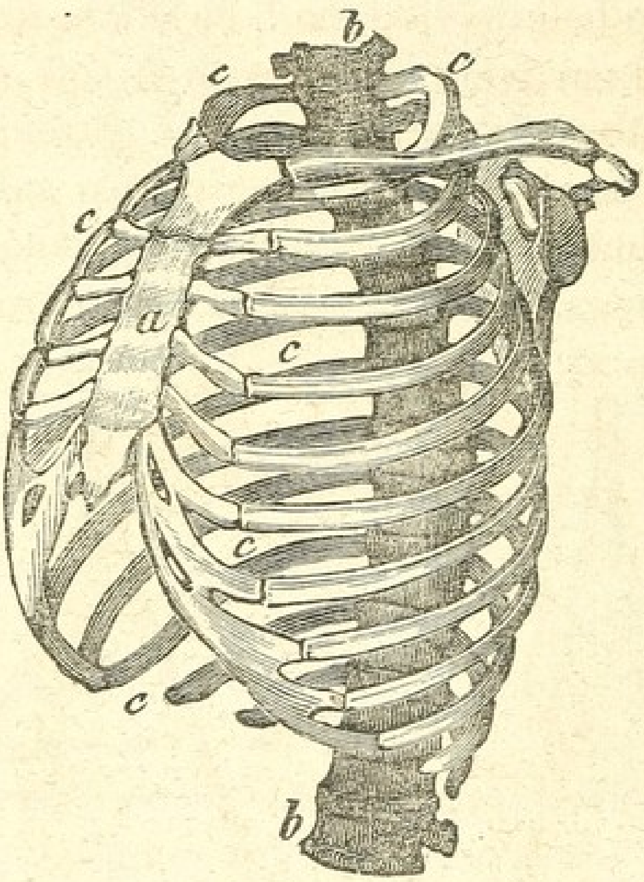
pair of bellows thus arranged. In Fig. 27 the sides of the bellows are brought near together, and so some of the air is forced out, and the spaces or air-cells are small. So when expiration is performed by the chest

Give the illustration of the bellows. What is *expiration?*

the air-cells shrink as the air passes out of the trachea. In Fig. 28 the sides of the bellows are moved apart and the air-cells are enlarged, the air rushing in through the nose to fill them up. Just so, when the chest expands in inspiration, the air-cells in the lungs enlarge, and the air fills them by rushing in through the trachea.

10. That you may understand how the movements of the chest are made in inspiration and expiration, I

Fig. 29.



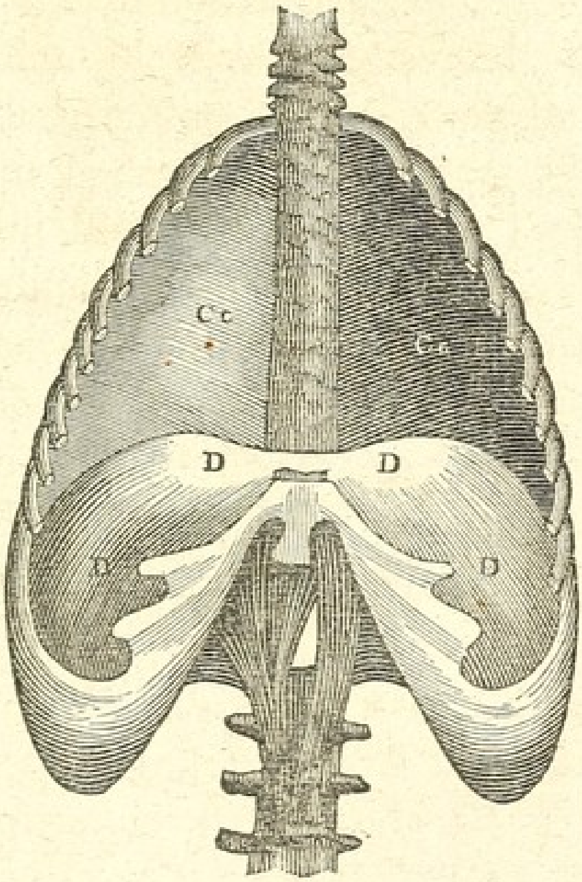
must describe to you the structure of the chest. Its walls are made up of bones connected together chiefly by muscles. The bones that form the framework of the chest you see in Fig. 29. The spinal column *b b* is the grand pillar that supports this barrel-shaped

Give in full the illustration of breathing presented in Figs. 27 and 28.

framework. The ribs *c c c* are fastened very strongly by ligaments to the spinal column. They are twenty-four in number, twelve on each side. They extend round towards the breast-bone *a*, in front.

11. The ribs do not join directly to the breast-bone, as you can see in the Figure. There are pieces of cartilage, or gristle, as it is commonly called, that connect them to the breast-bone. The object of this is plain. If the ribs extended to the breast-bone, they would break very easily, if they were struck. But the cartilages give a little, as it is expressed, whenever the chest receives a blow, and so the ribs are seldom broken.

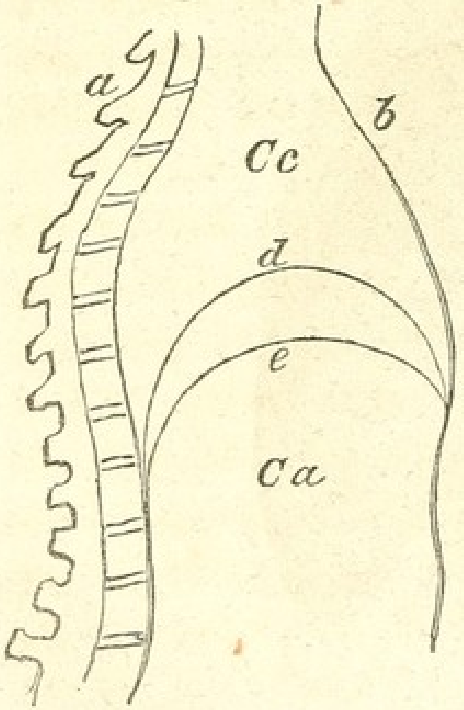
Fig. 30.



Describe the framework of the chest. How many ribs are there? How are the ribs connected with the breast-bone? What is the object of this arrangement?

12. This framework of the chest is connected together, as I have already said, chiefly by muscles. It is these muscles that work the chest in the movements of breathing. The principal muscle that acts in breathing is called the *diaphragm*. It is a stout muscular and tendinous sheet, extending across the lower part of the chest. It is the wall that separates the cavity of the chest from the cavity of the abdomen. Above it are the heart and the lungs, and below it are the stomach, the liver, the intestines, &c. It is represented in Fig. 30. Here you have the cavity of the chest, *Cc*, laid open, the ribs being cut away in front, and the heart and lungs taken out; *D D* is the diaphragm. It is fastened to the spinal column behind, to the breast-bone in front, and to the lower ribs all around the sides. You see that it is not flat, but is arched upward.

Fig. 31.



13. I will now show you how the diaphragm acts in respiration. You can see that if the fibres of the diaphragm contract or shorten themselves, it will not be arched up so high, and so there will be more room in the chest. The air, therefore, will rush in through the windpipe, just as it rushes into the bellows when you move the handles apart. This I will make clear to you

How is the framework of the chest connected together? Describe the diaphragm? What are above and what are below it? To what is it fastened? What is its shape?

by Fig. 31. Let *a* represent the spinal column, *b* the front wall of the chest, *Cc* the cavity of the chest, and *Ca* the cavity of the abdomen. At *d* is represented the diaphragm. You see that if the fibres of the diaphragm are shortened, so as to flatten its arch down to the line *e*, the room in the chest will be very much increased. This is what takes place every time that you make an inspiration or draw in a breath. When, on the contrary, you make an expiration, or force out the breath, the diaphragm is pushed upward, as at *d*, and so the room in the chest is lessened.

14. If when you draw your breath in, you will place your hand on the abdomen, you will perceive that it presses outward. This is because, as the arch of the diaphragm is flattened in inspiration, the contents of the abdomen are all pressed down by it. But when you force out the breath from the lungs the abdomen moves inward. For in expiration, the stomach, liver, &c., are moved upward, and they push up the arch of the diaphragm.

15. Commonly the diaphragm does most of the work in breathing. But there are other muscles that assist a little generally, and sometimes assist very much. They are muscles that move the whole framework of the ribs and the breast-bone forward and upward. By doing this they enlarge the room in the chest in front and at the sides at the same time that the diaphragm does below. Whenever you see the

Describe by Fig. 31 the manner in which the diaphragm acts. Why does the abdomen move outward in inspiration and inward in expiration? What muscles assist in breathing? Do these muscles act much ordinarily?

chest heaving from severe exercise, or from difficulty of breathing, in disease, these muscles are acting strongly, moving the ribs and the breast-bone upward and forward.

16. I said in the first part of this chapter, § 3, that the dark blood that comes to the lungs is changed to red blood in the air-cells. And you can see, from what you have learned in this and in the last chapter, how important it is that this change in the blood should be well and thoroughly accomplished. If the blood is not changed at all, death results at once; for the dark blood is a deadly poison to all the organs, if it goes to them in the arteries and gets into the capillaries. Life cannot go on without red blood is continually sent to the organs. This is the reason that life is so soon destroyed in drowning. No air can get into the lungs, and the air that is there is soon used up. The blood that comes to the lungs very soon therefore ceases to be changed, and so dark blood goes to the brain and all the other organs, the machinery all stops, and life ceases.

17. Life is destroyed in drowning, then, in the same way that it is when a cord is tied tightly around the throat. It is destroyed by keeping the air from going into the lungs, and not by having water get into them, as is very commonly supposed. Disease often produces death by keeping the air from getting freely into the air-cells of the lungs. The disease called croup, sometimes so blocks up the windpipe that

Why is it so important that the dark blood should be changed to red in the lungs? How is life destroyed in drowning? How does disease often produce death?

very little air can get through it into the lungs, and so it destroys life, because the blood cannot be changed anything like as much as is needed.

18. Life has been sometimes destroyed by confining too many persons together in one apartment. The difficulty here is really the same as in drowning. It is the want of air. Death occurs, because from the want of air the blood ceases to be changed in the lungs. I could cite many interesting cases of this character, but I will give you but one. A ship, called the Londonderry, had a large number of emigrants on board. A storm arose, and all the passengers were ordered to go below. They were very much crowded, and all the air which they breathed came to them through the hatchway, an opening in the deck. But as the sea dashed over the vessel, the water poured down this opening. The captain, therefore, had a tarpaulin (a cloth through which neither water nor air can pass) nailed over it. The result was that a large number of the emigrants died for want of air. Their cries of distress could not be heard from the noise of the storm, but a strong man at length forced a hole through the tarpaulin, and told the captain that the people were dying. The tarpaulin was torn off, and thus many of them were saved.

19. If fresh air is so absolutely necessary to life, then the health of the body must be injured, when, from day to day, the lungs do not breathe enough of it. One sometimes feels very languid in a crowded assem-

What is said of death being sometimes produced by a want of ventilation? Relate the case stated. How is the health injured by deficient ventilation, suffered from day to day?

bly. This is because enough good fresh air does not get into the lungs, and the work of changing the blood in them is therefore not well done. Now if this work is poorly done in the lungs every day, the blood, the building material of the body, will not be as good as if the lungs did their work well. The consequence will be that the building and the repairing will be poorly done. In other words, the body will not be vigorous, and will be liable to disease. Living in small or crowded apartments often does much harm in this way.

20. There is another way besides those that I have mentioned, in which the air can be prevented from getting to the lungs. The air-passages may all be open, and there may be plenty of air, but if the muscles of the chest cannot act, no air can go into the lungs through the windpipe. The air, you remember, goes in only because the space in the chest is enlarged by these muscles. If then these muscles are in any way prevented from acting, the air will be kept out from the lungs, and the person will die for want of air, just as he does when water or anything else shuts up the passages to the lungs.

21. Life is not very often destroyed in this way. It is sometimes, however, and I have already alluded in this chapter to a case of this kind. I mean the case spoken of in § 6, of a man with a bank of earth fallen upon him. In such a case death is caused very much in the same way that it is in drowning. In both cases air is prevented from getting into the lungs,

What happens if the muscles of the chest cannot act? How does death occur in such a case?

though in a different way in each; the blood is therefore not changed from dark to red; dark blood goes to the organs of the body; these organs stop work, for want of red blood, and life therefore ceases.

22. Though life is not often destroyed *suddenly* by pressure on the chest, it is in many cases destroyed gradually by this pressure. A great pressure, as you have seen, causes death at once, by keeping out the air entirely; but a small pressure prevents the lungs from getting as much air as is needed, and, although this does but little harm at any one moment, by being continued a long time it will injure the health and shorten life.

23. That you may understand just how this continued small pressure does harm, call to mind the way in which the blood is changed in the lungs. It is done, as I told you in §3, in the air-cells. Each one of these cells has to do its share of the work. It must change the blood that comes to it. And that it may do this, the air must go in and out of it freely. But this cannot be if the chest cannot be well expanded. Pressure on it will keep the air from going as freely into the cells as it should, and so the blood cannot be as thoroughly changed as is necessary to make it good material for building and repairing. The blood is poor blood, and therefore the vigor of the body is lessened and the health is injured.

24. Continued pressure around the chest does harm in another way also. The lungs, like any other machinery, cannot keep in good condition unless they

What effect is produced by a small but long-continued pressure on the chest? Explain how this effect is produced.

work freely. If they are continually pressed upon, so that they cannot expand freely as they take in the air, the tubes and cells get clogged here and there from time to time. The difficulty is not noticed perhaps for a long time, but at length the lungs become manifestly diseased. You see, then, that a continued pressure of the chest does harm in two ways. 1st, It does harm to the whole body, because it makes the blood poor. 2d, It does special harm to the lungs themselves.

25. If the chest is pressed continually while the lungs are growing, they will not be large enough to do the work that is needed. You have seen that in the building and repairing of the body the digestive machinery, the circulating machinery, and the machinery of the respiration, each has its own work to do. Now if any one of these sets of machinery is cramped and small, it will not do its share of the work well, and the body will be poorly built. When the chest is pressed upon during the growth of the body, the breathing machinery is cramped and is made small. There are not air-cells enough to change all the blood that the body needs as it grows. It therefore will not grow well. It will not be strong.

26. The chest is often much pressed by tight clothing while the body is growing. The lungs are in this way made to be very much smaller than they should be. In Figs. 32 and 33 you see this illustrated. In Fig. 32 is represented the chest of its natural size.

In what two ways does pressure on the chest do harm? What happens if the chest is pressed continually during the growth of the body?

Fig. 32.

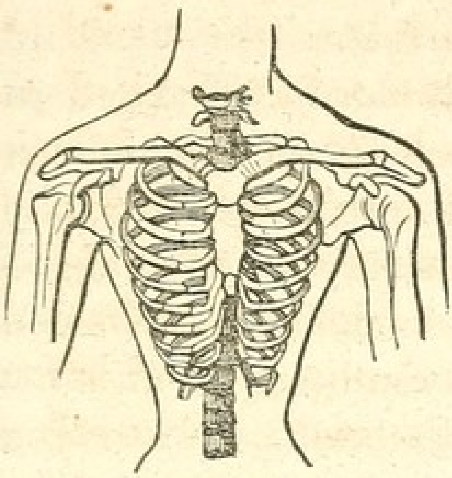
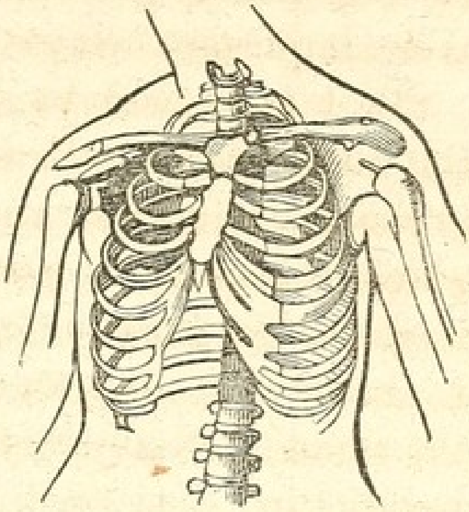


Fig. 33.



In Fig. 33 you see the chest as it is in one that has been girt round tightly all her life, so as to make her waist very small. The ribs, you see, are brought very near together, so that they could hold only very small lungs. Health and vigor cannot exist with such small breathing machinery. They are sacrificed in such cases for the sake of a small waist.

27. In China, instead of a small waist, a small foot is considered very desirable in a female. The foot is, therefore, put under pressure while it is growing, just as the chest often is among us. And it is astonishing how small and into what a shape it can be made to grow. In Fig. 34 is a side view of a Chinese lady's foot. In Fig. 35 is a view of the sole of the same foot. You see that all the toes but the great one are turned in under the foot. We laugh at the folly of the Chinese, but the folly of one that cramps the chest, as represented

Fig. 34.

Fig. 35.

Compare the compression of the chest with the compression of the feet as practiced in China.

in Fig. 33, is greater, because the lungs are much more important organs than the feet.

28. I have told you that the blood is changed in the lungs from a dark to a red color. You have been perhaps curious to know what other change takes place in it at the same time. It is very much changed in its *composition*. And the air in changing the blood is changed itself. The air that you breathe out is not the same as that which you breathe in. When you breathe in, it is fresh air that goes into the lungs; but when you breathe out, the air that comes from your lungs is partly a gas or air, called carbonic acid gas. This gas you cannot live in as you do in the air that is all around you. No animal can live in it.

29. If you should put a bird into a jar, and cover it over with a bladder tightly, so that no air can get in or out, the bird would breathe a little while and then would die. The explanation is this: The bird uses up the air in the jar, and the carbonic acid gas which he breathes out takes the place of the air. So it was with the passengers in the cabin of the Londonderry, mentioned in § 18. The cabin, with the tarpaulin nailed down over the hatchway, was to them as the jar with the bladder tied over it is to the bird. They, like the bird, used up the air, and the carbonic acid gas which they breathed out from their lungs, took its place in the cabin, as the carbonic acid gas from the lungs of the bird takes the place of the air in the jar.

30. This carbonic acid gas is carbon or charcoal

What is said of the change of the blood in the lungs? What is the difference between the air that you breathe in, and that which you breathe out? Explain the experiment with the bird.

united with a gas called oxygen. The amount of this carbonic acid gas that you breathe out from your lungs in the course of a day is such that it contains several ounces of charcoal. This gas comes from the blood in the lungs as it changes from dark to red blood. At the same time a part of the air that we breathe in is united with the blood. The air is composed of two gases, called oxygen and nitrogen. It is the oxygen that unites with the blood.

31. You see, then, that a sort of exchange is made in the lungs. The blood comes there from all parts of the body full of carbonic acid gas. This it lets out in all the air-cells, so that it can be breathed out through the windpipe. At the same time that it lets out this gas it takes in a supply of oxygen. It is this exchange of carbonic acid gas for oxygen that alters the blood from dark to red blood, and thus fits it to be used again in nourishing the body.

32. As all animals are throwing off from their lungs carbonic acid gas, and are taking oxygen into the blood, one would suppose that the oxygen in the air would all be used up, and that we should have carbonic acid gas everywhere in its place. How is it that it is not so? I will tell you. The carbonic acid gas is all taken away by the leaves, which are the lungs of plants. At the same time the leaves, give out oxygen. The leaves then do just the opposite to what our lungs do. They discharge oxygen and take in carbonic acid gas, but our lungs discharge carbonic

What is the carbonic acid gas breathed out made of? From what does it come? What part of the air unites with the blood? What is the exchange made in the lungs? What is the effect of this exchange?

acid gas and take in oxygen. An exchange, then, is constantly going on between our lungs and the leaves. Our lungs give them carbonic acid gas, and they give our lungs oxygen.

33. The lungs vary much in different kinds of animals. The gills of the fish are its lungs. But how, you will ask, does the fish get the air to his lungs while he is in the water? I will tell you. There is always some air in the water, and the air is made to act upon the blood in the fish's gills in this way: The fish makes the water run through his mouth, and then out through the feather-shaped gills. And as the water is passing out through them, the air in it changes the blood in the fine blood-vessels spread out there, just as the air in the air-cells of our lungs acts on the blood in the blood-vessels that are in them. The fish then may be said to breathe air and water together. We cannot do this, because our lungs are not fitted, as the lungs or gills of the fish are, to separate the air from the water. We should be drowned if we should try to do it. And, on the other hand, the fish dies when he is taken out of the water, because his lungs are not fitted, as ours are, to use air alone. He must have his air mixed up with water, or it is of no use to him.

34. It can be proved by experiment that it is the air in the water that keeps the fish alive. If a fish be put into a glass vessel filled with water, and covered with a bladder tied over it, so as to make it air-tight,

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Describe the exchange that takes place between the lungs of animals and the leaves of plants. What are the lungs of fishes? How do they use them? Why cannot fishes breathe air alone?

the fish will soon die, because it will soon use up all the air that is in that little quantity of water. When we speak, then, of fishes living in water, it is not strictly true—they live in water that has air mixed with it.

35. The lungs of insects are mere air-vessels here and there in different parts of the body. You can see the holes opening into them on the sides of the insect. The grasshopper has twenty-four of these holes in four rows.

36. There is a curious arrangement of the breathing machinery in birds. They have sacs or bags in different parts of the body that are connected by tubes with the lungs. These they make use of in flying. When they wish to fly upward, the lighter they make themselves the better. They therefore force air from the lungs into these sacs. But when they wish to come down quickly they let the air out of the sacs. Birds that fly very high, or are long upon the wing, have many of these sacs, and even some of the bones are made in them so that they can hold air.

37. The chief use of the machinery of the respiration is, as you have seen in this chapter, to bring the air to the blood in the lungs, that it may purify it and fit it to be used again. But the Creator almost always makes a thing useful in other ways besides the use for which it is particularly designed. This is true of the respiration. This is made use of in man and in many other animals for the production of the voice.

How can you prove that it is the air in the water that keeps fishes alive? What are the lungs of insects? What peculiarities are there in the breathing apparatus of birds? What is the chief use of the respiration? What is another use of the respiration?

38. The breathing machinery, then, besides being a chemical laboratory for changing the blood, is also a musical instrument. I will speak of the different parts of this instrument. You feel in the upper part of your throat, in front, a firm body, the larynx, commonly called Adam's-apple. This is the music-box of the instrument; that is, it is the place where the voice is made whenever you speak or sing. The chest is the bellows to this little organ in the throat. It holds the air in its lungs, and blows it out through the windpipe into this music-box to make the voice.

39. The voice is made in the larynx very much as sounds are made in other musical instruments. It has two flat cords stretching across it, and the air comes out between them. When you force out the air from the lungs, it strikes on these cords and a sound is made, just as when you blow on a clarionet the air from your mouth makes the sound by striking on the reed. It is the vibration or shaking of the cords by the air that makes the sound of your voice. You can see this vibration in some instruments as they are played upon. You can see it in the strings of a violin as the player draws the bow across them. And the air does to the cords of the music-box in your throat the same thing that the bow does to the violin. It makes them vibrate. You can see this vibration, also, if you look into a piano while some one is playing on it, and observe the strings as they are struck by the keys.

40. The air is passing out and in through the chink

Describe the apparatus of the voice. How is the voice made? Trace the resemblance between the apparatus of the voice and musical instruments.

between the cords of the larynx continually as you breathe. But it does not, as you know, always produce a sound. I will explain to you why it is that a sound is sometimes made as the air passes through this chink, and sometimes is not. When the cords are loose they do not make any sound. They are loose when you merely breathe. But when you speak or sing, they are tightened. You know that the strings of a violin must be stretched tight, or they will give no sound. And so it is with the cords of your larynx. When you whisper, these cords are loose, and the air goes quietly by them, and the voice is made by the mouth and lips. In whistling, also, they are loose, and the sound is produced by the air as it passes through the lips.

41. There are little muscles that tighten the cords of the music-box in your throat when it is needed. When you are merely breathing, these muscles do not act. But when you speak or sing, they contract, and thus tighten the cords. The different notes of the voice depend upon the degree to which these cords are tightened. When the note is a high one, they are tightened very much; but when the note is a low one, they are tightened but little. The working of the little muscles in tightening these cords is regulated by the mind in the brain, by means of the nerves that go to them.

42. It is only animals that live in the air that have a voice. Fishes have none. Some animals can live

Why does not the air always produce a sound as it goes back and forth through the cords of the larynx? By what are the cords of the larynx tightened? How are the different notes of the voice produced?

both in the water and in the air. This is the case with frogs. If you watch a frog, you will see that he makes no noise while under water, but he does all his croaking when he puts his head up into the air.

43. Man is the only animal that can talk to any extent with his voice. He does it in this way: The sound, being made in the larynx, is put into various shapes, as we may say, as it comes out through the mouth. The palate, the tongue, the teeth, the lips, &c., give it these various shapes. This is what is called the *articulation* of the voice.

CHAPTER VI.

BUILDING AND REPAIRING.

1. We are so accustomed to see plants and animals *grow*, that we do not think of the wonderful processes by which growth is effected. We get the idea in our childhood, that growth is a very simple thing. But it is not so. It is very complicated, and there are many things about it that are very mysterious.

2. Everything which grows is *made*. Growing is *building*. There must be, therefore, something to build with—that is, a building material. In plants, the sap is the building material; and in animals, it is the blood. Every part of the human body is *built;* and, as you will see in this chapter, there are every-

What animals have a voice? What is the *articulation* of the voice? Is growth a simple process? What is growing? What is the building material in plants, and what in animals?

where little builders, that are always at work in building or in repairing.

3. All the various structures of the body are made or built from the same thing, the blood. This appears very wonderful, when we observe how different from each other some of these structures are. For example, how different are the white hard teeth from the soft red gums that surround them, and yet both are made from the blood.

4. That you may see how great is the variety of the structures formed out of the blood, I will direct your attention to some one part of the body. Look, for example, at the eye. Observe how many and how various are its parts. I will mention most of them. They are, the bony socket; the eye-lids; the eye-lashes; the firm white coat of the eye; the clear round window in front; the beautiful iris; the three different fluids that are in the eye-ball; the muscles that move the eye; the cushion of fat in which it rests; the nerves; the tear-gland, &c. All these parts, so different from each other, are made from the blood. And so it is with all the different parts in every portion of the body.

5. Not only are all the structures of the body built from the blood, but the vessels that carry the blood to them, and the heart that pumps it into them, are made from the blood that they contain. This is not less wonderful than it would be to have the pipes of an aqueduct made out of the water that is in them.

From what are all the different structures in our bodies formed? Illustrate the variety of structures made from the blood by the parts of the eye. What is said of the blood-vessels and the heart?

6. The fluids of the body, as well as its structures, are made from the blood. The glands that secrete these fluids make them from the blood that flows through them. Thus the tear-glands make the tears that moisten the eye from the blood. The liver makes the bitter yellow bile from the blood also. And so of the rest of the glands. Observe, that the glands are made from the same blood from which their secretions are formed. Thus the tear-gland and the tears are made from the same blood. That is, the factory is built with the very material from which it manufactures its product.

7. You can see better how wonderful it is that all the parts of the body are made from one common building material, if I compare the building of the body to the building of a house. When a house is built, there must be gathered together a great variety of materials. There must be beams, boards, shingles, &c., and nails to fasten them together. There must be bricks made of clay. Lime must be obtained from one place, sand from another, and hair from another; and these mixed make the mortar to fasten the bricks together. There must be stone for steps and foundation, and various other purposes. Glass must be obtained for the windows, and paper for the walls. A variety of materials is required, to make paints of different colors. All these and various other things must be collected, to build a house. And then, to finish the house after it is built, materials are needed

What is said of the fluids and the glands that secrete them? Give the comparison between the building of the body and the building of a house.

from every quarter, to provide the various articles of furniture, as carpets, chairs, sofas, beds, bureaus, mirrors, lamps, &c.

8. Now, in the house which your spirit inhabits, the body, there is a much greater variety of structure and furniture than there is in the houses that man builds; and yet all of it is built of the same material. Many of its parts differ from each other much more than the different parts of a house. It would be passing wonderful if bricks and boards and nails were made out of the same thing, but these articles are not so much unlike each other as the hair, the skin, and the teeth. Some of the parts of the body are totally unlike the blood, and it seems impossible that they can be made from it. It would seem comparatively easy to make the red muscles out of the blood, but it is not so with such structures as teeth, nails, tendons, hair, &c.

9. I will now show you how the blood is used as the building material of the body, and what are the workmen that thus use it. The blood is not used for building and repairing while it is in the arteries, nor while it is in the veins, but only while it is in the capillaries. The heart sends it through the arteries to the capillaries, that it may be used there. Then, after it is used, it goes back to the heart through the veins. The heart, and the arteries, and the veins are therefore simply an apparatus or set of machinery for circulating the building material. This apparatus may be called the

What is said of the difference between the structures of the body and the blood from which they are made? Where is the blood when it is used for building? What is said of the apparatus of the circulation?

common carrier of the body. It carries the building material to the very door, as we may say, of all the little builders everywhere.

10. It is supposed that the building is not done by the capillaries themselves. These merely hold the blood, while some other small vessels, called formative vessels, use it to build with. These formative vessels have the power of selecting from the blood, while it is passing through the capillaries, just what they need to make the different structures. Some are bone-makers, some nerve-makers, some skin-makers, &c. The bone-makers select from the blood what is needed to make bone, the nerve-makers what is needed to make nerve; and so of all the various textures of the body.

11. Sometimes the formative vessels fail to make the right selection, as for example, when bone is formed where it should not be. Thus, sometimes in aged persons, the arteries become here and there bony. In this case some of the artery-makers leave off their usual business and go to making bone. Sometimes even the valve-makers in the heart do this. When warts appear upon the skin it is because the skin-makers at those places leave off their regular business, and make something else. But such irregularities are not common. Generally, the formative vessels very faithfully adhere to their regular work, as we may express it, and choose just the right material from the blood, as it passes along by them in the capillaries.

By what vessels is the building of the body done? What is said of the selecting power of these vessels? Illustrate the fact that they sometimes err in their selection.

12. Each set of formative vessels appear to work together, as if there was some kind of agreement between them. If there were not this concert of action there would be confusion. The different parts would not be properly formed. If there was irregularity, for example, among the bone-makers, the bones would not be regularly made. There would be bunches, and sharp points, and rough places, where there is now smoothness and regularity.

13. This concert or agreement of action in the formative vessels, is seen in the different shapes that the same kind of structure takes in different parts of the body. Thus, every bone differs in shape from every other bone. That is, every set of bone-makers have a plan of their own, which is different from the plan of every other set. For example, the bone-makers that make the knee-pan have a very different plan from another set in the same neighborhood that make the long thigh-bone. So also the makers of any muscle have a different plan from the makers of any other muscle. And so of other kinds of structures. The formative vessels everywhere act upon some regular fixed plan, just as if they thought it out, and agreed together as to what they would do.

14. This concert of action is so perfect in each set of the formative vessels, that the different sets do not interfere with each other when working in the same neighborhood. Each set keeps at work commonly within its own bounds, and does not encroach upon the

What would result if there were not a concert of action among the formative vessels? How is this concert of action seen in the different shapes given to the same kind of structure?

work of another set. Thus the tooth-makers and the gum-makers never interfere with each other. There are, as you have seen, many different structures in the eye, but there is no interference between the different sets of workmen in constructing the eye and in keeping it in repair. The builders, for example, that construct the white part of the eye-ball never encroach upon those that make the clear window in front, that fits into the white part, as the crystal of a watch does into the case. They only build up to the edge of this window all around, as if they agreed to build along this circular line.

15. You can see this concert of action very curiously exhibited in the formation of the lips. I told you in chapter II, § 20, that the red covering of the lips is somewhat like both the skin and the mucous membrane that lines the mouth, and yet it differs from either of them. The lip-makers then are between two sets of workmen, that are making textures somewhat similar, and yet they keep their work very distinct from that of the workmen on either side. They are always making the red delicate texture of the lip, and never go to making skin with the skin-makers on the one side, or mucous membrane, with the workmen on the other.

16. This concert of action in the formative vessels is beautifully shown in the increase of the size of the different parts of the body, as the child grows up to manhood. All the different structures in any part

How is concert of action seen in the fact that the different sets of formative vessels never interfere with each other? Give the illustration in regard to the lips.

keep the same proportions as they increase in size. For example, as the finger of the child grows to be the large finger of the adult, all the different sets of builders do just the right amount of building. The nail-makers make just enough nail, the skin-makers enough skin, the bone-makers enough bone, &c. If the builders did not work after some plan, there would be too much of one structure and too little of another, and the finger of the man would not be like the finger of the child. And so of other parts.

17. There is another thing to be noticed about this agreement of action in building the body. There are two halves of the body, which are generally just alike. The right hand is like the left, the right side of the face is like the left, and so of the other parts. That is, for every set of builders on one side of the body there is another set on the other side, working after precisely the same plan, as if they had agreed to do so. Sometimes this agreement is not fully carried out, and one part is not shaped exactly like its corresponding part on the other side. Thus, the two sets of nose-makers in the two halves of this organ sometimes do not work exactly after the same pattern, and there is some irregularity, perhaps one-sidedness.

18. What I have just said of the body, as being made of two halves just alike, is not true of all the organs within the body. While the brain has two halves just alike, this is not true, as you have already seen, of the lungs, the heart, the stomach, the liver, &c. But each

How is the concert of action in the formative vessels seen in the regular growth of the body? How is it seen in the two halves of the body? Is the concert always perfect?

of these organs is constructed after a fixed plan of its own, and the formative vessels, in constructing it after this plan, must have an agreement in their operation.

19. From all that I have said in the last few paragraphs, it appears that there is as much agreement of action among the formative vessels of the body, as there would be if they were intelligent workmen, and worked under directing leaders. In what way the Creator makes them to work together thus, we do not understand.

20. There is not only building going on in every part of the body, but there is repairing also. And they go on together. You remember that I said in the first chapter, that the machinery of the body is in use all the time that it is building, or rather all the time that it is changing from small machinery into large machinery. There is therefore some wear from this use, and hence repairing is needed all the time.

21. The way in which the repairing is done is this. When any particles in any part become useless, they are taken out of the way, and are carried off in the dark blood. At the same time the formative vessels take new particles from the red blood in the capillaries, and put them in the place of those that are removed. As you work the muscles, some of the particles get worn out and useless, and so they are carried off, and new particles are put in their places. As your mind uses the brain in thinking and studying, it

What organs of the body do not have two halves just alike? How is concert of action shown in constructing them? Do we know how this concert of action in the formative vessels is produced? What is said of the repairing of the body?

wears out some of the particles there, and they are taken away, and new ones are supplied. And so of other parts of the body.

21. In this way there is a change going on continually in all parts of the body. There are probably scarcely any particles in your body now that were there when you was born. It is a very common notion that the whole body changes once in seven years. But this is not so. There is no such regular period for the change. As long as any particle is useful in its place it remains there; but when it becomes useless it is taken up and carried away.

22. The change is more rapid at some times than it is at others. You know how very fast sick persons sometimes become thin, and then how fast they gain flesh when they begin to eat again. In such cases a large portion of the body is entirely changed in a very short time. The change in young children is sometimes very great. They become so poor in a little time that the loose skin hangs upon their limbs like clothes; and then when the disease is gone, and the appetite returns, the limbs soon become plump again. Now the changes which you see so plainly in such cases are going on all the time slowly and quietly in the body. Old useless particles are constantly taken away, and new particles put in their places.

23. It is to effect these constant changes in the growth and repair of the body that the blood is in motion everywhere. If these changes were not going

Describe the way in which the repairing is done. What is said of the change that is occurring in all parts of the body? Is this change going on always just alike? In what cases is it very rapid?

on, there would be no need of having the blood circulate. In some animals these changes are stopped in cold weather, and the blood stops moving. Great multitudes of such animals as frogs, bats, flies, spiders, &c., go into retirement in the autumn to sleep through the winter. Their bodies remain without change all this time. They are alive, but as still as death. The machinery of life is still, and so there is no wear and tear. There is therefore no repairing to be done, and so there is no need of having the blood circulate. And as there is no circulation there is no need of respiration.

24. When the warm weather comes, these animals wake up from this state of torpor. The blood begins to move again, and they breathe, so that the air can go into the lungs and change the blood. They begin to eat, too, so that some new blood can be made. A gentleman who was curious on this subject, kept some frogs and snakes in this torpid state in an ice-house for three years and a half, and then revived them by bringing them out into the warm air.

25. I have said that the useless particles that come from the wear and tear of the organs in their daily use are taken up to be carried away in the dark blood. I will now show you how this waste matter is disposed of. There are various ways of carrying it off. Some of it is discharged by the lungs. At every breath some part of the waste matter of our bodies is thrown off from the lungs in the form of carbonic acid gas, as

Why is the blood constantly in motion everywhere? What is the situation of some animals in winter? What effect does the warm weather of spring produce in them?

you learned in the chapter on Respiration. Other portions of the waste matter are removed by the skin, others by the kidneys, others by the liver, &c.

26. The waste matter is all sent off by these different organs, each doing its share, and in its own way. Observe how it is done. The waste matter is in the blood. Now as the blood goes to these organs, the lungs, the skin, the liver, the kidneys, each does its duty in cleansing the blood of the waste matter. And in doing this each organ seems to have the power of choosing just that part of the waste that it is its business to throw off. And it never makes a mistake, and throws off good particles instead of bad ones. But we know that these organs have no thought nor knowledge, and therefore cannot choose. And the perfect way in which they are made by the Builder of our bodies to do their duty is a mystery which we cannot understand. Each organ, I have said, has its own way of getting rid of the waste matter. For example, it is thrown off in the lungs in the air that we breathe out, while by the skin it is thrown off in a very different form—in the perspiration.

27. The skin is so important an organ in throwing off the waste of the body, that I will describe its structure. There are really two skins—a thick inner skin, and a thin outer one, called the scarf-skin. The coloring matter of the skin is not in the inner skin, but in the inner layers of the scarf-skin. When the skin is rubbed off, as it is expressed, it is only this

In what various ways is the waste matter of the body disposed of? Describe the manner in which it is done. What is said of the selecting power of the different organs in getting rid of the waste? Is it thrown off in the same form from the different organs?

scarf-skin that is removed, and the inner skin, called the true-skin, is laid bare. It is the scarf-skin that is raised when a blister is applied.

28. The true-skin is very sensitive, for it has a great number of nervous fibres in it. This is for the purpose of having the skin act as a sentinel for the inner organs. If the skin did not, by its nerves, warn of the approach of danger, these organs would be much oftener injured than they now are. The scarf-skin, which is not sensitive at all, makes a soft delicate covering for the inner sensitive skin. The true-skin, without this covering, would look badly, and would feel too keenly. I shall say something more about the skin as a sensitive organ in the chapter on the Nervous System.

29. The perspiration of the skin is in two different forms. When the skin feels soft, but does not look moist, there is a moisture going from it all the time in the form of vapor. This is called *insensible* perspiration, because we cannot see or feel it. If you place your hand, when it appears dry, upon a glass, and hold it there for some time, the glass will become moist from the insensible perspiration. The skin is sometimes covered with moisture, perhaps in drops, as, for example, after brisk exercise on a warm day. This is called *sensible* perspiration.

30. The perspiration is separated from the blood in the skin by innumerable little glands. The pores through which it is discharged are the outlets of the

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Describe the structure of the skin. Where is the coloring matter of the skin? What is said of the sensitiveness of the skin? What is the use of the scarf-skin? What is the difference between *sensible* and *insensible* perspiration? By what is the perspiration formed? What are the pores of the skin?

tubes from these glands. There is another set of glands in the skin that separate an oily fluid from the blood. These oil-factories are most abundant wherever the skin particularly needs oiling, as at the joints, where one part of the skin rubs against another, and where the skin is exposed to the air, as in the face.

31. The skin then serves several different purposes. 1. It is a firm, but soft and beautiful covering for the body. 2. By its nerves it warns of the approach of danger. 3. It also, by its nerves, as the organ of touch, gives knowledge to the mind of objects around us. 4. It discharges, in its perspiration, much of the waste matter of the body.

32. The change that I have described in this chapter, as going on in all parts of the body, produces to a great extent the heat of the body. It does this by a kind of combustion or burning. You remember, that in the chapter on Respiration I told you that the oxygen of the air enters the blood in the lungs, and goes with it to the heart, and then is sent, with it, all over the body. Now, this oxygen, when it comes to the capillaries, is united to carbon, that is, charcoal, and makes carbonic acid gas. This gas goes to the heart with the dark blood, then is sent with it to the lungs, and there is thrown off, as I have already told you. At the same time, the oxygen also unites in the capillaries with another substance, a gas called hydrogen. It is this union of the oxygen with the carbon and the hydrogen that makes the heat of the body.

33. Now this is very much like what takes place in

What other glands are there in the skin, and where are they most numerous? Mention the four different purposes which the skin serves. Describe the process by which the heat of the body is chiefly produced?

combustion. When we burn charcoal, that is, carbon, in the air, it unites with the oxygen of the air; and it is this union that makes the heat that is given out. So too, when the chemist burns oxygen and hydrogen gas together, it is their union that produces the heat. So it is in the capillaries of the body. The union of the oxygen with the carbon and the hydrogen makes the heat of the body. There is a fire, then, we may say, in every part of the body in the fine blood-vessels, although there is no flame.

34. Carbonic acid gas is produced by the burning of charcoal in the air. So also it is produced by the fire in the capillaries. It is carried from them with the blood to the lungs, and there it is discharged through the windpipe. The windpipe may then be called the smokepipe or chimney, through which the smoke of this general combustion in the body is let off into the air. It will be interesting to notice here that the windpipe answers three different purposes. 1. It conducts fresh air to the lungs. 2. It carries off the bad air, or, as we may express it, the smoke of the fire that is in the body. 3. While carrying off the bad air it acts, when we speak or sing, as the conducting pipe of the organ of the voice in the throat from the bellows at work below, the chest.

35. Observe that in this combustion of the capillaries a part of the fuel is furnished from the waste of the body. The carbon and hydrogen that unite with the oxygen are, to a great extent, produced by this waste. As the oxygen comes in the red blood to the

Trace the resemblance between this and the process of combustion. What three purposes does the windpipe answer?

capillaries, the useless particles that are to be thrown off furnish carbon and hydrogen to be burned with the oxygen. And then what results from this burning is carried back in the dark blood in the veins.

36. When anything is burned up it is spoken of as being destroyed, but this is not so. The burning merely changes matter into some other form. Thus, when carbon or charcoal is burned in air, the oxygen of the air is taken away, and the charcoal disappears. But there are ashes left, and a quantity of carbonic acid gas has been formed. So, when oxygen and hydrogen are burned together, they both disappear, but in disappearing they form water. The same thing is true of the combustion in the body. The oxygen and carbon are burned up together in the capillaries; but carbonic acid gas results, just as when charcoal is burned in the air, and this gas is carried to the lungs, to be thrown off through the chimney, the windpipe. Oxygen is burned up also with hydrogen in the capillaries, and water results, just as when the chemist burns them together. Much of this water thus formed is thrown off by the lungs in vapor. It is supposed that a man discharges from his lungs in this way about two quarts of water in every twenty-four hours.

37. You can see now why it is that exercise increases the heat of the body. During exercise the heart beats quicker than usual, and so sends the blood more rapidly everywhere. More blood passes there-

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From what does the fuel for the combustion in the body mostly come? Is it strictly correct to speak of a thing as being *destroyed* when it is burned? What are the products of the combustion in the capillaries? What becomes of these products?

fore through the lungs. The breathing is quickened also, and as more air is taken into the lungs, of course more of the oxygen of the air unites with the blood. But the oxygen is a part of the fuel that is burned in the capillaries, and the more fuel there is the greater is the heat. The other parts of the fuel, the carbon and the hydrogen, are increased also. For these come, as I have before told you, from the waste of the system, and there is more wear and tear, and therefore more waste, when the body is exercised than when it is quiet.

38. You can see, also, the principal reason that some animals are so much warmer than others. You have often heard the expression, as cold as a frog. The frog belongs to that class of animals that are called cold-blooded. These cold-blooded animals make but little exertion, and so there is but little wear and tear of the system. There is therefore but little carbon and hydrogen furnished for the fire in the capillaries, and but little heat is made. As there is so small a quantity of carbon and hydrogen to be burned, there is not much oxygen required, and so the breathing is performed in a very lazy manner.

39. If you watch a frog you will see that he exerts himself but little in comparison with warm-blooded animals, as birds, for example. He never seems to take any pleasure in exercise. He never gambols. He sits still when he can, and leaps only when he is obliged to do it. He does not even croak but seldom. But to the bird exertion is a pleasure. He is ever on

How does exercise increase the heat of the body? What is the chief cause of the difference between warm and cold-blooded animals?

the wing. There is much wear and tear, therefore, in his system, and an abundance of carbon and hydrogen is ready to be burned up with the oxygen. His blood circulates rapidly, and he breathes quickly in order to supply all the oxygen that is needed. And the fire which thus burns so briskly in all his capillaries makes him a warm-blooded animal.

40. A good supply of pure air is necessary to enable the system to keep up its heat. The reason is, that when the air is impure, there is not a sufficient quantity of oxygen supplied. This part of the fuel being deficient, the fire is low, and there is too little heat.

41. The supply of oxygen is often deficient from pressure on the chest. Those whose lungs are thus prevented from becoming as large as they need to be, are therefore much more readily affected by cold than those who have chests of the proper size. They require more clothing to keep them warm. The heat-making power in them is lessened, because the lungs that take in that important part of the fuel, oxygen, are not capacious enough. And this lessening of the heat-making power of the body is a great source of disease.

42. It is only in a *vigorous* and *active* state of the body that the proper amount of heat is produced. In a state of vigor, the blood is rich and is well-charged with that important agent of combustion, oxygen. And when the body is active, the change that goes on

Give the comparison made in relation to the frog. Why is a free supply of air necessary to keep up the heat of the body? What is said of pressure on the chest in relation to animal heat?

briskly everywhere supplies the proper quantity of carbon and hydrogen to be burned with the oxygen in the capillaries.

43. The body needs to be well nourished in order to maintain its heat. For its vigor depends to a great extent upon its nourishment. The poorly fed are weak, and are easily pinched by the cold. They have not enough of carbon and hydrogen and oxygen in them to keep up a good fire in the capillaries.

44. You see, then, that there are three things needed to maintain the heat of the body. 1. A full supply of fresh air; 2, sufficient exercise; and 3, a due amount of food. If there be a deficiency of any one of these three things the body will be weak and easily chilled.

45. There are some kinds of food that make more heat than others, because they contain more carbon and hydrogen; that is, more fuel for burning with the oxygen. Animal food, and especially that which is oily or fatty, is of this character. This is the reason that more of this kind of food is needed in winter than in summer. It is the reason also that the inhabitants of cold climates eat more meat, and especially fat meat, than those who live in warm climates. The fat and oil which the Greenlander devours in such quantities are used up as fuel, to keep up the heat of the body, in the midst of the intense cold to which it is exposed. By eating largely of such food, he can

Why are vigor and activity necessary to maintain the animal heat properly? What is said of food? What then are the three things needed for the heat of the body? Are all kinds of food alike in furnishing fuel for the animal heat? What is said of food in relation to different seasons and different climates?

get along with less clothing than he would otherwise require, because it makes so much heat.

46. The carbon and hydrogen that are burned with the oxygen, are not furnished wholly from the waste particles of the body. Some of this fuel comes directly from the food we eat, when the waste does not afford enough of it. Some of it also comes from the fat which is stored up here and there in the cellular membrane of the body. When we are sick, and cannot eat, the fat lessens very rapidly, being burnt up, as we may say, to keep the body warm. So also, when an animal goes into winter-quarters, and becomes torpid, or *hibernates*, as mentioned in § 23, in this chapter, he is kept warm in this state by the fat in the body. He becomes very fat in the autumn; but when he crawls out of his quarters in the spring he is very lean, because his fat has been burned up, in keeping him warm through the winter.

47. In this chapter I have shown you what changes are going on in the building and repairing of the body. You have seen that waste particles are everywhere constantly taken away, and new ones are deposited in their places. You have seen that in doing this the blood is changed in the capillaries from red to dark blood. I have shown you that this is a chemical change, and so every little capillary is a chemical laboratory. And finally, you have seen that there is a fire in each one of these laboratories, and that in this way the heat of the body is chiefly maintained.

What two other sources for fuel for the combustion in the body, are there besides the waste particles? Give the summary in § 47.

CHAPTER VII.

THE NERVOUS SYSTEM.

1. I HAVE thus far told you only about building the body and keeping it in repair. You have seen in the previous chapters that the blood is the common building material of the body—that it is the office of the digestive machinery to separate from the food the nourishing part of it, and fit it to become blood—that the circulating machinery circulates the blood everywhere, that it may be used as building material—that the formative vessels, the real builders of the body, everywhere use it to build and repair—and that the machinery of the respiration keeps the blood fresh and in good condition, by continually changing it after it has been used by the builders.

2. Digestion, circulation, respiration, and formation, are then all engaged in building and repairing machinery. In the remaining chapters of this book I intend to explain to you the uses for which this machinery is built.

3. The mind uses this machinery. First, it uses some of it to learn what is going on around it. It uses the apparatus or machinery of the eye to see with; that of the ear to hear with; that of the nose to smell with; that of the mouth to taste with; and that of the skin to feel with. In all these cases the

Give the summary of subjects treated of in the previous chapters. What are to be the subjects of the following chapters as stated in § 2? What uses the machinery of the body? For what purpose does the mind use the machinery of the senses? Illustrate.

mind is *acted upon*. Light acts upon it by means of the eye; sounds act upon it by means of the ear; odors act upon it by means of the nose, &c. The mind is in these cases *passive*. It *receives* impressions.

4. But secondly, the mind is in an *active* state, in using some of the machinery of the body. That is, it makes impressions upon the world around. It does this by moving the muscles. For example, it moves the muscles of the voice, and thus produces sounds. It works the muscles of the face, to give it expression. It sets in motion the muscles of the arm and other parts of the body, when we work.

5. You see, then, that the purpose of all the machinery is to have a communication between the mind and all that is around it. The mind, by some parts of the machinery, makes impressions, and by other parts receives impressions. And you see, also, that all that goes *into* the mind gets there by means of the machinery of the senses, and all that comes *out* from the mind comes by the machinery of the muscles. That is, all the knowledge that enters the mind enters by the senses; and the mind uses this knowledge, in acting upon things and beings around it, by means of the muscles.

6. Now the mind makes all this use of the machinery of the body by means of the nervous system. The brain is the great centre of this system, and here the mind has its seat. And the mind is connected with the organs of the senses by the nerves that

In what state is the mind in using this machinery? In using what machinery is it in an *active* state? Illustrate. What is said of the communication between the mind and the world around it? By means of what does the mind make use of the machinery of the body?

branch out from the brain, and go to these organs. It *receives* impressions by the nerves that connect the brain with the organs of the *senses*, and it *makes* impressions by the nerves that go to the *muscles*.

7. The brain then may be considered the great central workshop of the mind. There it sits and operates by the nerves upon all the machinery of the body. It receives messages by one set of nerves, and sends out messages by another set. The nerves by which it receives messages are called nerves of *sensation*. The nerves by which it sends out messages are called nerves of *motion*. You can see how this is by a single example. If you put your finger too near the fire, you feel pain in it, and instantly draw it away. Now see what takes place in this case. The sensation made by the fire goes by the nerves of sensation to the brain, so that the mind feels it; and then the mind sends a message or order by the nerves of motion to the muscles of the arm, and they draw the finger away.

8. We know that the nerves are the means of this connection between the mind and the various parts of the body in this way. If the nerves of any part are divided, the part cannot move, and there is no feeling in it. For example, if the nerves of the hand are divided, you can pinch or prick it without producing any feeling, because the mind has lost its connection with it. And the muscles of the hand will not act if the mind sends a message to them, because

What is said of the brain? What of the nerves of sensation and of motion? Give the illustration in § 7. How do we know that the nerves are the means of communication between the mind and the different parts of the body?

the message can go no further than where the nerves are divided, just as when a telegraph wire is broken, the electricity can go only to the point where it is broken.

9. The nerves are white cords. Each nerve is made up of a great number of tubes. These tubes are so small that they can be seen only by the aid of a very powerful microscope. Each tube is altogether by itself. It is never seen to communicate with any of the other tubes that are bound up with it in the same nerve. Each of these tubes then goes by itself from the brain, where it begins, to the place where it ends in the body. To every separate fibre of any muscle there is probably one of these tubes. This is the telegraphic wire by which the fibre is told by the mind in the brain to act. As each fibre receives a message by itself, whenever the muscle acts, what a multitude of messages are sent to the whole muscle!

10. Some of the tubes in the nerves are for sensation, and others are for transmitting the messages or impressions to the muscles. These two kinds of tubes are very commonly bound up together in the same nerve to go to any part. And yet they are entirely separate in their office. For example, in the great nerve that goes to the arm, the nervous tubes for the muscles and the tubes for sensation are bound up together. But as the nerve branches out to be distributed, the two kinds of tubes are separated. And the same tube never transmits sensation to the brain and brings back a message to a fibre or a muscle.

Of what are the nerves composed? Do the tubes in them communicate together? What two kinds of tubes are there in the nerves?

The sensation goes by one set of tubes, and the messages to the fibres of the muscles come by another set.

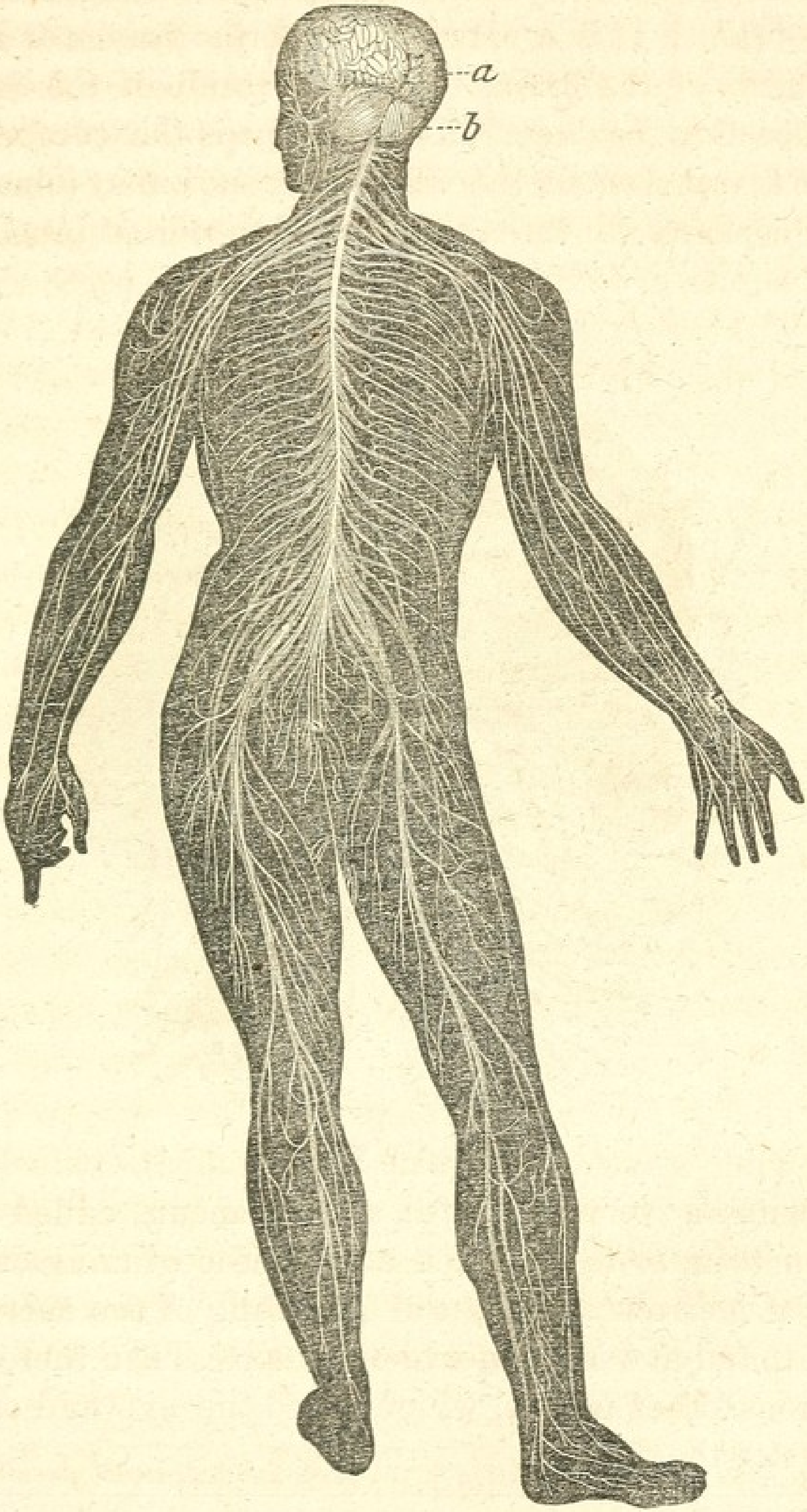
11. In the body and in the limbs the two kinds of tubes are bound together in the same nerves. But in the face the two kinds of tubes are in two separate sets of nerves. There we have nerves of sensation and nerves of motion separate from each other, while everywhere else they are mingled together. But where they are thus mingled, they are just as separate in their office as where they are in separate nerves.

12. Here, in Fig. 36, is a representation of the brain and spinal marrow, with the nerves branching out from them in all directions. At *a* is the *cerebrum*, the upper large brain filling up a large part of the skull, and at *b* is the *cerebellum*, the smaller brain lying underneath the cerebrum. You see the spinal marrow extending from the brain down the back. It is very much like the brain in its structure, and should really be considered as an extension of the brain itself. You see that nerves branch out from the brain and the spinal marrow all over the body.

13. You observe that the whole of this nervous system has two exactly similar halves, just as it is with the system of bones, and the system of muscles. The cerebrum has two parts just alike, called the two *hemispheres* of the brain. So it is with the cerebellum. There are two sets of nerves also for each half of the body that are just alike.

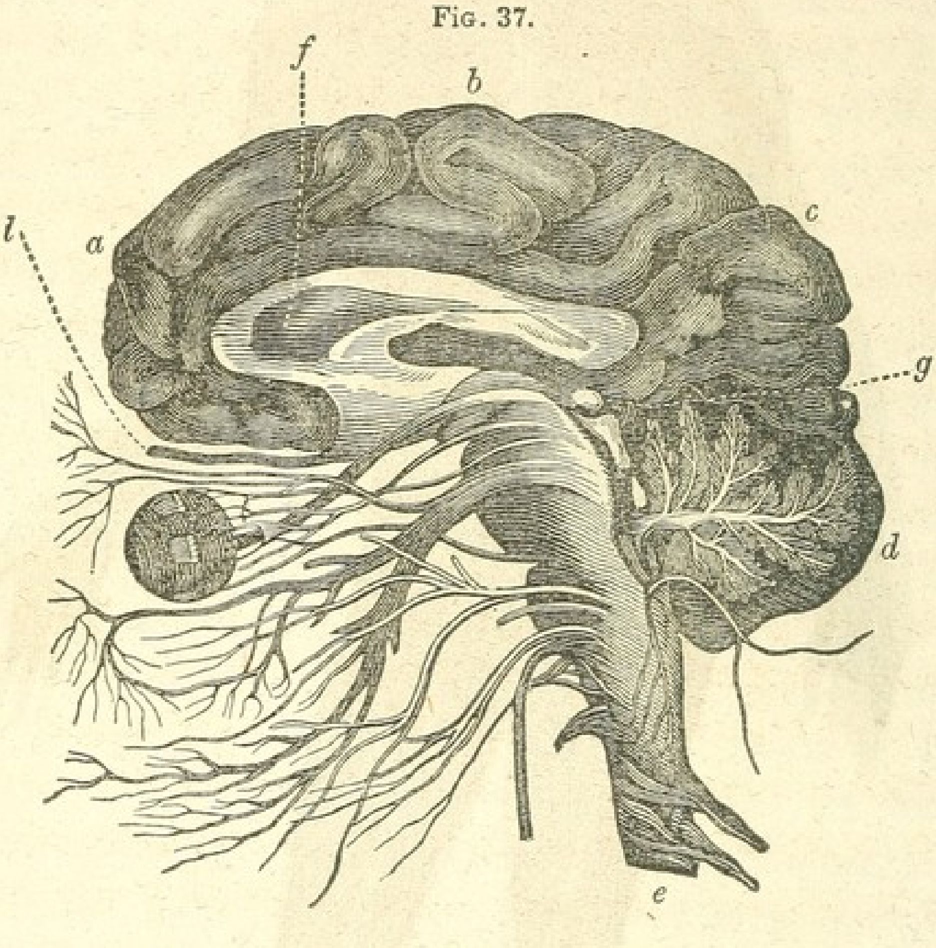
In what parts of the body are these tubes mingled together in the same nerves? Where are they in separate nerves? Describe the arrangement of the nervous system represented in Fig. 36. Is the nervous system single? What are the hemispheres of the brain?

Fig. 36.



14. In Fig. 37, you see the general arrangement of the brain. It is a view of one of the halves or hemispheres of the brain. It is the inside of the hemisphere that you see. At *a b* and *c* is the cerebrum; at *f* is represented the white substance that joins this hemisphere to the other; at *d* is the cerebellum,

Fig. 37.

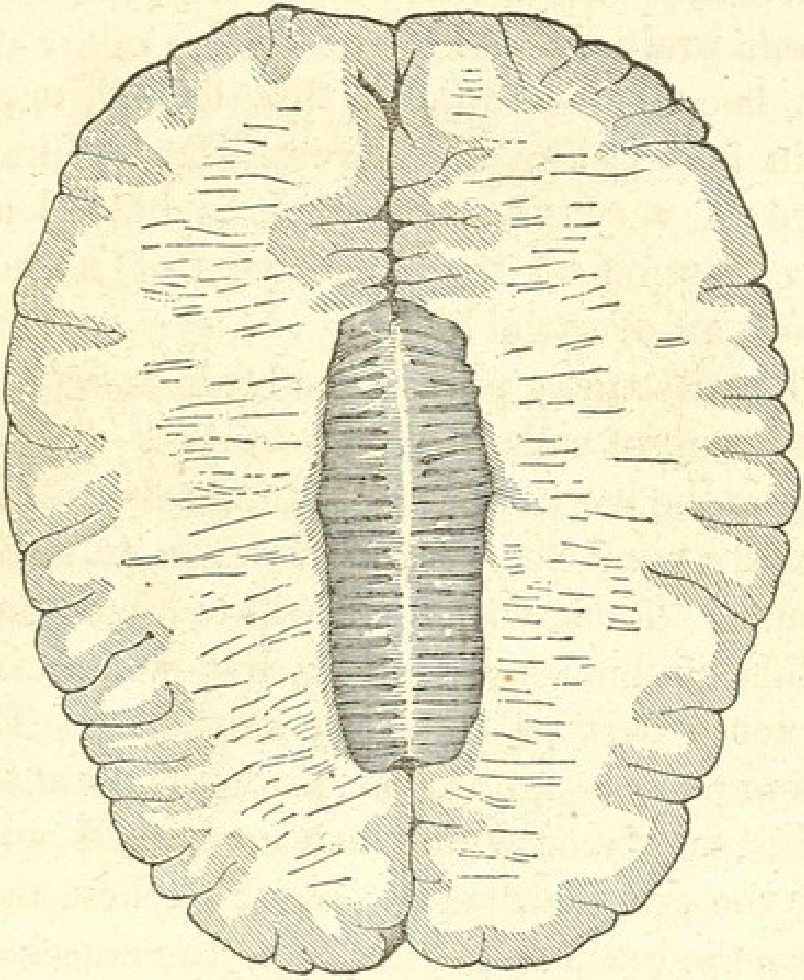


showing a very beautiful arrangement, called the *arbor vitæ*, or tree of life; at *e* is the beginning of the spinal marrow; at *g* is the beginning of the nerve of sight, and at *l* is the nerve of smell. Then there are various other nerves, which go to the eye and other parts of the face.

Describe the representation of the brain and its nerves, given in Fig. 37.

15. You observe that the surface of the brain is very irregular. The brain does not touch the inside of the skull, but it is covered by three different membranes, one of which is very strong and thick, so as to protect this delicate organ from injury.

Fig. 38.



16. The brain is soft, something like blancmange. It is the softest organ in the body. It is composed of two kinds of substance. These are quite well represented in Fig. 38. Here the upper half of the brain is cut off, and you see the upper cut surface of the

What is said of the surface of the brain, and of its coverings? What is the consistence of the brain?

lower half. The outer shaded part is a grayish substance. All on the inside of this is a white substance. You see the dividing line between the two halves or hemispheres. In the middle of the Figure is represented a substance which makes a connection between the hemispheres. It is probably by means of this connection that the two halves of the brain act together as one brain.

17. It is curious to observe that the white part of the brain is just like the nerves. It is, like them, composed of very fine tubes. It is indeed a great central collection of the beginnings of nerves that branch out all over the body.

18. The outer gray part of the brain is, on the other hand, made up of cells, instead of tubes. This is supposed to be the working part of the brain. The mind acts directly upon the gray part when it moves any of the body. Thus, when you will to have your hand move, the mind does something, but what we know not, to some part of this gray substance. Then an impression or message is sent through those tubes in the white substance which are connected with this part of the gray substance. And as these tubes extend from the brain in the nerves to the muscles of the hand, the hand is moved.

19. In sensation all this is reversed. The impression travels just the contrary way. It goes to the brain, and not from it, as it does in motion. If any one touches you, the impression is carried by the nervous

What are the two kinds of substance in the brain, and how are they arranged? What is the white substance? Of what is the gray substance composed? What is supposed in regard to it? What happens in motion, and what in sensation?

tubes to some portion of the brain. The gray substance at this part of the brain receives the impression from the tubes in the white substance, and so the mind feels it.

20. You observe that I have used the words impression and message in speaking of the communication of the mind, by the nerves, with all parts of the body. I use them because they are the best words that I can use in our present state of knowledge on this subject. We do not know what it is that is sent along the nerves. We only know that something passes through these tubes whenever the mind feels anything, or excites the muscles to action. And not knowing what it is, we speak of it as a message or an impression.

21. There have been many suppositions on this subject. Some have supposed that electricity travels along the nerves just as it does along the wires of a telegraph. They suppose that it goes from the brain when the mind excites the muscles to action, and that it goes towards the brain when we feel any sensation. Others have supposed that there was a vibration or shaking of the substance in the tubes of the nerves from one end of them to the other. But these are mere suppositions, and there is no proof that they are true. Whatever it is that passes through the nerves, it must pass through each of the multitude of little tubes separately, for, as you remember, each tube has no communication with any of the other tubes with which it is bound up.

22. Not only are there different nerves for sensa-

Do we know what is sent along the nerves? What has been supposed in regard to it?

tion and for motion, as you learned in §10 and §11, but there are also different nerves for different kinds of sensation. Thus, the nerve that informs the mind of a tickling or a pain in the nose, is not the same nerve that informs the mind of the odors that you smell. The snuff-taker feels the tingling of the snuff with one nerve, and smells it with another. So, too, in the eye, the nerve with which the mind feels a pain there is not the same nerve with which it sees.

23. There are also about the face different nerves for different kinds of motions. Thus, the nerve through which the lower jaw is moved, in eating, is not the same nerve by which the mind works the muscles of the jaw in laughing and in speaking.

24. There is no organ that has so many different nerves as the eye. It has two different nerves for sensation and four for its various motions. Its machinery of nerves and muscles is therefore very complicated.

25. All parts of the body are not equally supplied with nerves. Some parts are very scantily supplied, and therefore have but little feeling, as it is expressed. There are few nerves in the bones, and so when a limb is cut off, the sawing of the bone occasions no pain. There is not much feeling in the muscles, for although they are well supplied with nerves, the tubes in these nerves are the tubes for motion mostly, and few of them are for sensation. The skin has a full

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What is said in §22 of the different kinds of nerves? What is said of the nerves of motion in the face? What organ has more nerves than any other? What is said of different parts of the body in regard to their supply of nerves?

supply of the nerves of sensation. In cutting off a limb, therefore, the chief suffering is in dividing the skin.

26. The skin is fully supplied with nerves for two purposes: 1, that it may act as the organ of the sense of touch, and 2, that it may warn of danger. It is, as I have said in another place, a sentinel to guard the organs inside against injury. It feels the least touch. Its nerves at once send their warning of danger to the mind, and the mind sends its orders for action to the muscles, so that the danger may be retreated from. And as the skin stands guard so faithfully, there is no need that the muscles and bones and other internal parts should be very sensitive.

27. There is one office of the nerves that I have not mentioned. The different organs of the body sympathize with each other, and it is through the nerves that they do this. Thus, when you have a headache from a disordered stomach, it is because the brain sympathizes with the stomach. When tears flow in grief, it is because the tear-glands are excited to unusual action through the nerves. The sympathy in this case is with the brain. The sorrowful mind, by its thoughts, affects the brain. Then the tear-glands, by means of the nerves which go from the brain to them, sympathize with it, and so they make and pour forth a flood of tears.

28. There are many actions in the body that result from the connection of different parts by the nerves.

For what two purposes is the skin fully supplied with nerves? Why is there no need that the muscles and bones should be very sensitive? By what is the sympathy of the different organs of the body maintained?

Thus, when there is something in some of the pipes of the lungs, causing an irritation there, we cough in order to throw it off through the windpipe. But the muscles that perform the coughing motion are not in the pipes. They are outside of the lungs in the frame-work of the chest, and remove the irritating substance by forcing the air out against it. Now the reason that these muscles are excited to this action is that they are connected by nerves with the pipes where the irritation is felt. So it is in sneezing. If something irritate the lining membrane of the nose, the muscles of the chest throw the air from the lungs with great force up through the nose to expel the offending substance. They could not act in this way if they were not connected by nerves with the lining membrane of the nostrils. A message, as we may say, is sent from the irritated spot down to the muscles of the chest through the nerves, telling them to send up a blast of air to expel the intruder.

29. From what I have told you in this chapter in regard to the nerves, you can see that the nervous system is a very complicated system. I have spoken only of those things in it which you can easily understand. In my larger work on Physiology I go into this subject much more extensively, and what you have learned in this book will prepare you to understand fully what is contained in that.

Upon what do many actions in the body depend? Illustrate by the acts of coughing and sneezing.

CHAPTER VIII.

THE BONES.

1. THE bones of the body serve many different purposes. The three principal of these I will notice. 1. They form the solid framework of the body. In this respect they are to the body what timbers are to a building. 2. Some of the principal bones also form cavities in which important organs are securely inclosed. Thus, the soft delicate brain is made very secure by being inclosed in that round box of bones called the skull or cranium. So, also, the lungs and the heart, as you saw in the chapter on Respiration, are very carefully shut up in a barrel-shaped frame of bones, united firmly by ligaments and muscles. 3. The bones serve another important purpose in being moved by muscles. When they move upon each other at the joints it is the muscles that make them move. The bones are, therefore, a part of the machinery that the mind moves by means of the nervous system. This use of the bones shows you why I introduce this subject here.

I have told you in Chapter II, § 3, of what two substances the bones are composed, and shall, therefore, say nothing here on that subject.

2. The bones in our bodies are covered up from view by the ligaments, muscles, tendons, and the skin. But this is not so with the skeletons of all animals. Some have their skeletons on the outside of the body.

What are the three principal purposes that the bones answer? Of what two kinds of substance are the bones composed?

This is the case, for example, with turtles, crabs and lobsters. With them the skeleton is a coat of mail to defend the soft parts from injury.

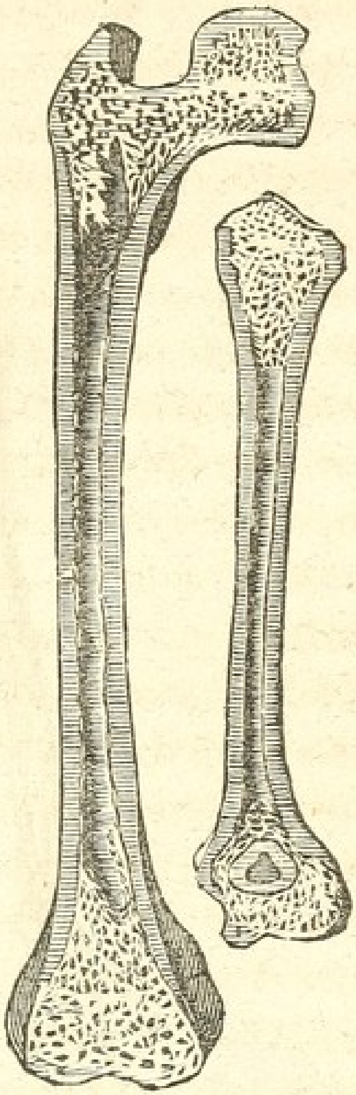
3. The bones, although they are so hard, grow together with all the soft parts that surround them. Thus, when the arm of a child grows to be the stout arm of a man, the bones enlarge equally with the muscles, tendons, &c. They enlarge, just as these other parts do, from particles added by the formative vessels from the blood; for, although they are so hard, the blood circulates in them.

4. The teeth, which are so much like the bones, differ from them in regard to growth. When a tooth first shoots up out of the gum, its body is as large as it ever will be. It cannot grow larger, as the bones do, because the hard enamel can have no circulation in it. If the teeth could grow larger there would be no need of having a second set to take the place of the first. There would then need to be simply an addition of more teeth as the jaw enlarged. But as it is now, all the first set are removed, because they would be too small for the large jaw of the adult, and thirty-two large teeth take the place of the twenty small ones of the first set.

5. The bones are not perfectly solid. They would be too heavy if they were so. Some parts of them are made up of cells, as the large ends of the long bones. The shafts of these bones are hollow. This is for the purpose of making them strong, and at

By what are the bones in our bodies covered? Are they covered up in all animals? What is said of the growth of bones? How do teeth differ from bones? Why are there two sets of teeth?

Fig. 39.

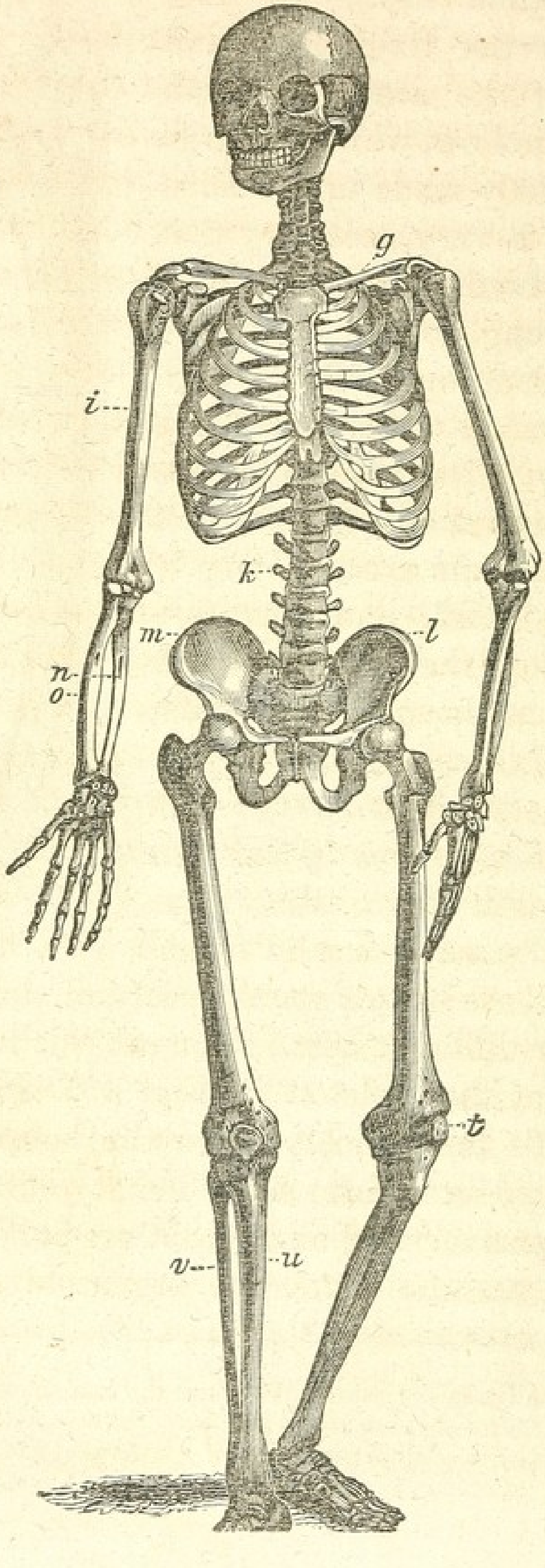


the same time light. In Fig. 39 you see the thigh-bone and the bone of the arm. In both the shaft is hollow, while the large ends are chiefly made up of cells. In birds it is very necessary that the bones should be light while they are strong, so that they may not be burdensome in flying. In them, therefore, the bones are very hollow. They are so for the same reason that the stalks of tall grass and of grain are hollow. If these were solid, and therefore more slender, they would break very easily as the wind bent them over. And in constructing buildings, the architect very well knows that a hollow pillar has more strength than the same quantity of wood in a solid form.

6. The bones have a great variety of shapes according to their different uses. You see this to be true as you look at the skeleton in Fig. 40. In the skull, which holds the brain, you see the bones so shaped and arranged as to form a somewhat round box. At the under part of this box in front are bones of various shapes to accommodate the organs of four of the

Why are the bones not solid? How are the long bones at their ends? Why are the shafts of these bones hollow? Why are they very hollow in birds? What is said of the stalks of plants and the pillars of buildings?

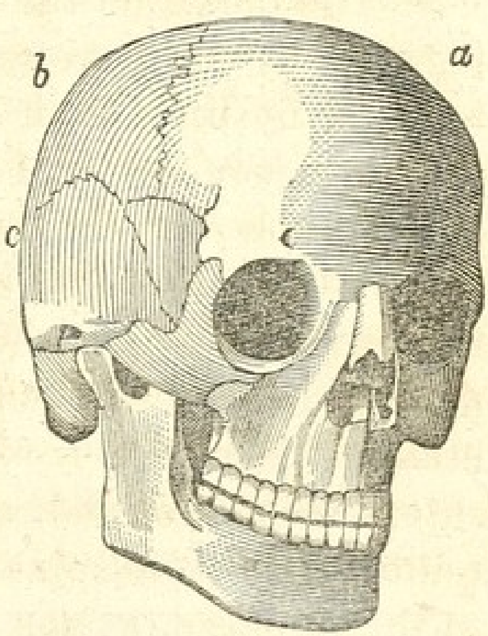
Fig. 40.



senses, seeing, hearing, tasting and smelling. Then there is the bone of the lower jaw, shaped something like a horse-shoe. The bones of the chest form a barrel-shaped cavity for the heart and lungs. The *spinal column*, *k*, made up of twenty-four bones, extends the whole length of the body as its main pillar. To this are fastened the slender ribs which are joined to the flat breast-bone in front by means of cartilages. The spinal column, you observe, stands firmly supported upon a thick bone which is wedged in between two broad flaring bones, *l* and *m*. This bowl-form collection of bones, called the *pelvis*, supports the contents of the abdomen. You observe the large bones of the thigh and leg, which are made for firmness, and the lighter bones of the upper extremity, which are fitted for quickness and variety of motion. I will now notice some of the bones more particularly.

7. In Fig. 41 you see the bones of the head—that is, all of them that are in sight in front. There are twenty-two bones in the head, but some of them are out of sight. Fourteen of these belong to the face. Eight belong to the *cranium*, that is, the part of the skull that holds the brain. Of these observe particularly the large bone of the forehead, *a*, called the *frontal* bone, the

Fig. 41.



What is said of the shapes of bones? Describe the skeleton as represented in Fig. 40. How many bones are there in the head? How many of them belong to the cranium? Describe these as seen in Fig. 41.

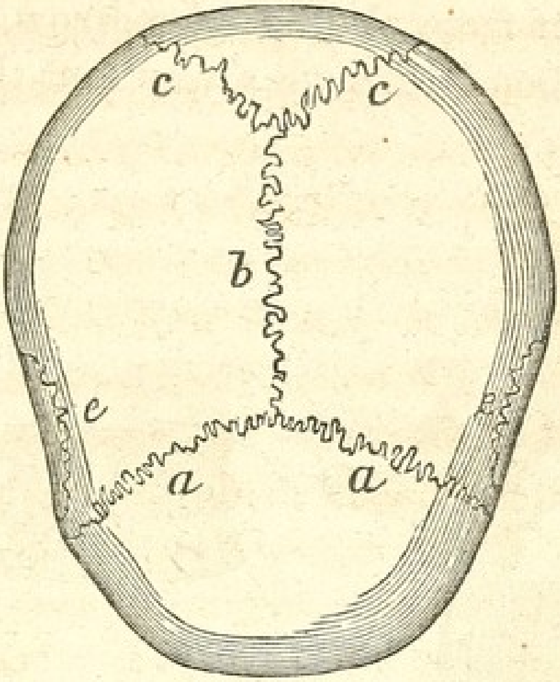
parietal bone, *b*, and the temporal bone, or bone of the temples, *c.* There is a bone in the rear, forming the back of the cranium, as the frontal bone forms the front. These bones, with two others on the under part of the cranium, make the round box that holds the brain.

8. The cranium is made round because it will not break as easily as it would if it were of some other shape. This is one reason also why it is made up of so many different bones, instead of being one solid, tight box. If a blow be received on the head, these bones give a little upon each other, as it is expressed, and so they are not often broken. They give more in the child than in the adult, because, besides being less brittle, they are less tightly put together. It is well that it is so; for if it were not, the skull would often be fractured, in the frequent falls which the child has.

9. The bones on the top of the head are fastened together by what are called *sutures.* They are locked together by little teeth of bone, which shoot by each other, as you see in Fig. 42. Here *b* is the suture across the top of the head between the two parietal bones: *a a* is that between the two parietal bones and the frontal bone in front; and *c c* is that between the parietal bones and the bone at the back part of the cranium. In the young child these joinings by suture are not formed, and in the infant the bones are quite apart in some places, especially at the upper part of the forehead, as you can perceive by the touch.

Why is the cranium round? Why is it made of so many bones? What are the sutures of the skull? What is said of the joinings of the bones of the skull in the child?

FIG. 42.



10. The bones of the cranium, together with their coverings, are well fitted to guard the delicate brain from injury by the blows to which the head is so much exposed. When a blow is received, its force is broken by the hair, the skin, and the muscles, that extend over the bones. And then the bones themselves, as I have before said, give a little upon each other. It requires therefore a very hard blow to break the skull.

11. The spinal column is the most wonderful part of the bony machinery of the body, because it serves so many different purposes. It is the great pillar of the body, and yet it is a chain of twenty-four bones, that can be bent considerably, especially in some parts of it. And besides, there is a canal moving through all this chain of bones, in which lies securely the spinal marrow, an organ as delicate and as essen-

How is the delicate brain guarded against injury? Mention the several uses of the spinal column? Of how many vertebræ is it composed?

tial to life as the brain itself. Then there are nerves branching out from the spinal marrow, between the twenty-four bones, in such a way that they are never pressed upon.

Fig. 43.

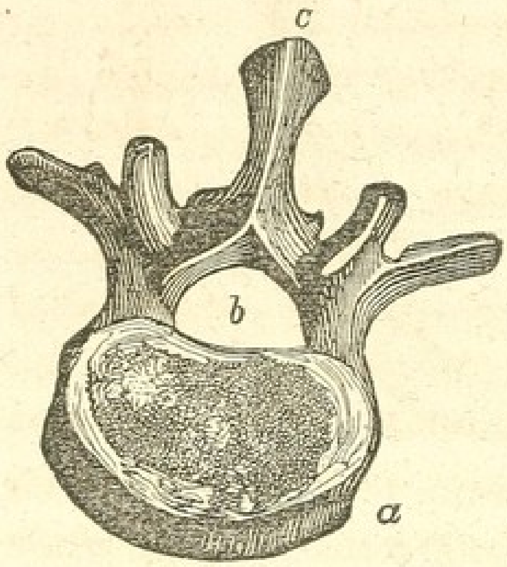
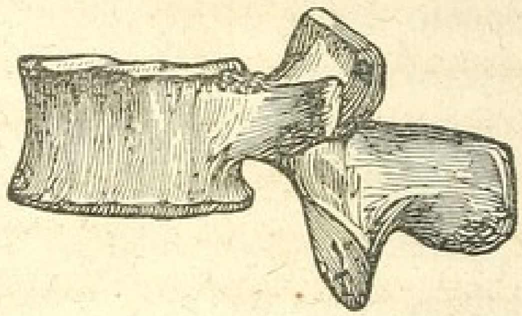


Fig. 44.



12. The twenty-four bones of the spinal column are called *vertebræ*, (plural of vertebra.) In Fig. 43, you see one of these vertebræ; *a* being the body of the bone; *b* the hole through the vertebra which forms its part of the canal for the spinal marrow; and *c* the *spinous process*, as it is called. The hard ridge that you feel in passing your finger up and down the middle of the back, is the row of these spinous processes. Each vertebra has six other processes, only two of which you can see in the figure. The bones of the whole column are so locked together by these processes, that they cannot be separated from each other or dislocated without being broken. In Fig. 44 you have a side view of the same vertebra. As you look at the spinal

Describe the vertebræ as represented in Figs. 43 and 44. How many processes or projections has each vertebra? What is the use of them? By what are they covered?

column in front, it is a round smooth column; but in the rear the processes make it very jagged. These are all, however, covered up by muscles, except the row of spinous processes.

Fig. 45.

13. In Fig. 45, you see the whole column, with the stout bone on which it stands. It is represented as sawn down through its whole length, so that you see but half of it. You see the bodies of the vertebræ in front, and the spinous processes on the other side. Between the row of the bodies of the vertebræ and the row of spinous processes you see the canal in which lies the spinal marrow. You observe that there are spaces between the bodies of the vertebræ. These spaces are filled with pieces of cartilage or gristle. If it were not for these cartilages you could not bend the back-bone forward at all, but could only bend your body on the heads of the thigh-bones, with a hinge-like motion, which would be very stiff and awkward. As it is, when you bend forward, in addition to this hinge-like motion, the bodies of all the vertebræ come nearer together. In doing so the cartilages between them are compressed, and so are made smaller. And as you straighten up again, these cartilages, by their elasticity, return to their usual

Describe the spinal column as represented in Fig. 45. Of what use are the cartilages?

size again. From the constant pressure on these cartilages, as you go about during the day, you are not quite as tall at night as you are in the morning. So also in old age, one becomes less tall than in the vigor of manhood, because these cartilages shrink.

14. The spinal column can be bent not only forwards, but in other directions also—to either side and backwards. This chain of bones can also be somewhat twisted, as we may express it, as you turn your body one way and another. As you do this, each bone moves with a rotary motion a very little. But as there are twenty-four bones, all these little motions between them together make a considerable twist of the whole column. Now, as there is through the whole length of this column a rod of very delicate substance that must not be pressed upon, all these motions have to be most carefully arranged. The bones must be nicely fitted with all their processes; they must be well fastened together with ligaments; and then the muscles that move all these twenty-four bones must all of them work exactly aright. All this is done, and the back-bone, as we call it, is a set of machinery vastly more complicated and more nicely arranged than any machinery that man ever contrived.

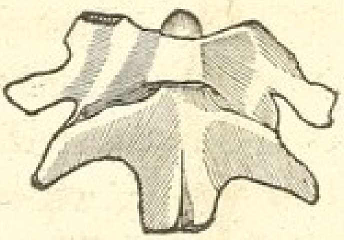
15. But the most wonderful part of this machinery is at the top of the column. There the motions are more free than in any other part of the column, as you see when you bow your head, and bend and turn

In what part of the day are you the tallest? What is said of the various motions of the spine? What is said of it as a piece of machinery? What is the most wonderful part of this machinery?

it in various directions. There are two different motions made by the head on the top of the column. The first of these is when you move the head backward and forward. In doing this it rocks on the first vertebra, the topmost bone of the spinal column. For this purpose there are two smooth rounded surfaces, that work in two smooth, hollow places in the vertebra.

16. The other motion is when you turn your head to look at the one side or the other. In performing this rotary motion the skull does not move alone, as in the first motion, but it moves together with the first vertebra. The first vertebra in this motion moves on the second around a tooth-like process that stands up from this second vertebra. This tooth works in a smooth notch on the inside of the first vertebra. It is bound very fast in this notch by a strong ligament, so that it may not, in any of the quick motions of the head, be made to press on the delicate spinal marrow which lies against it. In Fig. 46 you see these two vertebræ, and notice the tooth-like process of the second standing up on the inside of the first vertebra.

Fig. 46.



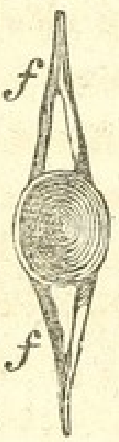
17. You see, then, that when you move your head backward and forward, you move it in a hinge-like way on the first bone of the spine; and when you turn the head to look to the right or the left, you

How many motions are performed by the head on the top of the spinal column? Describe the manner in which the first of these motions is performed. Then the second.

turn the head and this first bone together as one thing on the tooth-like process of the second bone. There is an arrangement somewhat like this in the standard of telescopes. There is first a *hinge-joint*, as in the case of the head, so that you can move the telescope up and down so as to look as high or as low as you wish. There is, also, in the standard another joint, with a *rotary* motion, by which you can turn the telescope so as to see as far to the one side or to the other as you please. This is like the motion performed between the first and second vertebra.

18. The vertebræ vary much in different kinds of animals. Here, for example, in Fig. 47, is the vertebra of a fish, which you see differs very much from the vertebræ of man, as represented in Figs. 43 and 44. It has but two processes, *f f*. In man there is a single short spinous process behind, while the vertebra is round in front. But in the fish there are two quite long spinous processes, one in front and the other in the rear; or rather, we should say, according to the common position of the fish in the water, one above and the other below. There is a curious contrivance in the arrangement of the vertebræ of the fish for making the spine flexible. Each vertebra has a cup-like cavity on each side towards the next vertebra. Each two vertebræ then put together make a cavity of this ◇ shape. This cavity is lined with a

FIG. 47.



Give the comparison between this arrangement and that of a standard of a telescope. Describe the vertebræ of a fish and their arrangement.

membrane making a sac, and in this is a fluid something like the white of an egg. These sacs, thus filled with fluid, make soft cushions between all the bones of the spine, upon which the bones rock in the various motions of the fish. This arrangement you can observe for yourself whenever you have fish on the table.

19. In snakes the spinal column is exceedingly flexible. It is made so in two ways. First, there is a great number of vertebræ. The result of this is, that in a very extensive motion of the whole spine the motion between each two vertebræ is very little. The motion is divided up, as we say. The rattlesnake has over two hundred vertebræ, and the great boa-constrictor has three hundred and four. Secondly, the flexibility of the spine of these animals is secured by having a ball and socket joint between all the vertebræ. A smooth round ball in each vertebra works in an equally smooth cup-like hole in the one next to it.

20. The framework of the chest I have described to you in the chapter on Respiration § 10. There are two bones outside of this barrel-shaped framework that I will now notice. First, there is the collar-bone *g*, Fig. 40. This is fastened to the breast-bone at one end, and at the other end is fastened to a process of the shoulder-blade, and helps to make the top of the shoulder. It is a sort of prop or brace, that keeps the shoulder braced out in its place.

By what two means are the spinal columns of snakes made so flexible? How many vertebræ has the rattle-snake? How many has the boa-constrictor? What is the use of the collar-bone, and how is it placed?

21. The shoulder-blade is a very singular bone. Its back part, that which is towards the spine, is quite thin, and is covered on both sides with muscles that move it. It is designed to give freedom to the motions of the arm. When you draw your arm back very much, you can see that there is considerable motion of the shoulder-blade. This is because the muscles that are attached to it pull it back, at the same time that other muscles pull the arm in the same direction. And as the shoulder-blade forms at its upper part the shoulder-joint, these muscles in pulling back the bone pull back the whole joint, and of course the arm with it. You can see that the arm could not be drawn so far back if the shoulder-joint were made without any shoulder-blade. It could have been so made, but it would have been awkward and stiff in its motions.

22. Where the shoulder-blade forms the shoulder-joint there is a shallow cup-like surface, lined with cartilage, which is as smooth as the finest polished ivory. The bone of the arm which fits into it has its end in the form of a ball, which is also tipped with cartilage as smooth as that in the cup. Observe what keeps this ball in the cup as it moves about in it. There is a thick skin attached all around the edge of the cup and fastened down over the ball. Besides this stout ligament, there is another remarkable contrivance for keeping the round head of the bone in its place. The tendon of a large muscle works in a

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Describe the arrangement of the shoulder-blade. How does it make the motions of the arm free? Describe the shoulder-joint. In what two ways is the joint guarded against dislocation?

groove on the front of this head of the bone, and thus holds it so as to keep it from slipping out of the cup.

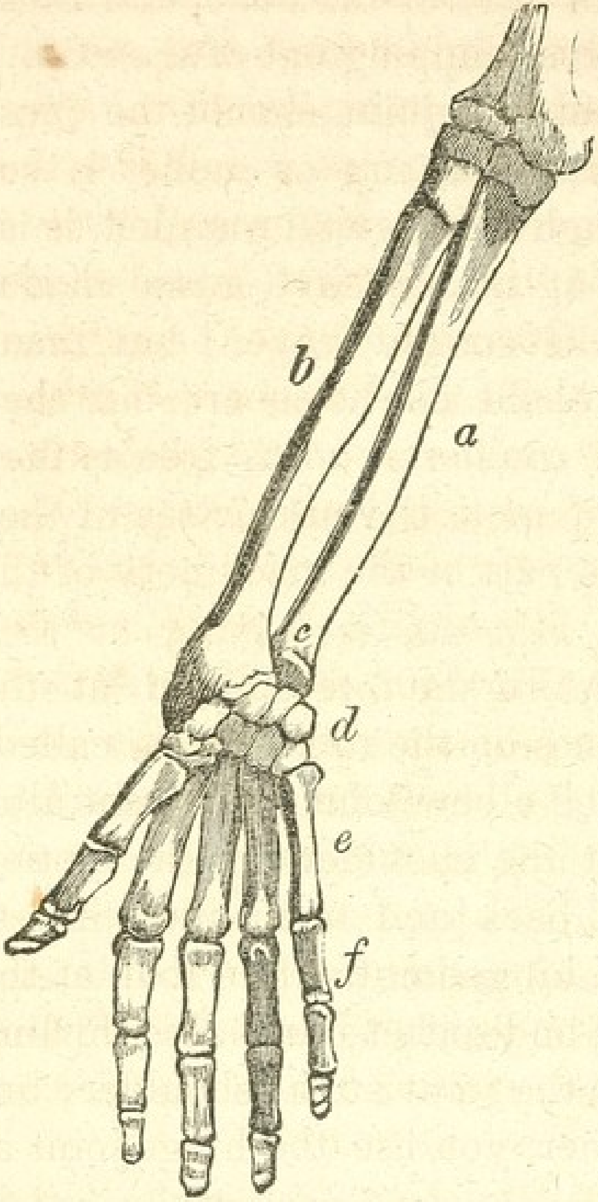
23. It is necessary that the joint should be thus carefully guarded, because the cup or socket is so shallow. As it is, although it is so well guarded, it is very often dislocated. It might have been made more secure by having the socket deeper; but then the motions of the arm could not be as free as they are now, and freedom of motion you can readily see is very important in this part of the machinery of the body.

24. The arm-bone, *i*, Fig. 40, is jointed at the elbow, with the two bones of the fore-arm (so called) and seen at *o* and *n*. The elbow-joint is different altogether from the joint at the shoulder, for the motion is in one direction only, back and forth like a hinge. It is therefore called a hinge-joint, while that at the shoulder is called a ball-and-socket-joint. In whirling a skipping-rope, you use the joint at the shoulder; but in striking with a hammer, you use the hinge-joint at the elbow.

25. The hand moves on the fore-arm at the wrist with a hinge-joint. The fingers have hinge-joints, except where they are joined to the hand. There they have, besides the hinge-like motion, something of the motion of a ball-and-socket-joint. The motions of the thumb are, as you see, quite different in some respects from those of the fingers.

Why is this joint so carefully guarded? How could it have been made more secure? Why was it not? Describe the elbow-joint. How does it differ from the shoulder-joint? Describe the joints of the wrist and fingers and thumb.

Fig. 48.



26. Besides these motions that I have described, there is a *rotary* motion of the arm, as you turn the palm of the hand up and down. This is done by a peculiar motion of the two bones of the fore-arm. I will make this clear to you by Fig. 48. You see that the largest end of the *ulna*, *a*, is at the elbow, while the largest end of the *radius*, *b*, is at the wrist. Now, the hinge-like motion at the wrist is performed wholly with the large end of the radius. The small end of the ulna, marked *c*, has nothing to do with it, but is loose, and has a rolling motion on the end of the radius. It is just the reverse with these two bones at the elbow-joint. The hinge-motion there is performed with the large end of the ulna, *a*, and the small end of the radius, *b* has nothing to do with it, but rolls on the end of the ulna.

27. The effect of this arrangement is this. When the palm of the hand is upward, as represented in the

How is the *rotary* motion of the fore-arm made?

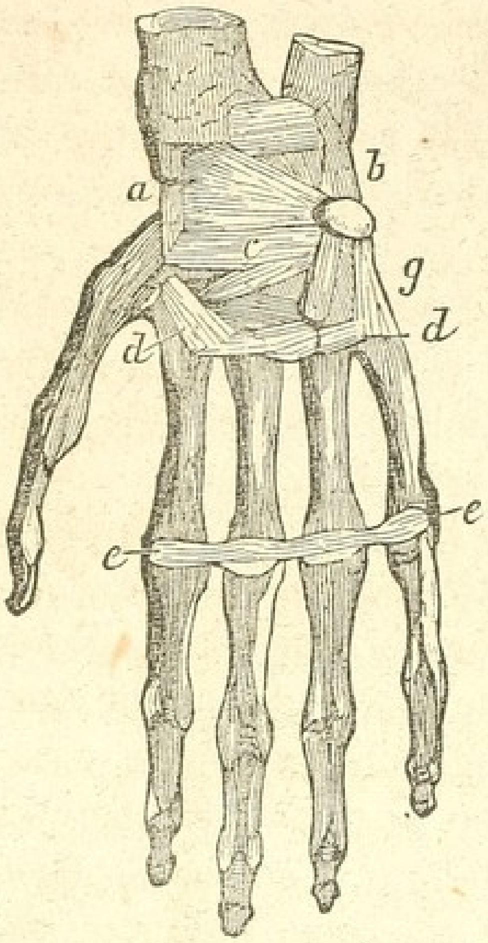
Figure, these two bones are, as you see, nearly parallel. But when the palm is turned over, they are, as we may say, twisted upon each other, the ulna, *a*, rolling on *b*, at its lower end, and the radius, *b*, rolling on *a*, at its upper end. You can see these two positions of these bones in Fig. 40. In the right arm you see the palm of the hand towards you, and the radius and ulna are parallel. In the left arm the palm is partly turned from you, and these bones are twisted upon each other by their rolling or rotary motion.

28. Observe now how many different motions there are in the arm and hand. They are, the motion of the ball-and-socket-joint at the shoulder, the hinge-motion at the elbow, the rolling of the two bones at the forearm upon each other, the hinge-motion at the wrist, the hinge-motions of the fingers at their joinings with the hand, together with something of a ball-and-socket-motion, the hinge-motions of the other joints of the fingers, and the free motions of the thumb differing somewhat from those of the fingers.

29. In observing these motions you will see the reason why there are different kinds of motion in different parts of this complicated machinery. You can see, for example, why there is a hinge-motion in one place and that of a ball-and-socket joint in another, and why the two motions are united in the joints which the fingers make with the hand, while the other joints of the fingers can perform only the hinge-motion.

Mention the different motions of the arm and hand in their order, beginning at the shoulder-joint. What is said of the two kinds of motion, the hinge-like and the ball-and-socket-motion?

FIG. 49.



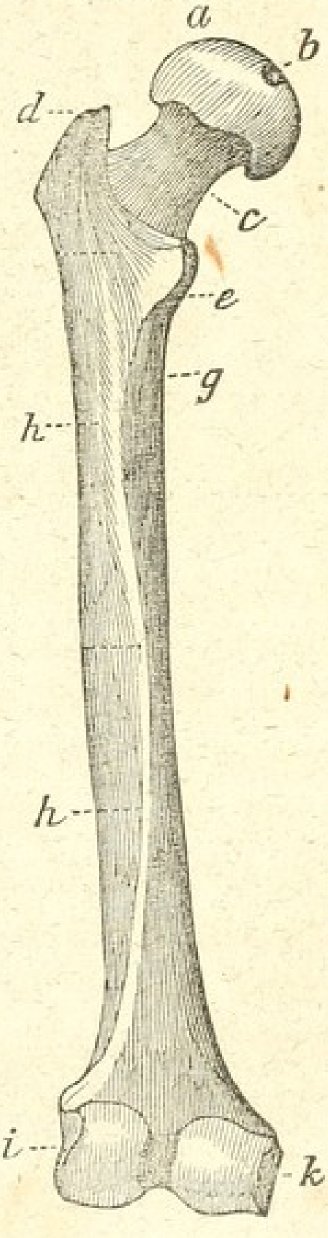
30. You see that there are many bones in the hand—twenty-seven in all. There are eight small bones called the *carpal* bones, represented at *d*, in Fig. 48. These are tightly packed together, and lie next to the bones of the fore-arm. The *metacarpal* bones, *e*, make the frame-work of the flat part of the hand. They are very much like the first row of the bones of the fingers, *f*. But they are firmly bound together by ligaments. These ligaments you can see in Fig. 49. At *d d*, you see those that bind the metacarpal bones together at their beginning, and at *e e*, those that bind them at their ends, where the bones of the fingers are jointed with them. At *a*, *b*, *c*, and *g*, are other ligaments that bind the carpal bones together.

31. You notice that there are twelve bones in the frame-work of the hand, aside from the fingers—that is, the eight carpal and the four metacarpal bones. The chief reason for having so many bones thus packed together is this. Although they are bound together, there is some little motion between them, and this makes the hand more light and springy than it would be if these twelve bones were all in one.

How many bones are there in the hand? Describe their arrangement. How many bones are there in the *framework* of the hand? Why are there so many?

32. The bones of the lower extremities have not so much freedom of motion as those of the upper. The chief object is firmness, as they support the weight of the body in moving about. They are larger therefore than the bones of the upper extremity, as you see in Fig. 40, and their joints are much more stout and secure.

FIG. 50.



33. In Fig. 50, you have a rear view of the thigh-bone. Its round head, *a*, fits into a deep socket in the pelvis, as represented in Fig. 40. Observe the reason of the difference in regard to the depth of the socket between this joint and the shoulder-joint. In the hip-joint strength is especially needed; while freedom of motion is more needed in the joint of the shoulder, and so its cup or socket is made shallow. The head of the thigh-bone is held in its socket by the same kind of ligament that I have described in § 22, as securing the shoulder-joint. It clasps the neck of the bone, *c*, and is fastened all around the edge of the socket. There is another ligament also. At *b* you see a little hole, in which one end of this ligament, which is short and stout, is fastened. The other end is attached

What is said of the difference between the bones of the upper and the lower extremities? Describe the thigh-bone. Why is the socket of the hip-joint deeper than that of the shoulder-joint? Describe the ligaments of the hip joint.

to the bottom of the socket. At *d* and *e* are two projections, to which are attached large muscles, that move the thigh. Along the whole length of the bone is a rough ridge, *h*, for the attachment of muscles. At *i* and *k* are two smooth surfaces, which form with the large bone of the leg, the hinge-joint at the knee.

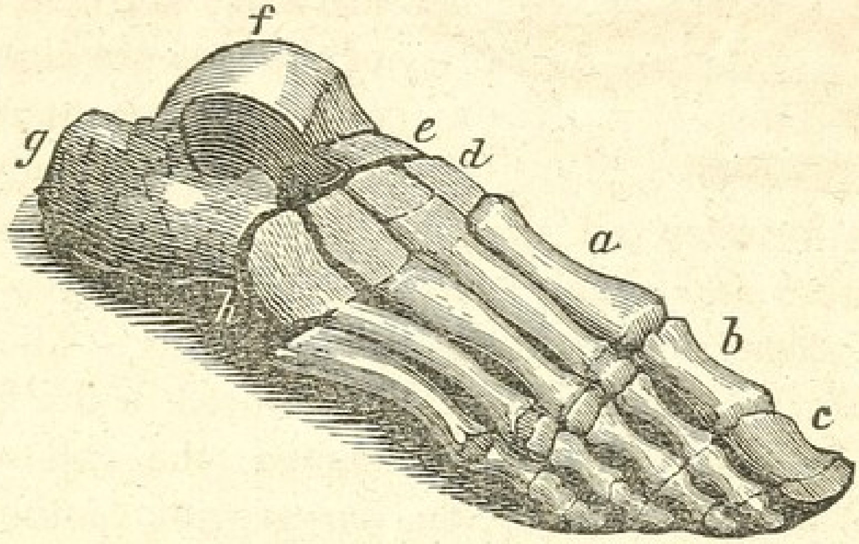
34. There is a small thick bone fitting over the knee-joint in front, called the knee-pan. This is seen at *t*, in Fig. 40. One of its uses is to shield the joint. It wards off blows, and prevents the joint from being injured by falls. It has another very important use, of which I speak particularly in my larger work on Physiology.

35. The leg has two bones. One of them, *u*, Fig. 40, is very large. It sustains the whole weight of the body. It has two smooth surfaces at the knee-joint, on which work the two smooth surfaces of the thigh-bone, *i* and *k*, seen in Fig. 50. The other bone of the leg, *v*, Fig. 40, is very slender. It is firmly connected with the large bone by ligaments and muscles. The two chief uses of this bone are, to furnish a hold for some of the muscles, and to make the outer side of the ankle-joint. The inner side of this joint is made by the larger bone. This joint is made by these two bones projecting down over a bone in the foot represented at *f*, in Fig. 51. It is a hinge-joint. It is made quite loose, however, so that the foot can be turned inward and outward. And yet it is a very firm joint, for the bones of the leg jut over strongly on each side, and the ligaments are very stout.

What is said of the knee-pan? Describe the bones of the leg. What are the uses of the small bone of the leg? What is said of the ankle-joint?

36. In Fig. 51 are represented the bones of the foot. At *e d f g* and *h* are the seven bones of the *tarsus;* at *a* are the five bones of the *meta-tarsus;* and at *b* and *c* are the fourteen bones of the toes—twenty-six in all.

Fig. 51.



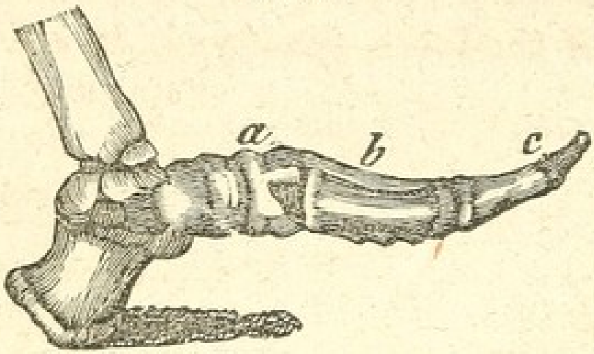
The reason for having so many bones in the foot is the same as that stated in regard to the hand in § 31. The springiness thus given to the foot is quite important in guarding against shocks. You can realize this if in jumping you come down on your heels, instead of coming down on your feet as is usually done. Some animals that leap much have special guards against shocks in the thick elastic cushions on the bottoms of their feet. You can see these in the cat and dog.

27. The arched form of the foot assists in giving springiness to it. You can see that the tread is much less elastic when the foot happens to be flat. This

How many bones are there in the foot? Why are there so many? What is said of the importance of elasticity in the foot? What contrivances are there in the feet of some animals?

arched form is represented in Fig. 52, which gives a side view of the bones of the foot. In this figure the

FIG. 52.

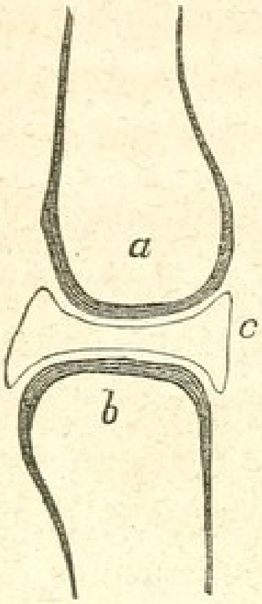


bones of the tarsus extend from the heel to *a*; the meta-tarsal bones are at *b*; and the bones of the toes are at *c*. In every movement of the foot there is some little motion between all these bones, and it is this that gives ease and grace to its motions. Observe what is the order of its movement in walking. The heel first touches the ground, as represented in the figure. Then, as the body moves forward, the ball of the foot at *b* presses firmly on the ground as the heel rises. Now, as the change of pressure is made from the heel to the ball of the foot, there is a little giving between all the bones of the tarsus *a* and the metatarsus *b*, and this makes the motion an easy one. If all this part of the foot were one bone, the motion would be stiff and awkward, and not elastic and graceful as it now is.

38. The ends of all the bones are tipped with cartilage so that they can move easily upon each other. And besides this, the ends thus tipped with this fine but smooth substance are lined with a very fine membrane, so arranged as to make a close sac. This you can understand by Fig. 53, in which *a* and *b* are the ends of two bones, the sac *c* being represented as se-

What is said of the arched form of the foot? Describe the movement of the foot in walking. How is it made easy and graceful? With what are the ends of the bones tipped?

Fig. 53.



parated from the bones, in order that the arrangement may be clear to you. It is as if a little bladder were placed between the bones, fastened on all over the two surfaces at their ends. This bladder or sac has a little fluid in it like the white of an egg. This fluid is to our joints what oil is to the joints of machinery. When a train of cars stops at a station you see men with their little cans oil the boxes of the wheels both of the locomotive and the cars. And great pains is taken with the joints of all kinds of machinery to keep them oiled. But the joints in our bodies keep themselves oiled, as we may say. It is done in this way: The fluid in the sac of a joint oozes from the inner surface of the sac, just as the perspiration comes from the pores of the skin. But the same fluid does not remain in the joints year after year. Such constant rubbing would, after a while, make it unfit for use. It is, therefore, constantly renewed. There are all over the inside of the sac little absorbing vessels that take up the fluid as fast as it becomes unfit for use, and there are secreting vessels that pour out fresh fluid to take its place.

What other provision is there for the easy working of the joints? Compare with common machinery. How is the fluid in the sacs of the joints kept fresh?

CHAPTER IX.

THE MUSCLES.

1. I HAVE already explained to you in Chapter II. the manner in which the muscles act. You there saw that when a muscle acts, its fibres all shorten themselves. Now, when a muscle contracts or shortens itself, it swells out or becomes thicker. You can see this if you watch the bare arm of some one who is at work. You can feel this swelling of the muscles in your own arm as you move it. Straighten out your arm, and then grasp it with your other hand half-way from the elbow to the shoulder. Now bend up your arm forcibly, and you will feel the large muscle on the front of your arm swell out and harden as you grasp it. It is just as it is with a piece of india-rubber. If you stretch out the india-rubber, it becomes smaller; and then if you let it go, it contracts like the muscle, and as it contracts, it, like the muscle, becomes thick again.

2. The muscle, however, contracts in this case from a different cause than that which makes the india-rubber contract. The india-rubber contracts because it is stretched—it merely goes back to its usual state by its elasticity, as it is termed. But the muscle has a power of contracting which is something more than elasticity. It contracts because the mind tells it to do so by means of the nerves, the telegraphic wires

What is the state of a muscle when it contracts? Make the comparison between the muscle and india-rubber. How do they differ from each other in the causes of their contraction?

that go from the mind's seat, the brain. The nerves, as I have told you in the chapter on the Nervous System, branch out and distribute their fibres to all the fibres of the muscles. And every fibre of a muscle thus receives a message from the brain whenever the muscle contracts.

3. The muscles have elasticity, just as the india-rubber has, and there is a contraction in them by means of this elasticity. This is seen when a muscle is cut in two, by accident, or, as is sometimes done, in the operations of the surgeon. In this case the two cut ends separate from each other considerably, because they are drawn apart by the contraction of the fibres of the muscle. But this contraction does not take place from any message sent to these fibres from the mind. It arises from their elasticity simply, just as the contraction of the india-rubber arises from its elasticity. Muscles, then, have two kinds of contraction. The one kind is from their elasticity; the other is when they are excited to action through the nerves. I shall speak of these two kinds of contraction in another part of this chapter.

4. Muscles commonly end in tendons. While the muscles are red, the tendons are white and shining. Tendons are the ropes or rigging with which the muscles pull the bones and other parts. They are of different shapes. Some of them are long and slender. You can see tendons of this shape on the back of the hand very plainly in thin persons. The muscles that work them are in the full arm above. You can see

Show how the muscles have two kinds of contraction. What are tendons? What is said of their shape?

that this is so, if while you work your fingers back and forth, you take hold of the arm a little below the elbow with the other hand. You feel very distinctly there the movement of the muscles as they contract and relax themselves.

5. The tendons are much smaller than the muscles that pull them. You can see this in the case of the hand and arm. The muscles that move the hand and the fingers make up the full part of the arm; but the wrist, where their tendons go to the hand, is very slender, because these tendons are so small. You can see the same thing in the "drumstick" of a fowl. In the slender leg are the tendons lying along the bone, while the bulky muscles that work them are above.

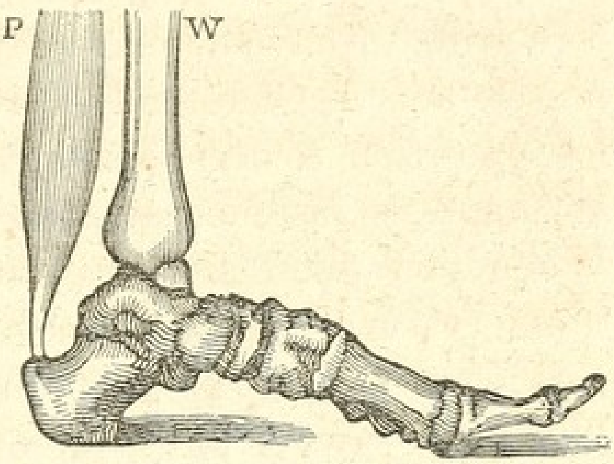
6. While the tendons are so small, they are very strong. It is exceedingly rare to have them break, even in the most violent efforts. It is well that it is so, for it is very difficult to heal a broken tendon. When a bone is broken, the two ends can be held accurately together, and therefore are easily united. But when a tendon is broken the muscle to which it belongs draws the part that is fastened to it away from the other end. And, therefore, with the very best of care, it is difficult to make them heal at all.

7. I will now speak particularly of some of the muscles, that you may understand how they act. In Fig. 54 is represented the lower part of the large muscle that raises the heel when we walk. The large bone of the leg and the bones of the foot are represented. P, the muscle, makes up most of the bulk of

What is said of the size of the tendons? What of their strength? Why is it difficult to heal a broken tendon?

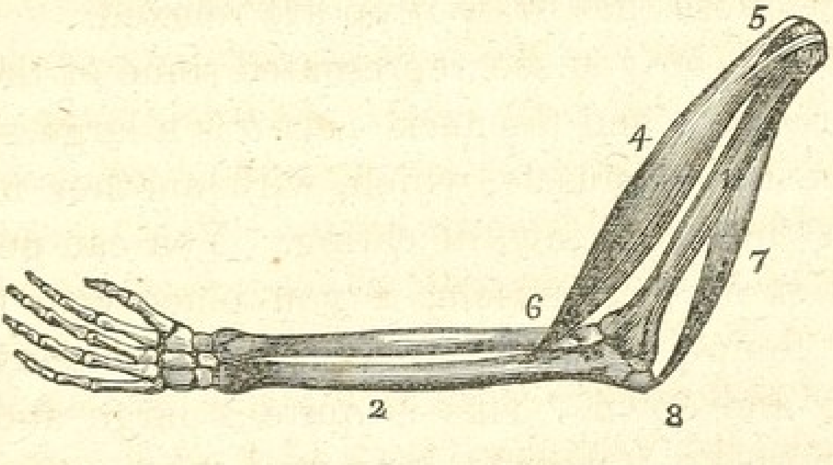
the calf of the leg. The weight of the body rests upon the bone W. Now, in walking, as we raise the body in taking a step, we do it first by raising the heel with the muscle P, the pressure being on the ball of the foot, F. This muscle does here with the weight of the body what the muscles of your arms do to the load in a wheelbarrow when you raise it by the handles.

FIG. 54.



8. In Fig. 55 are represented two of the principal muscles of the arm, 4 and 7. Between these is the bone of the arm, 1, and at 2 are the bones of the fore-arm, as the part of the arm below the elbow is commonly called. At 4 is the muscle that acts when you

FIG. 55.



bend the arm at the elbow. At 5 is its double attachment at the shoulder-joint, and at 6 is where its ten-

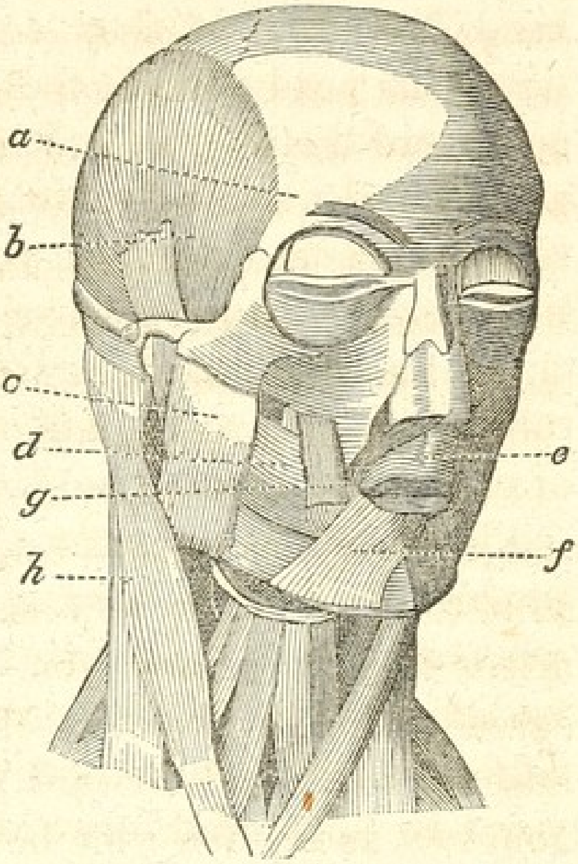
Describe the arrangement and action of the muscle represented in Fig. 54. Describe the muscles represented in Fig. 55.

don is fastened to the radius, one of the bones of the fore-arm. I have described the manner in which this muscle acts in Chapter II. § 10. The muscle that acts in opposition to this, and straightens the arm out, is at 7, and is fastened at 8 to the point of the elbow. When you bend and straighten your arm by turns, these two muscles take turns in acting, like two sawyers that are working a long saw back and forth. While one sawyer pulls, the other lets the saw go. So it is with these muscles. When the muscle 4 contracts, the muscle 7 is relaxed; and when 7 contracts, 4 is relaxed. And so it is with other muscles. Thus, when you swing your leg back and forth, there are two sets of muscles that perform these two opposite motions, and while one set are contracting, the other are relaxing. So it is with the motion of the lower jaw up and down in eating. While the muscles that move it up are contracting, those that pull it down are relaxed; and then, while those that pull it down contract, those that draw it up are relaxed.

9. In Fig. 56 you see represented some of the muscles of the face and the neck. At *b* is a large, spreading, fan-shaped muscle, which, with another muscle, *c*, raises the lower jaw, in eating. You can perceive the action of this muscle, if you place your fingers on the temple of either side, while you move the jaw up and down. This is quite a large and powerful muscle. Observe, how well it is packed over the side of the head, so as to make no uncomely

Give the comparison made in regard to their action. What other illustrations are given of opposite motions in muscles? Describe the muscles represented in Fig. 56, and explain their operation.

Fig. 56.



projection there. For this purpose, it is shaped very differently from the muscles of the arm in Fig. 55. There are some other muscles in this figure, which I will barely notice.—There is at *a* a small muscle, which, coming from the bone at the top of the nose, is fastened to the skin of the eye-brow.—When it contracts, it wrinkles the eye-brow.—At *g* is a muscle that draws up the corner of the mouth, and at *f* is a muscle that draws down the lower lip. At *d* is a muscle which serves several purposes. It pulls back the corner of the mouth ; and when we are eating, by pressing the food towards the middle of the mouth, keeps it from getting outside of the teeth. When one blows upon an instrument strongly, this muscle gives firmness to the cheek, so that the air shall not press it out too much. From its doing this, it is called *buccinator*, from *buccinare*, to blow a trumpet.

10. At *h*, in Fig. 56, you see a long muscle, which begins just behind the ear, and goes down to the top of the breast-bone. You see another muscle on the other side of the neck exactly similar to it. This pair of muscles is very plainly seen in the neck of a thin

Explain the action of two muscles in the neck in bowing the head.

person. When they contract together, you bow the head forward. If they contract exactly alike, you bow your head straight forward. But if one of them acts more than the other, then you bow your head in a one-sided way. If you observe persons as they bow to those whom they pass, you will see that they often bow more or less in a one-sided way. That is, one of these muscles pulls upon the head harder than the other does. In some, this unequal action of this pair of muscles becomes a habit.

11. Observe now what a variety of motions can be produced by these two muscles alone. First, the *extent* to which you bow the head forward can be varied to any degree you please, by varying the degree of the contraction of these muscles. When you bow your head forward very much they contract strongly; and when you bow it forward but little, they contract slightly. And their contraction can vary in all degrees between the greatest and the slightest. So also the *direction* in which the head is bowed can be varied to any extent you please. You can bow the head in any direction, either to the right or left, by varying the inequality of the action of the two muscles. If you bow your head very much to one side, you make one of them contract much more strongly than the other. But if you incline the head only a little towards one side, the muscle of that side contracts only a little more than that of the other side. And the inequality in their contraction can be varied in all degrees between the smallest degree and the

Show the variety of motion that can be made by them in two ways —in regard to the *extent* and the *direction* of the motion.

greatest. You will realize the truth of what I have told you in this paragraph, if you try the experiment on yourself, and observe how much you can vary the bowing of your head both in extent and direction.

12. Now, if so much variety of motion can be produced by only two muscles, how great is the variety when there are many muscles in action, each of which can have its contraction varied in all degrees. You see this well illustrated in the hand and arm. Raise your hand, and think what the muscles do when you perform this motion. Although it seems to you so simple a motion, many muscles are engaged in performing it. And each one of these muscles has its particular part to do in making the motion. In doing its part it must contract just enough. If it pull too much, or too little, it will interfere with the action of the other muscles, and there will be a failure in the motion. But there is no such failure. All the muscles contract just enough, and the hand is raised exactly as the mind directs. Now, if you raise it again in a little different position, all these muscles act in a little different way. And you can go on to raise it in a great variety of ways, altering the height and direction each time by altering the action of all these muscles.

13. At the same time that you vary the motion of the hand, you can also vary to almost any extent the motions of the fingers, by the varied action of the muscles that work them. You can get some idea of

What is said of the variety of motion when many muscles act together? Illustrate by referring to the hand. What is said of the exact manner in which each muscle does its part?

the variety of these motions if you watch a person that is writing, or one that is playing on a piano. For every one of these exceedingly varied motions there must be a variation of the action of a great number of muscles. Each muscle must in every motion perform its particular part exactly right, or there will be an interference with the action of the other muscles, and consequently a failure in the motion. But, commonly each muscle contracts exactly right, and so each one of the motions that so rapidly follow each other is performed just as the mind directs.

14. If you examine some of the motions performed by the fingers, that appear very simple, you will see that they are performed by a very complicated machinery. Take, for instance, that seemingly simple movement made in buttoning your coat. If you watch the fingers, as they put the button through the button-hole, you will see that the movement is quite a complicated one. It is so much so, that no man could make a machine in the shape of the hand that could perform it. And the same can be said of other motions.

15. The tongue exhibits great variety in its motions. If you stand before a glass, and, opening your mouth, move about your tongue rapidly, it looks as if some little tricksy spirit were in it playing on its fibres. But each of these fibres is put exactly in its right place, and contracts exactly aright in all the varied

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What is said of the variation of the motions of the hand and fingers in such actions as writing, or playing on a piano? What is said of some apparently simple motions of the fingers? What is said of the movements of the tongue, and of the arrangement of its fibres?

motions of this organ, as we use it in speaking, and eating, and swallowing.

16. The act of swallowing seems to you a very simple thing, but it is really a complicated act of a complicated set of machinery. There are many muscles that work together in doing it, and if they did not work right there would be failure in the motion, and choking would result. Observe that different muscles work in different parts of the act. When you first begin the act, the food is thrust back chiefly by the muscles of the tongue. As it goes back, the epiglottis, the lid of the larynx, is shut down by its muscles, so that the food may slide over it into the œsophagus that lies behind the windpipe. This lid, which thus shuts over the top of the passage to the lungs when we swallow, is raised up by its muscles when we speak or breathe. It is like a little tongue extending back from the root of the tongue itself. After the food has passed over this lid it goes down through the œsophagus into the stomach. But it does not simply fall down. The œsophagus is a tube, made in part of muscular fibres, so arranged that the food is really pushed by their action through this tube. So complicated is all this machinery, and so nice is its operation, that it would be impossible for any man to make a machine of the same shape that could perform the act of swallowing.

17. It seems to you a simple thing to speak. But every time that you speak there is a large number of muscles brought into action. There are the muscles

What is said of the act of swallowing? Describe the different parts of this act.

of the chest that force the air out through the windpipe—the muscles that move the cords in the music-box, the larynx—the muscles that move the epiglottis, the lid of the larynx—and the muscles that move the palate, the tongue, the jaws, and the lips. You cannot utter a word without the action of all these different muscles. And they must act just right, or there would be something wrong in the sound of the word.

18. As the different acts of speaking, laughing, breathing and swallowing follow each other so rapidly, there is vast variety in the changing action of the muscles. Especially busy are those little muscles that work the lid of the larynx, opening it when we breathe, or speak, or laugh, and shutting it down when we swallow. So securely do these door-keepers guard this door to the windpipe, that it is a rare accident for a crumb or a drop to get into it.

19. In performing the different motions that I have alluded to, such as swallowing, speaking, and the motions of the hand, there must be a concert or agreement of action among the muscles. The concert is as real as it would be if the muscles, like men that are pulling at ropes, understood each other, and agreed together as to what they would do. It is, indeed, a more perfect concert of action than ever occurs among a company of men in pulling ropes, especially when they pull upon different ropes. It is difficult

What different sets of muscles are engaged in the act of speaking? What is said of the variety of muscular action as we speak and breathe and laugh and swallow almost at the same time? What muscles are then especially busy? What is said of the concert of action in the muscles?

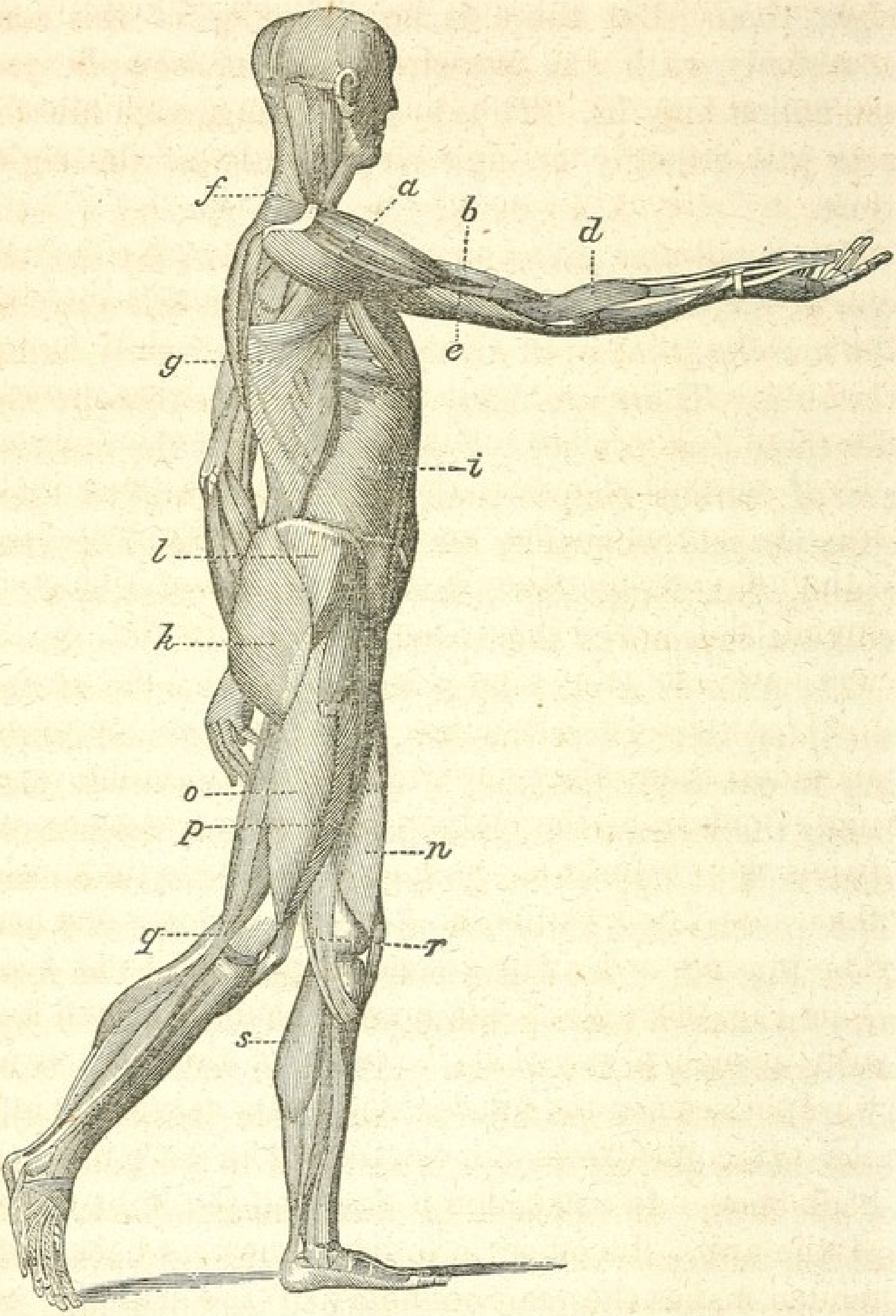
for each man tō pull just enough and at exactly the right time. But there is no difficulty of this sort commonly with the muscles, however complicated the action may be. Thus in swallowing, each muscle acts just strongly enough and exactly at the right time.

20. I will now give you a general view of the muscles of the body. In Fig. 57 you have a side view of the muscles, that is, of all those that lie directly under the skin. There are many other muscles that lie under these that you see. You observe that the muscles are of various shapes and sizes, according to their situation and what they are intended to do. They are round, flat, long, short, fan-shaped, circular, &c. I will notice some of them particularly.

21. At *a* is a very large muscle at the top of the shoulder, that raises the arm, at the same time carrying it out from the body. At *b* is the muscle that bends the fore-arm at the elbow. At *e* is the muscle that acts in opposition to *b* and straightens the arm. The muscles at *b* and *e* are the same as those at 4 and 7 in Fig. 55. At *d* is a muscle that turns the fore-arm in such a way that the palm of the hand is upward, as seen in the figure. At *g* is a very large muscle. It comes from almost the whole length of the back-bone, and its tendon is fastened to the back part of the arm. Its office is to draw the arm back. Its tendon makes the rear boundary of the arm-pit. At *i* is one of the large, flat muscles of the abdomen. At *l* and *k* are two muscles that move the thigh. At *o*

Describe the muscles of the body as represented in Fig. 57.

FIG. 57.



and *p* on the right thigh, and at *n* on the left, are seen three muscles that serve to throw the leg forward. They do this by pulling on the knee-pan. At *q* is the tendon that forms the outer hamstring, and at *r* are the two tendons that form the inner one. The muscles that pull these hamstrings are on the back part of the thigh. When they act they make the leg swing backward, and therefore do just the opposite of what is done by the muscles *n*, *o* and *p*. At *s* is the muscle that makes the back of the calf of the leg. Its strong tendon, which is fastened to the bone of the heel, you can feel very plainly through the skin. It is this muscle, a part of which is represented in Fig. 54, at P.

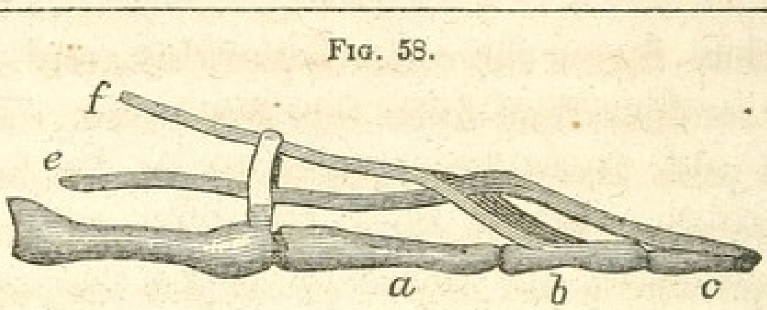
22. The muscles differ greatly in *size*. Some are very large, and some are exceedingly small. Contrast, for example, the muscles of the arm that wield the hammer and the axe, with the muscles that move the cords of the larynx in speaking and singing. These muscles of the voice are very delicate, and they produce the various notes by motions so small, that many of them could be measured by the breadth of a hair. Birds that mount up so beautifully in the air, have large muscles to work their wings. But the muscles that move their little musical cords, as they carol so sweetly, are so small, that it is difficult to find them when we dissect the larynx.

I will now notice some especial contrivances in the muscles and tendons.

23. There is a beautiful arrangement of the tendons in the toes and the fingers. In Fig. 58 is a representation of this arrangement in one of the fingers. At *a*, *b* and *c*, are the three bones of the finger. At *f*

What is said of the size of the muscles? Give the contrasts mentioned.

Fig. 58.



is the tendon that bends the second bone, *b*. This is divided into two parts, as you see, just at its end, where it is fastened to the bone. Through this division the tendon *e* passes, to go to the last bone, *c*. In the Figure the tendons are raised up so that you may see the arrangement clearly. This arrangement is seen in each of the fingers and in each of the toes.

24. There is a very curious contrivance in the sole of the foot. There is a muscle in the calf of the leg, from which there comes down a tendon that is divided into four, for the purpose of bending the toes. Now, there is a short muscle in the bottom of the foot that sends four tendons to join those that come down from the muscle in the leg, so as to help them pull the toes. The reason for this arrangement is this. If all the muscle that is needed to pull the toes were to be put into the sole of the foot, it would make the foot too large at that part; so the thing is done with two muscles, put in different places, instead of one muscle. It is the same sort of contrivance with that to which a man would resort, if he wished to move something with ropes, manned by a company of men, but could not conveniently get men enough into one spot to do it. He would fix some other ropes in another spot, in

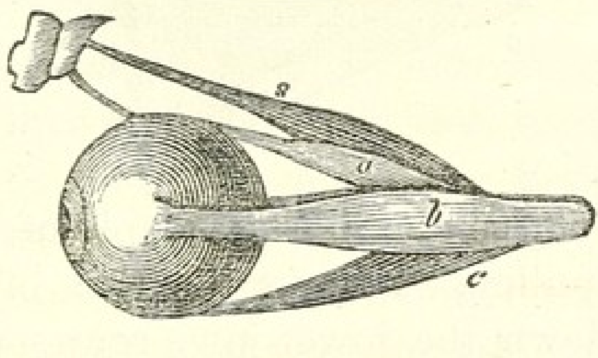
Describe the arrangement of tendons represented in Fig. 58. Describe the arrangement of muscle and tendons in the sole of the foot. Give the comparison made in regard to it.

such a way that a second company of men could help the first. This short muscle in the sole of the foot has received the singular name of *massa carnea Jacobi Sylvii*—that is, the fleshy mass of James Sylvius, the anatomist who first pointed out this arrangement.

25. We have many examples of tendons working with a pulley-arrangement. This is the case with the tendons that go from the muscles in the leg to the foot. They are bound down by ligaments at the ankle, and work under them, just as a rope works through a pulley. If it were not for these ligaments the tendons would fly out continually when the muscles acted, making projecting cords under the skin. There are similar ligaments at the wrist.

26. There is a beautiful example of the pulley-arrangement in the eye, which you see in Fig. 59.

Fig. 59.

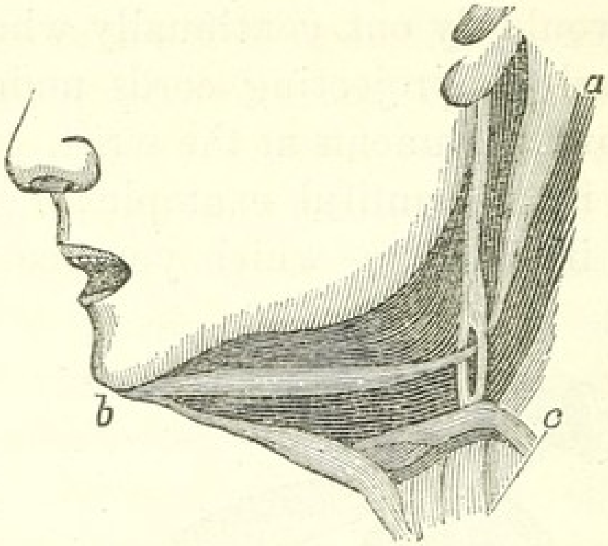


There are six muscles that move the eye-ball. Five of them are represented. There are four *straight* muscles. Three of them are marked *a*, *b* and *c*. You see just the upper edge of the fourth one behind *b*. These muscles come from the back part of the socket of the eye, and have tendons that are fastened to the

What is the pulley-arrangement at the ankle and wrist? Describe the muscles of the eye-ball as given in Fig. 59.

eye-ball. The muscle *a*, when it contracts, turns the eye upward; *c* turns it downward; *b* turns it to one side, and its opposite muscle turns it to the other side. But there are some other rolling motions of the eye that are performed by two *oblique* muscles, as they are called. One of these, *s*, is represented. It has a long tendon, which passes through a ring in the cartilage in the roof of the socket, and then turning back is fastened, as you see, to the upper part of the eye-ball.

FIG. 60.



27. I will notice one more example of the application of the pulley. It is in the case of the muscle that draws down the lower jaw, represented in Fig. 60. It is in reality two muscles. One, *a*, is attached to the bone behind the ear, and the other, *b*, is attached to the inside of the chin. They join together by a tendon; and this tendon, as you see, works in a loop, as a rope does in a pulley. You can see that when these two muscles, *a* and *b*, contract, they draw

Describe the arrangement of the muscle that pulls down the lower jaw.

down the jaw. Now observe, that the jaw could be drawn down in a much more simple way than this. It could be done by a muscle going straight from the chin to the top of the breast-bone. But this would make the neck look very ugly, and hence this pulley-arrangement was adopted. The machinery that draws down the jaw is in this way kept out of sight, and so does not interfere with the beautiful shape of the neck.

28. This regard to beauty of shape, so manifest in the arrangement of this muscle in the neck, may be observed in the arrangement of the muscles generally. They are so arranged, for example, in the limbs, as to give to them a graceful shape. The muscles which move the hand and the fingers are mostly placed in the arm, giving to it the full and flowing outline which makes it so beautiful. If they were placed in the hand, where they do their work, the hand would be a very clumsy instrument. I could give many other examples, but these are sufficient.

29. You see that there are in the body, in its two halves, two sets of muscles that are alike, just as it is with the two halves of the brain and the two sets of nerves. The exact equality of the two sets of muscles is strikingly exemplified in the muscles of the mouth. The mouth is held in the middle of the face, because the muscles on each side of it are exactly alike, and pull alike upon its two corners. If the muscles on one

What is the need of this peculiar arrangement? What is said of regard to beauty in the arrangement of the muscles? What is said of the two sets of muscles in the two halves of the body? How is the mouth held in the middle of the face?

side were stronger than those on the other, the mouth would be drawn to the side of the strongest. Sometimes the muscles on one side of the face are palsied, and then the mouth is drawn to the other side.

30. When the face is palsied upon one side, the two kinds of contraction that I noticed in § 3 are well illustrated. When the muscles of the face are quiet, the difference between the two sides is not very great. For the muscles are then only under the influence of their elasticity, and this is not much less in the palsied muscles than in the opposite ones. But the moment that the muscles are excited to contraction by the nerves, as in speaking or laughing, the mouth is drawn very much to one side, giving the face a very odd appearance.

31. Sometimes muscles are for some reason permanently contracted, and thus cause deformity. Squinting is produced in this way. The straight muscle on one side of the eye-ball contracts more strongly than the straight muscle on the opposite side. Thus, if the eye turns in towards the nose, the inner muscle contracts more strongly than the outer one.

32. The expression of the countenance depends entirely upon the action of muscles. The chief of these muscles of expression are those that wrinkle the eye-brows, and those that pull up and pull down the corners of the mouth. When one laughs, the corners of the mouth are drawn up, as seen in Fig. 61. But when one cries or is very sad, the corners of the

What is said of the two kinds of contraction when the face is palsied on one side? How is squinting produced? Upon what does the expression of the countenance depend? What muscles are the chief agents of expression?

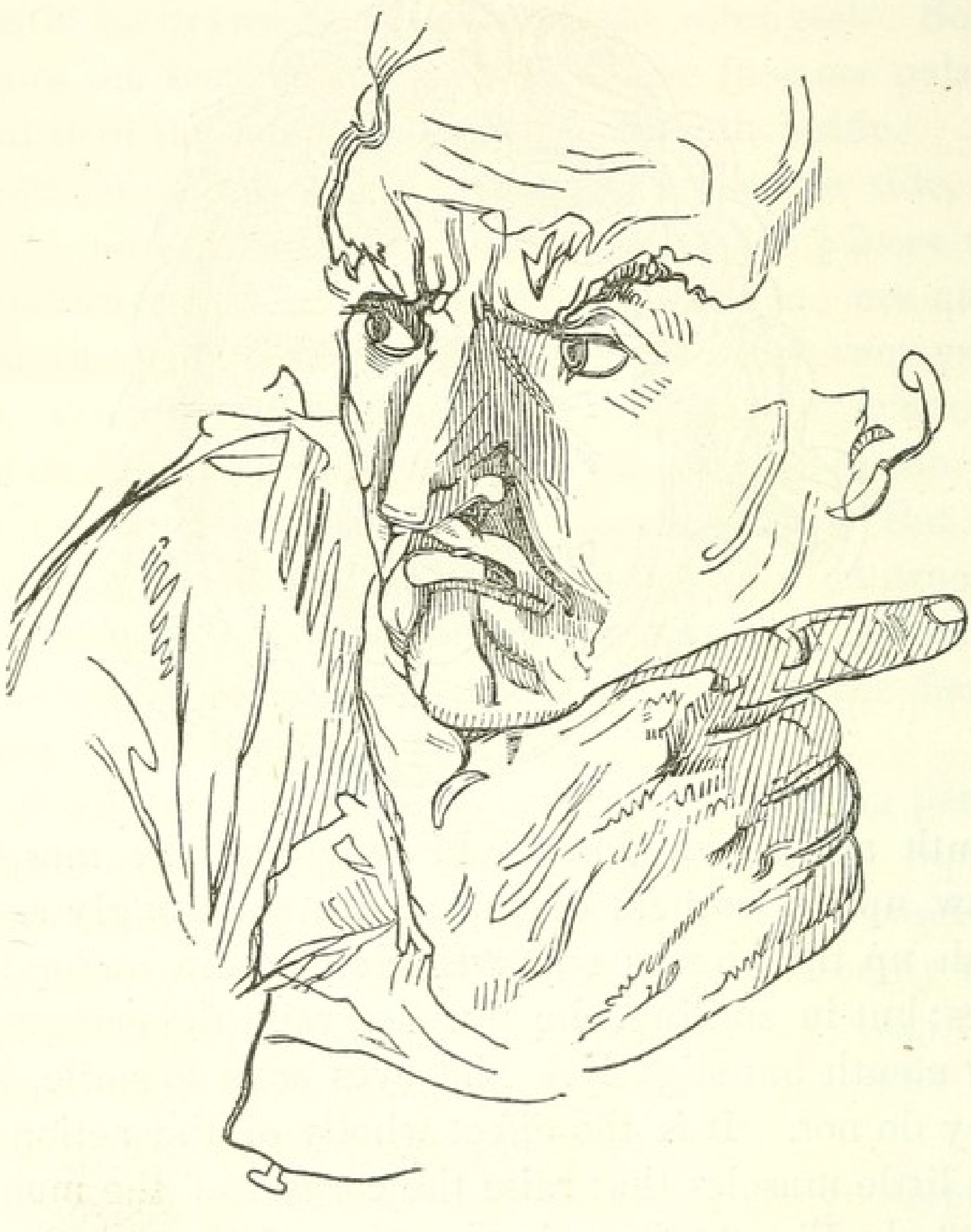
Fig. 61.

mouth are drawn down. In laughing, the muscles draw up the corners of the mouth so strongly as to push up the cheeks and wrinkle the skin under the eyes; but in smiling, the muscles raise the corners of the mouth but slightly. The eyes *seem* to smile, but they do not. It is the effect wholly of the action of the little muscles that raise the corners of the mouth.

33. In Fig. 62 there is an action of the muscles of expression entirely different from that in Fig. 61. Here is an expression of jealous, peevish melancholy. The corners of the mouth are drawn down, and the eye-brows are wrinkled by the muscle *a*, represented in Fig. 56. This makes the eyes look cross. Now, if the eyes remained just the same, and the muscles that wrinkle the eye-brows and those that pull

Explain the action of the muscles in Figs. 61 and 62.

Fig. 62.



down the corners of the mouth were relaxed, the eyes would look pleasant. This subject of the expression of the countenance I treat in full in my larger work on Physiology.

34. I have spoken mostly of those muscles that act in obedience to our will. These are called *voluntary* muscles, and they are excited to act through nerves that come from the brain. The muscles of our limbs, for example, are excited to act through the nerves

that come to them from the brain when the mind wills them to act. But there is another class of muscles that act without our willing them to do so. They are called *involuntary* muscles. The heart, for example, is a bundle of muscles, that are always acting without being told by the mind to act. As the stomach churns the food, as mentioned in § 13, in Chapter III., the will has nothing to do with the contraction of its muscular coat. And so the muscles of breathing keep at work without being told to do so by the will.

35. These involuntary muscles, then, are parts of the muscular machinery that do not depend upon the mind to make them act. They act when the mind is asleep as well as when it is awake. While the voluntary muscles are resting, some of the involuntary muscles are ever at work. The heart is always pumping the blood, and the muscles of breathing are always working the chest to bring fresh air into the lungs.

36. You see at once the reason why such muscles are involuntary. If they were voluntary, the mind would have to attend to them all the time to keep them at work, for life would cease if the respiration and the circulation stopped. The mind, therefore, not only could not have any time for sleep, but it would have every moment occupied with keeping the circulating, breathing and digestive machinery in operation, and could not attend to any thing else. But as it is, all this machinery keeps at work continu-

What is the difference between voluntary and involuntary muscles? Give examples of both kinds. What is their difference as to resting? Why are the heart and the muscles of respiration involuntary?

ally without any superintendence on the part of the mind, except the attention that is required to supply the digestive machinery with its material, the food that we eat.

37. But the muscles of the respiration are not wholly involuntary. Although they commonly work without the mind's superintendence, the mind can regulate their action to some extent. We can, for example, breathe quicker or deeper than usual if we wish to do so. But though the mind can regulate the action of the breathing muscles, it cannot wholly control it. No one can stop his breathing, as he can stop walking, by simply willing that it shall stop.

38. Now, there are two reasons why the mind has this partial control over the muscles of respiration. The first is, that it uses them in certain acts, as speaking, singing, blowing, &c. Another is, that the mind needs to direct in their use when the lungs are in any way embarrassed. So long as there is no difficulty, the breathing is performed by the muscles involuntarily, without any superintendence from the mind. So long as the mind feels no inconvenience it scarcely ever spends even a thought upon the breathing. But as soon as there is embarrassment there is a disagreeable sensation—that is, the mind is informed of the embarrassment through the nerves. It, therefore, attends now to the breathing machinery, in order to have the breathing performed in the best manner possible. For example, when a man is suffering with

How much are the muscles of respiration influenced by the will? What two reasons are there for this? How much notice does the mind take of the working of the machinery of respiration?

asthma, the mind directs the use of the muscles of the chest, so as to get as much air as possible into the lungs. But when the asthma is gone, the mind ceases to superintend these muscles, and the breathing goes on again by their involuntary action.

39. While the muscles of respiration are both voluntary and involuntary in their action, the heart is wholly an involuntary muscle or set of muscles. No one can make his heart beat more quickly or more slowly by determining that it shall. He may do it by exercise, or by thinking of exciting subjects, but he cannot do it by any direct action of the will.

CHAPTER X.

THE EYE.

1. The eye is one of the principal instruments that the mind uses in getting a knowledge of the world around it. Though it is a small organ, it is a very complicated set of machinery. It has many structures in it differing much from each other, as you will see as I proceed. It has six nerves, as I have before told you, and four of these are the nerves by which the mind works the muscular machinery of this organ.

2. You will see, in this chapter, that the eye is an optical instrument. It is, therefore, constructed somewhat like the optical instruments that man makes,

Is the heart in any measure a voluntary muscle? What is said of the structure of the eye? What kind of instrument is it? What instruments is it like?

but is much more perfect. For example, it is like a telescope, and it is also like a camera-obscura. And I shall show you, that in some respects it is like the instrument used in taking daguerreotypes.

3. The eye is contained in a deep bony socket, which you see in Fig. 41, on page 111. As you look at the eye you see only its front, with a portion of its sides, as it rolls in its socket. It is in shape like a globe, but it is not perfectly round. Its front part, where the clear window is, stands out a little. The eye has a complete case enclosing all its soft and delicate parts. But this case is not all alike. It has two parts which are very different from each other. There is a thick white part called the sclerotic coat, from a Greek word, meaning hard. It is what is commonly called the white of the eye. It is this coat that gives the firm feeling to the eye when you press your finger upon it. But this coat does not extend over the front of the eye. There is there, as you see, a clear transparent part of altogether a different structure. This fits into the white coat very much as a watch-glass fits into the case. It is called the cornea.

4. Looking through this window of the eye, you see a little behind it a delicate colored curtain, called the iris, with a round opening in it called the pupil. The iris is differently colored in different persons. And we call the eye blue or brown or gray, &c., according to the color of this curtain. Through the pupil we look into the very inner chamber of the eye. This

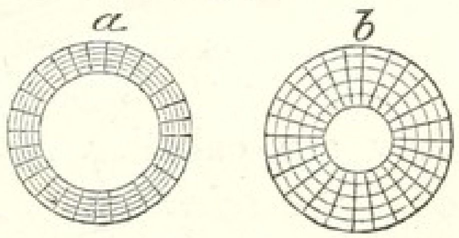
What is the situation of the eye? What is its shape? What is the sclerotic coat? What is the cornea? How does it fit into the sclerotic coat? What is the iris? What is the pupil of the eye? Into what do we look through the pupil?

always has a dark appearance, because, as you will soon see, this chamber has a lining of a dark color.

5. The iris makes the eye very beautiful. But it is not a mere ornament. It is an important part of the machinery of the eye. Its chief office is to regulate the quantity of light that goes into the eye. You can see how this is done. If you look into the eye of any person while you hold a light at some distance, you see that the pupil is quite wide open. Now bring the light near the eye, and you will see the pupil instantly grow smaller. This is because the iris or curtain has contracted its opening in order to keep too much light from going into the eye. In the glare of a bright sun this opening that lets in the light becomes very small; but in the dark it is very wide open, because the eye then needs all the light that it can get.

6. I will now explain the way in which the iris acts in regulating the quantity of light that enters the eye. The iris has two sets of fibres, straight and circular. These are represented in Fig. 63. In *a* the pupil is wide open. Here the circular fibres are relaxed, and the straight ones are contracted. In *b* the pupil is contracted. And here the fibres are just the reverse of what they are in *a*—the straight ones are relaxed and the circular ones are contracted.

Fig. 63.



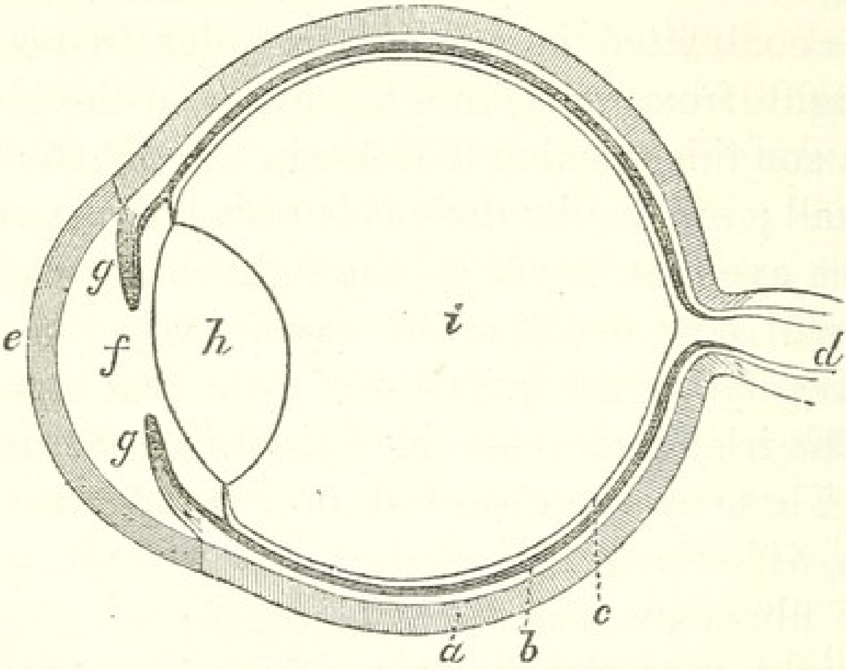
7. The fibres of this round curtain must be very nicely arranged, and be made to act with great exactness; for the iris is always perfectly even as it en-

What is the chief use of the iris? How would you show its use? Explain the manner in which the iris acts.

larges or contracts its opening, and there are never any wrinkles in it. If any person should attempt to construct a curtain after this form, with a round opening in it, he could not in any way fix the strings by which the opening would be made smaller or larger, so as to keep the curtain always smooth and its edge always regular.

8. I will now give you a more full and particular description of the parts of the eye. In Fig. 64 you have a map of the eye. It has three *coats*, as

Fig. 64.



they are called. At *a* is the thick, strong, white coat, the *sclerotica*. Into it the *cornea*, *e*, the clear window of the eye, fits, as I have before told you, like a crystal of a watch in the case. These two parts, the cornea and the sclerotica, really together make one coat. Inside of the sclerotic coat is the *choroid* coat, *b*. This is of a dark color. Why

What is said of the regularity of action of the iris? Describe the parts of the eye as represented in Fig. 64.

this is so I will tell you in another place. At *c* is the *retina*. This is very thin, and is chiefly composed of the fibres of the optic nerve, *d*, that enters the eye at its back part.

9. The eye has three *humors*, as they are called. There is the *aqueous*, or watery humor, *f*, in the front part of the eye behind the cornea. The iris, *g g*, is in the midst of this humor. It divides the chamber that contains the humor into two parts. The part of the chamber which is in front of the iris is, as you see, much larger than that which is behind it. At *h* is the crystalline humor, or *lens*, as it is more often called. This lens is a substance like *hard* clear jelly. Then behind this, filling up all the space, *i*, is the *vitreous*, or glassy humor, which is like *soft* jelly. You see that it is this vitreous humor that fills up a great portion of the ball of the eye.

10. The object of all this apparatus that I have described is to have images of objects formed upon the *retina*, *c*. That these images are formed there can be proved by an experiment. Take an ox's eye, and peel off carefully the thick rind at the back part, that is, the sclerotic coat, so that very little but the retina is left. If now you hold a candle before it, you can see the image of the candle on the retina at the back part of the eye. So, if you place it in a hole in the window-shutter, the images of objects, such as houses, trees, &c., can be seen pictured on the retina.

11. This picturing upon the retina takes place with every object that we see. If we look at a single ob-

What is the object of the apparatus of the eye? How can you prove that images are formed on the retina?

ject, as a candle, its image is formed distinctly in the back part of the eye. And so, also, if we look at a wide prospect, all the multitude of objects that we see are pictured there in a space that a sixpence would cover.

12. I will now explain to you in what way these pictures are formed upon the retina. It is the light that forms them. The rays of light that come from the sun are reflected from every object in all directions. And when you see an object, it is because these rays reflected from it enter your eyes, and make its image in them. For example, when you see a tree, the light which is reflected from the tree passes into the window of the eye, and pictures out a tree on the retina.

13. In this formation of the pictures of objects on the retina, the eye is like the instrument called the camera-obscura. In this instrument there is a dark chamber into which light is admitted through glasses in a tube. The light that thus comes in, pictures in the dark chamber of the instrument the trees, houses, and other objects that are in front of the tube. And as you look into this chamber through an opening, you see the picture. That dark chamber in the eye, that is filled with the vitreous humor, is like the dark chamber of the camera-obscura, and the lenses and humors of the eye serve the same purpose as the glasses in the tube of this instrument do.

14. In this formation of pictures of objects, the eye is also like the instrument used in taking daguerreo-

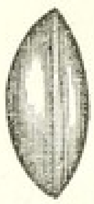
In what way are the images of objects pictured on the retina? Trace the resemblance of the eye to the camera-obscura.

types. When your daguerreotype is taken, the rays of light that shine upon your face are reflected or thrown off from it into that round window that you look at in the instrument. These rays enter through this window into a dark chamber, just as they do in the camera-obscura, or in the eye, and picture your image on a plate of metal there. This plate of metal is to this instrument what the retina is to the eye.

15. The metallic plate in the daguerreotyping instrument differs from the retina in one important respect. The image made on the retina does not remain, but that which is formed on the metal does. The surface of the metal is prepared in such a way that the image made by the light is left there. It is a beautiful idea that light should thus be the pencil to paint your picture. And yet, whenever any one looks upon you, the light paints your picture in his eyes upon the retina, just as it does upon the metallic plate in the daguerreotyping instrument. Indeed, every object that is seen, is for the moment daguerreotyped upon the retina. And as you look at object after object, there is a constant succession of pictures made there.

16. The eye is in some respects like a telescope. It has lenses like this instrument. The projecting cornea in front acts as a lens. But the principal lens of the eye is the crystalline lens, which is represented in Fig. 65. The rays of light are brought nearer together

Fig. 65.

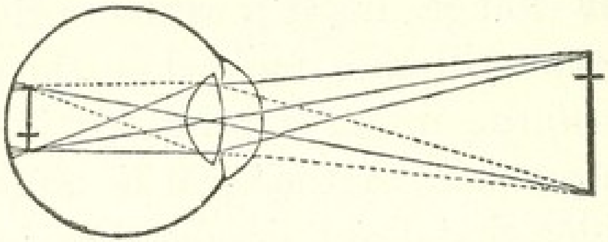


How does the eye resemble the daguerreotyping instrument? What is the difference between the picture on the retina and that on the plate of metal in the daguerreotyping instrument? How is the eye like a telescope?

by the lenses of the eye, just as they are by the lenses of the telescope.

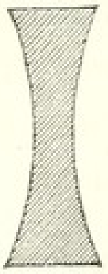
17. The lenses and humors of the eye must be very exactly arranged, in order that the sight may be perfect. They must be so arranged that the images of objects shall be formed distinctly on the retina. Now in *near-sighted* persons the lenses and humors are so arranged as to make the rays that form the images come together too quickly, before they reach the retina. This

Fig. 66.



is represented in Fig. 66. The result is, that a confused instead of a clear image is formed on the retina. If the retina could be brought forward to where the figure of the cross is represented, the image would be clear. The common remedy for the near-sighted is a glass, that has an effect upon the rays of light the opposite of that which is produced by the cornea and the crystalline lens—that is, a glass which separates the rays instead of bringing them nearer together, and so prevents the rays from coming together in the eye too soon. Such a glass is called a *concave* lens. Its two sides are hollowed out more or less, as represented in Fig. 67. The crystalline lens, seen in Fig. 65, is, on the other hand, a *convex* lens.

Fig. 67.



What is said of the arrangement of the lenses and humors of the eye? What is the difficulty in the near-sighted? What is the remedy?

18. That large rear chamber of the eye, where the images of objects are pictured on the retina, I have told you, is a dark chamber. It is made so by a coloring substance which is in the choroid coat. If it were not dark our vision would be indistinct, from the glare of light in the eye, just as it is when we go into a room where the walls are all of a very light color. In the albino there is none of this coloring matter in the choroid coat, and therefore he cannot see well in a bright light. Some animals, that use their eyes only in the night, have none of this dark matter in them, because it is only needed when the bright light of day is shining into the eye.

19. I have thus shown you how the images of objects that we see are pictured in the retina. But this is not all the process that we call seeing. There is something more needed besides the formation of these images, in order to have the mind see the objects. Now the mind does not *look* into the dark chamber where the images are, as we look into the chamber of the camera-obscura. The mind gets a knowledge of the images in a different way from this. It gets it by means of the optic nerve, the end of which spread out forms the retina. The images pictured there make impressions on the net-work of the nerve, and these impressions go to the brain by this nerve, and the mind feels them. In regard to the use of the word *impression*, in speaking of the operation of the

What is the cause of the darkness of the large rear chamber of the eye? Why is it made dark? How is it in the albino? How is it in some animals? In what way does the mind get its knowledge of the images made on the retina?

nerves, I refer you to what I have said in the chapter on the nervous system, § 20.

20. The eye may be in perfect order, so that the images of objects may be pictured accurately in its dark chamber, and yet there may be no seeing. For the nerve may not be able to pass the impressions on to the brain. A tumor, for example, may press on it so that nothing can pass through its little tubes. It is by means of the nerves, then, that the mind makes use of its optical instruments, just as is true of all the other apparatus or machinery of the body.

21. There is one thing very curious in regard to the pictures formed on the retina. They are always inverted or upside down. If you look at a man, for example, he is pictured on your retina with his head down. And so of every object. Accordingly, in Fig. 66 the image of the cross in the eye is represented upside down. But although the images of objects are thus reversed on the retina, your mind sees everything right-side up. How this is we know not, but in some way the matter is so fixed in the brain or the nerves, that the right impression goes to the mind.

22. Observe another thing. There are two eyes. Of course there are two images of every object that you see, and two impressions are carried by the two optic nerves to the brain. And yet the mind receives but one impression, and so sees but one thing. This is because the two eyes are alike, and work alike. If this were not so, there would be confused and double

What is said in regard to the optic nerve as being necessary to seeing? What is said of the position of the images on the retina? What is said of the fact that we have two eyes?

vision. If the eyes were not alike throughout, the pictures in the two retinas would not be alike, and two different impressions would be sent by the two nerves to the brain, and then you would always see two things instead of one—two faces, two trees, two houses, and so on. So also, if the muscles of the eyes did not work alike you would see double. For this reason, if you press your finger on the side of one eye, you see everything double; for you keep the two eyes from moving together as they usually do.

23. There are several reasons for our having two eyes or optical instruments for the mind to use, instead of one. You could not look in so many directions with but one eye. You do not use both eyes together all the time, but you use one or both, as you find most convenient. Then again, if you lose one eye by any accident, you have another. And we cannot conceive of any way of placing a single eye in the face so as to look as well as two eyes do.

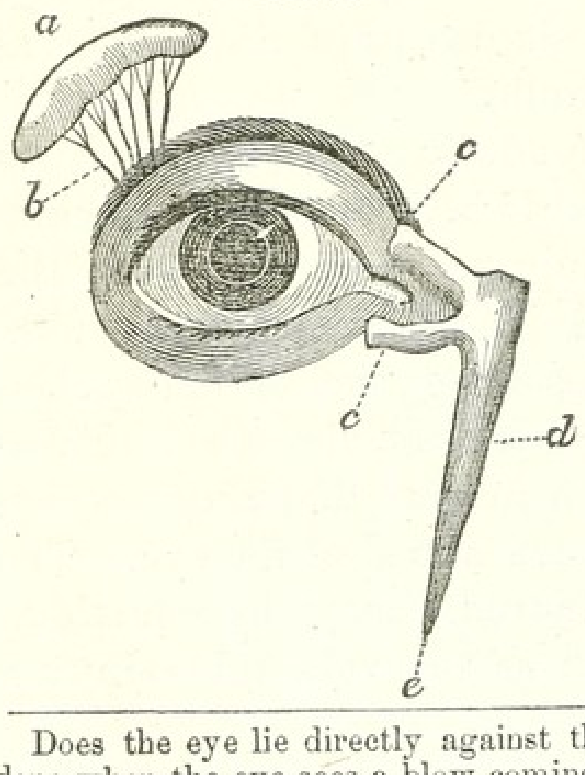
24. The eye is a very tender, and at the same time a very important organ. It is, therefore, very carefully guarded against injury. Observe, how the bones jut out all around it; the bone of the forehead, that makes the projecting roof of the socket, the cheek-bone, and the bones of the nose. These parapets of bone are so arranged that they receive almost all the blows that are aimed at the eye. The eye is therefore seldom injured, except by something thrust straight into it, so as to avoid these jutting

How is it, that with two eyes our vision is not confused or double? What reasons can be given for our having two eyes? How are the bones about the eye arranged so as to guard it?

walls around it. Then, too, the eye has a cushion of fat, and does not lie against the hard bone of the socket. Now, if the eye sees a blow coming, the muscle that makes the motion of winking shuts the lids, and pushes the eye back against this soft cushion. This, of course, not only covers it up, but sinks it deeper between the parapets of bone, and so puts it more out of the reach of the blow.

25. The eyelashes serve to keep light things, flying in the air, from entering the eye. The muscle that so quickly shuts the eye-lids, however, does more at this business of keeping out intruders. The eye-brows, besides being an ornament, are of some use as a protection. If they were not there, the perspiration on the forehead would continually run down into the eye, and would irritate and inflame it. The eye-brows are the eaves of the roof of the eyes' habitation, and the perspiration drops from them upon the cheek below.

Fig. 68.



26. There is a beautiful apparatus for moistening and washing the eye. The tear-gland, that makes the wash for the eye, is situated above the eye, a little toward its outside, as repre-

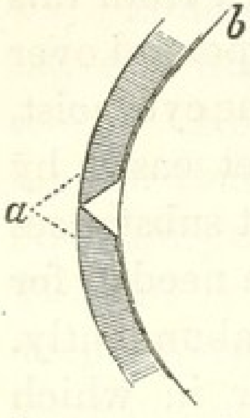
Does the eye lie directly against the bone of its socket? What is done when the eye sees a blow coming? How is the eye protected by the eye-lashes? How by the muscle of the eye-lids? How by the eye-brows?

sented at *a*, in Fig. 68. The tears are carried from this factory by little ducts, as seen at *b*, and are poured over the surface of the eye. They serve to keep the eye moist, so that it can be moved about in its socket easily by the muscles. They also serve to wash out substances that get into the eye, and when they are needed for this purpose the tear-gland makes them abundantly. Fishes have no tear-gland, for the water in which they live answers the purpose of tears in their case. Neither have they any eye-lids, as they are not exposed to dust, or motes, or flying insects, as animals that live in the air are. For the purpose of moistening the eye, the tears come from the gland in a small amount all the time. Of course, there must be some contrivance for the passing off of the tears, or they would continually run over the edges of the lids. The contrivance is this. If you will look at the edges of the eye-lids, you will see on each, near the end toward the nose, a very little opening. Into these openings, seen at *c c*, in the Figure, the tears go, and pass through two ducts which unite in one, *d e*. This ends in the nose. This sink-drain of the eye, as we may call it, is continually emptying its contents there.

27. Sometimes this drain gets stopped up, and then the tears overflow their banks, the lids, and run down the cheeks. When one weeps, the tear factory makes

Describe the tear apparatus? What two purposes do the tears serve? Why have fishes no tear-glands and no eye-lids? Describe the drain by which the tears are carried off. From what causes may the tears overflow the lids?

Fig. 69.



tears so fast that the drain cannot take them all away, and there is an overflow. There is a curious contrivance for carrying off the tears when the eyes are closed in sleep. The lids close in such a way as to leave a three-cornered canal between them and the surface of the eyeball, as represented in Fig. 69. In this diagram the line *b* is the surface of the front of the eye, and *a* points to the edges of the two lids. The little open space which you see shows you the form of the canal. It is through this canal that the tears flow, all the time that we are asleep, to the openings that lead into the sink-drain.

28. There is still another contrivance, in regard to the tears, which I will notice. Along on the edge of each lid, among the roots of the eye-lashes, are some little glands that secrete an oily substance. This, besides oiling the eyelashes, serves to keep the tears in the eye. It makes an oily line all along the edge of the lid; and, as water does not mix with oil, the tears will not pass over this line unless they are more abundant than usual. If it were not for this simple but effectual contrivance, the tears would be constantly diffused over the edges of the lids, and the lids would therefore be all the time wet. This would certainly be the case with the lower ones.

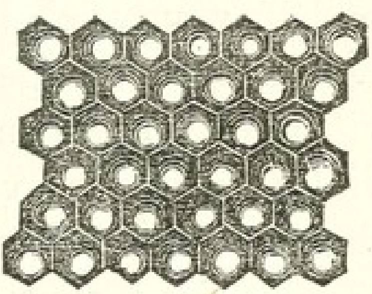
29. Such is the wonderful apparatus of the human eye. It would be interesting now to show you how

What contrivance is there for carrying off the tears during sleep? Mention the contrivance for keeping the tears from moistening the outside of the eyelids.

the eyes of different kinds of animals vary from the human eye in their arrangements. I will speak, however, only of the *compound* eyes found in insects. They are made up of many eyes. Thus in the two eyes of the common fly there are eight thousand little eyes, as the microscope shows us. In some insects they amount to twenty thousand. Each of these is a tube, at the bottom of which an image can be formed, just as you have seen that there is on the retina of the human eye. Each of these eight thousand eyes in the fly sees perfectly of itself, having its own nerve of sight. The fly therefore can see in various directions, without turning its head, and it sometimes uses one part of this extensive optical apparatus and sometimes another, according to the direction in which it wishes to look or the number of things it wishes to see.

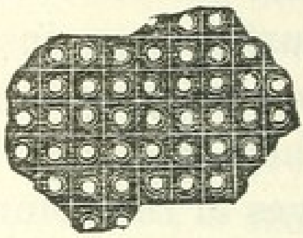
30. It has been found by the microscope that the little eye-tubes, of which the eyes of insects are made, are not always of the same shape. In some they are hexagonal or six-sided. This is the case with the eye of the yellow beetle, or May-bug. A magnified view of a small portion of the surface of this insect's eye is given in Fig. 70. In some butterflies the little eyes are of a square shape, as represented in Fig. 71. Why there should be this difference in shape we know not. These compound eyes of insects are

Fig. 70.



What is said of the eyes of insects? How many eyes has the common fly? How many have some other insects? Are the eyes of insects all shaped alike?

FIG. 71.



among the most wonderful things that the microscope has revealed to us. We admire the skill and power of the Creator as we look at the construction of the human eye; but His skill and power appear vastly more wonderful, when we think of the eye of a mere common insect, as made up of thousands of optical instruments, each, though so minute, being more perfect than any instruments that man can make.

CHAPTER XI.

THE EAR.

1. THE mind acquires the knowledge of sounds by the apparatus of hearing. This apparatus is very complicated, and some of it is exceedingly delicate. Before describing it I will say something of sound, in order that you may better understand the operation of this apparatus.

2. Sound is caused by a vibration or shaking of some substance. You can perceive this vibration in a bell if you touch it after it has been struck. If the bell is quite large you can see as well as feel the vibration. You can see it in the string of a piano or a violin. It is the vibration of the cords in the larynx that produces the sound of the voice. It is not solid bodies alone that produce sound by their vibration.

Why are the compound eyes of insects more wonderful than the human eye? How is sound produced? Give examples of sound made by the vibration of air?

It is often produced by the vibration of the air. This is the case in whistling. In the flute it is the vibration of the air in the instrument that produces the sound. And so of other similar instruments.

3. When the vibrations are equal, the sound is a musical one. But when they are irregular, the sound is a noise, that is, a confused sound.

4. Sound passes through the air by vibrations. It may be said to pass by waves in all directions, just as waves go in all directions on the surface of water when a stone is dropped into it. And as these waves in the water lessen as they extend from the spot where they begin, so the waves of sound lessen the farther they are from where the sound is produced. That is, the sound dies away in the distance, as it is expressed.

5. That sound is transmitted in this way through the air can be proved by experiment. If a bell be set to ringing under the glass receiver of an air-pump, as you pump the air out of the receiver, the sound of the bell becomes more and more faint, till at length you cannot hear it at all. The reason is, that the vibrations of the air lessen as the air itself lessens and becomes thin; and when the air is all pumped out, there are no vibrations to convey the sound of the bell. So, too, sounds made on the top of a very high mountain are not as loud as when made in the valley below, because the air at so great a height is very thin.

What makes the difference between a musical sound and a noise? How does sound pass through the air? Give the comparison in regard to the diffusion of sound. How can you prove that sound passes through air by vibrations?

8

6. Other substances besides air transmit the vibrations or motions of sound. If you put your head under water, and let some one strike two stones together under the water at some distance from you, you will hear the sound. That is, the vibration will come to your ear through the water. If you place a watch between your teeth, you hear its ticking quite as distinctly as when you put it to your ear. In this case the vibration goes to the nerve of hearing by the teeth and the bones, and does not go round by the air into the tube of the ear.

7. The vibration of sound passes more readily through solids than through the air. If you put your ear upon the end of a long log you can hear the scratch of a pin made at the other end. And yet you cannot hear it through the air at the distance of only a few feet. A deaf gentleman, as he rested the bowl of his long pipe upon his daughter's piano, found that he could hear the music much more distinctly than he could through the air. In this case the vibration went through the pipe to the teeth, and then through the bone to the nerve of hearing.

8. The vibrations or waves of sound are reflected by objects against which they strike. For this reason a sound can be heard further along a wall than in an open field. If one speaks in an open field, the sound is scattered in all directions. But the wall keeps it from being thus scattered. For the same reason, a

Illustrate the fact that other substances besides air transmit the vibrations of sound. What is said of the transmission of sound through solids compared with its transmission through air? Illustrate in various ways the reflection of sound.

speaker can be better heard in a building than in the open air. In this case the walls shut in the waves of sound. So, also, a speaker can be heard better when the ceiling is low than when it is very high. When the ceiling is high much of the sound of the voice is lost in the space above. In a speaking-tube, even a whisper can be heard at a great distance, because the waves of sound are so shut in by the tube.

9. In hearing, the waves of sound are caught by the outer ear, as it is called, and they go into the tube which you see there. The purpose of this outer ear is to collect these vibrations and direct them into this tube. It is well shaped on the whole for this purpose, but the ridges and prominences that you see on it do not render any assistance in this respect. They merely serve to make the ear a comely organ. Some animals have ears which answer much better in collecting the waves of sound than the ear of man does, because they need them. Man could hear more easily if his ears were larger, and were shaped more like the open end of a trumpet, but such ill-looking appendages are not necessary in his case. He sometimes assists the ear in collecting the vibrations of sound by putting his hand up behind it. Very deaf persons often use an ear-trumpet. The broad trumpet-shaped end is turned towards the speaker, so as to catch the waves of sound and direct them into the tube of the ear by the pipe of the instrument.

10. The vibrations of sound in the air, entering the

What is the purpose of the outer ear? What is said of its shape, and the irregularities on its surface? What is said of the ears of some animals? In what way is the ear sometimes assisted?

tube of the ear, strike upon a drum at the end of the tube. This drum of the ear is a membrane fastened to the bone, just as the drum-head of a common drum is fastened to its wooden rim. The vibrations that thus enter this tube as they strike the drum make it to vibrate.

11. The vibration does not stop here. It is communicated to a chain of little bones on the other side of the drum. The farther one of this chain of bones rests on another membrane or drum. The vibration is therefore communicated to this second drum. And this drum covers an opening into some winding passages in solid bone. These passages are filled with a fluid, and the vibration of the drum over the opening makes this fluid to vibrate or shake.

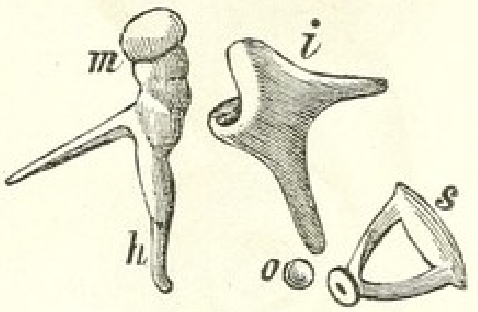
12. The fine delicate fibres of the nerve of hearing are in the midst of the fluid in the winding passages. They feel the vibration of the fluid there, and an impression goes by them through the trunk of the nerve to the brain, and is received there by the mind. And this completes the process of hearing. These winding passages, where the nervous fibres are at their post ready to feel the vibrations that come there, are the real *halls of audience*, as we may call them. I will now describe some of these parts more particularly.

13. The little bones in the ear are four in number. They are connected together, and are commonly spoken of as a chain of bones. In Fig. 72 they are re-

Upon what do the waves of sound entering the ear strike? Trace the transmission of the vibration inward from the drum of the ear. Where are the fibres of the nerve of hearing, and how are they affected? What completes the process of hearing?

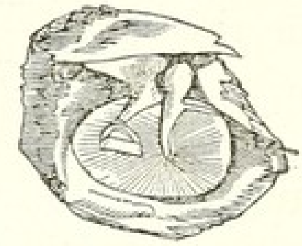
presented separate and considerably magnified, so that you can see their shape distinctly. They are named from their shapes. They are the *hammer*, *m;* the *anvil*, *i;* the round bone, *o*, the smallest bone in the body; and the *stirrup*, *s*. The long handle of the hammer, *h*, is fastened to the middle of the drum of the ear, and its blunt end fits on to the anvil. The little round bone is fixed between the slender end of the anvil and the top of the stirrup. And the bottom of the stirrup presses upon the second drum of the ear.

FIG. 72.



In Fig. 73 you have a representation of these bones, together with the drum of the ear. When the vibration of sound comes to these bones, the hammer receives it first and it passes to the anvil, then to the little round bone, then to the stirrup, which communicates to the drum that is over the opening to the winding passages.

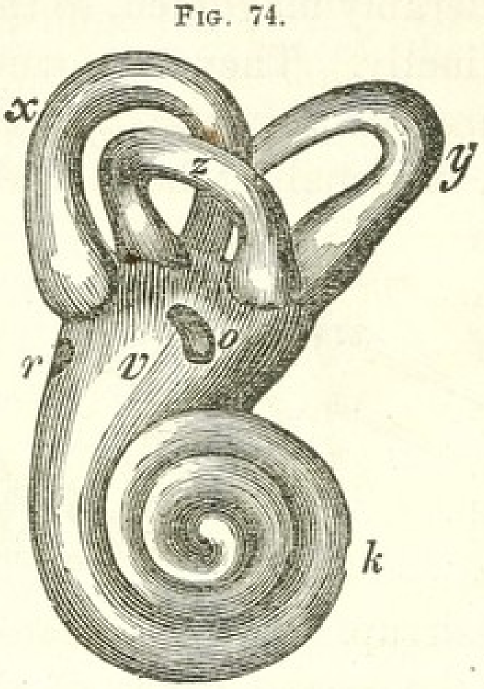
FIG. 73.



14. In Fig. 73 is represented, much magnified, the shape of the winding passages, which I have told you are in solid bone. The middle part of it, *v*, is the *vestibule*, or common hall of entrance to the passages. From this go out on the upper side the *semi-circular canals*, *x*, *y*, *z*, and on the lower side the passages of the *cochlea*, *k*. At *o* is the opening into the vestibule

Describe the little bones of the ear. In what order does the vibration of a sound pass through this chain of bones? Describe the winding passages.

Fig. 74.

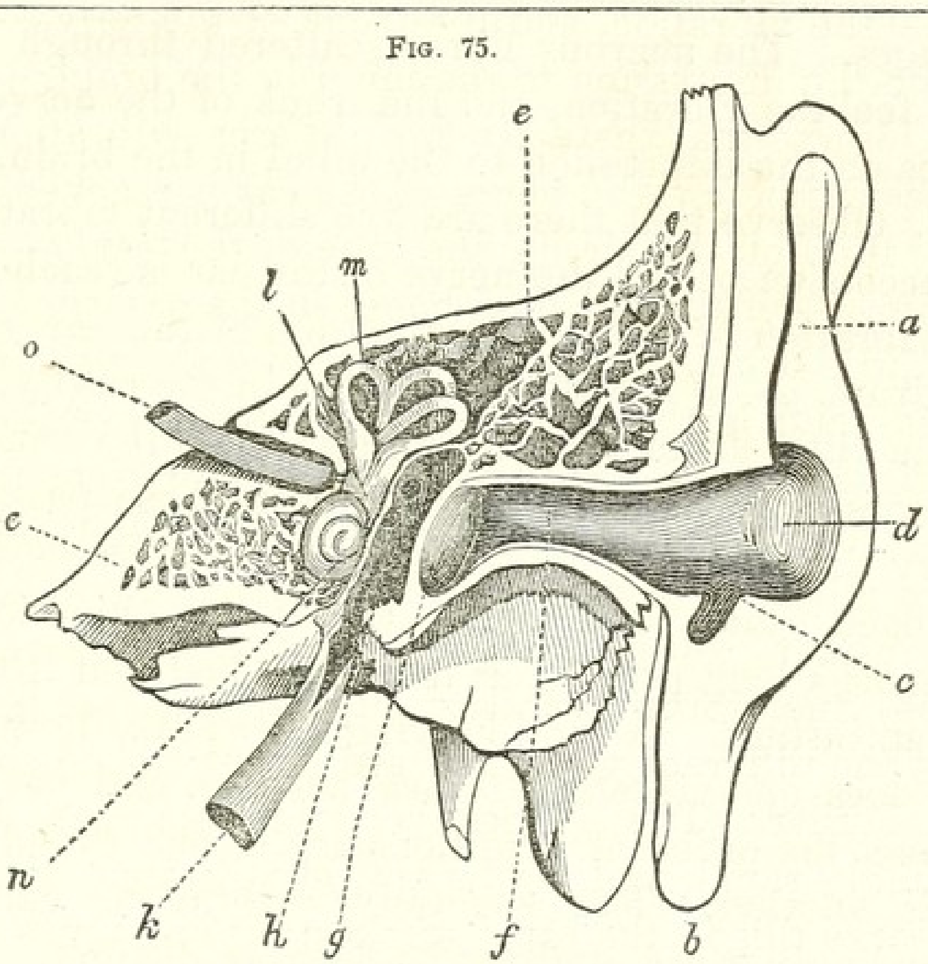


that is covered by the second drum. This drum, you will remember, is pressed upon by the stirrup-bone. At *r* is another opening, which is also covered by a membrane or drum. The cochlea is called so because it is shaped like a snail's shell. It is most curiously arranged, having two spiral passages, each taking two turns and a half around a pillar in the middle. This part of the ear represented in this figure is called the *labyrinth*, because the winding passages are so complicated.

15. Having thus noticed the different parts of the apparatus of hearing, let us look at it altogether, as represented in a map of it in Fig. 75. At *a b c* is the external ear; at *d* is the entrance to the tube of the ear *f;* at *g* is the drum of the ear. At *h* is the cavity beyond the drum where the chain of bones is, the bones being left out that the arrangement of the apparatus may be more clear to you. At *k* is a tube which comes from the back part of the throat to this cavity. If you shut your mouth and close the nostrils with your fingers, and then force the air strongly from your chest into the mouth, you can feel the air pass through this tube into the ear where the little bones are. At *l* is the vestibule of the labyrinth; at

Why are the winding passages called the labyrinth? Describe the various parts of the ear as represented in Fig. 75.

FIG. 75.



m are the semi-circular canals; at *n* is the cochlea; at *o* is the trunk of the nerve of hearing as it goes to branch out in the labyrinth; and at *e e* is the bone in which the labyrinth is inclosed.

16. I will now describe to you the process of hearing, tracing its successive steps by means of the map of the apparatus. The vibrations or waves of sound go into the tube of the ear, *d f*, and strike on the drum, *g*, making it to vibrate. This vibration is communicated to the chain of bones in the cavity, *h*. The last bone in vibrating shakes the little drum that covers the opening into the winding passages, *l m n*. This sends a vibration throughout the fluid in all these

Trace the process of hearing in its successive steps on this map of the apparatus.

passages. The nervous fibres scattered through this fluid feel the vibration, and the trunk of the nerve, *o*, passes on the impression to the mind in the brain.

17. Observe that there are five different vibrations in succession before the nerve of the ear is reached—the vibration of the air, in the tube of the ear, *f*—of the drum, *g*—of the chain of bones in the cavity, *h*—of the little drum over the opening into the winding passages—and lastly, of the fluid in these passages. Every time that a sound is heard, these vibrations follow each other, in the order that I have mentioned. It seems a long process, as it is described, but it takes but an instant. And in hearing one speak, how rapidly does one vibration follow another, and yet how distinct the different vibrations are as one sound succeeds another. The successive vibrations can be exceedingly rapid, and yet be entirely distinct. You can observe this in the rapid strokes of some kinds of machinery. You can observe it also, as you strike as rapidly as you can with a stick upon anything. For every blow of the stick you have the succession of vibrations that I spoke of in the first part of this paragraph. And you cannot strike fast enough to make the vibrations mingle together.

18. I have described hearing as it commonly occurs. But, as I have already told you in § 6, sounds do not always go in through the tube of the ear. They sometimes get to the winding passages by another way; as for example, the sound of the watch

How many different vibrations are there for every sound? What is said of the distinctness and rapidity of the vibrations as they follow each other?

when placed between the teeth. In such a case, there are not so many changes in the vibration as when we hear in the common way. There are only three vibrations to follow each other for every sound, viz., the vibration of the teeth, that of the bones between the teeth and the winding passages of the ear, and that of the fluid in these passages.

19. You see, then, by such cases that there can be hearing without using the drum of the ear or the chain of bones. Indeed these parts may be destroyed, and yet if the winding passages are not at all injured, the person can hear, though of course not as well as when the apparatus is all there. The winding passages, the halls of audience, as I have called them, are then really the *essential* part of the apparatus. And so long as the vibration of sound can in any way reach the fluid in them, and shake it so that the fibres of the nerve shall feel it, there will be hearing. But if the fluid be in any way let out of these passages there will be no hearing, although the drum of the ear and the chain of bones may be in perfect order, and may vibrate regularly to the sounds that come into the tube of the ear. The vibration in this case will stop at the stirrup-bone, and will not reach the nerve.

20. This innermost and most important part of the apparatus is very securely guarded from injury. The winding passages are inclosed in the hardest bone in the body. It is so hard that it is called the *petrous* or rock-like bone.

May sounds be heard in some other way than through the tube of the ear? What is the most important part of the apparatus of hearing? Explain in full. How are the winding passages guarded from injury?

21. The outer passage into the ear is well guarded, and in rather a singular way. Besides the hairs that are in the tube, which serve to catch particles that may fly in, there is also a waxy substance secreted there. And this substance, though it is so different from anything else in the body, is, like everything else, made from the blood. It is made by some very small glands situated in the lining of the tube. It is very bitter, and the odor of it serves to keep out small insects which might otherwise creep or fly in. It answers this purpose so well, that although the tube is always open, it is quite uncommon to have an insect get into the ear. And when one does, it becomes so enveloped in the wax that its struggles can do but little harm. Commonly the insect soon dies—perhaps, in part, from the bitter dose which he is obliged to take.

22. I have thus, in this and the previous chapter, treated quite fully of two of the senses. Of the other senses I have spoken incidentally in other parts of the book. The organs of the different senses differ from each other, as they are fitted to inform the mind of the different qualities of things around it. For example, the organ of *smell* is very different from the organ of hearing. Fine particles pass from bodies that give out an odor; and these, coming in contact with the nerve spread out in the nose, make an impression, which is transmitted by the nerve to the brain. But in hearing, no particles from the sounding body come in contact with the nerve. A mere shaking or vibration goes through the air to the drum

How is the tube of the ear guarded? Give the difference stated between the organ of smell and that of hearing?

of the ear, and is passed on from this through the chain of bones to the fluid that surrounds the fibres of the nerve of hearing.

23. In the sense of *taste*, the particles of the substance tasted are commonly applied in a coarser way to the nerve than in the sense of smell. In the sense of *touch*, the substances do not, as in smell and taste, come into actual contact with the nerves. They are felt through the cuticle; for this, as I have told you in § 28, Chapter VI., is not sensitive at all; that is, it has no nerves, but is only a soft delicate covering to the very sensitive true-skin.

24. In regard to the sense of *sight*, we know not what it is that enters the eye and pictures the images of things on the retina. Light is now generally supposed to be a vibration of an exceedingly fine substance, finer than air, which is thought to exist everywhere. The vibration of this substance, which is called ether, is thought to be like the vibration of air in sound. Like that, it goes in waves, in all directions, from where it begins. If light and sound are thus only motions, they are in some respects different motions. They never interfere with each other, though they are continually mingled together, and cross each other in all directions. They differ in one respect very much. Light is a much faster vibration than sound. If you look at a cannon fired at a distance, the flash comes to your eye much sooner than the sound comes to your ear. The same is true also of the flash of lightning and its sound, the thunder.

What is said of the sense of taste? What of the sense of touch? What is light supposed to be? What is said of the vibrations of light and sound?

CHAPTER XII.

CONNECTION OF THE MIND AND BODY.

I HAVE already said much of the connection of the mind and the body. I showed you in the chapter on the Nervous System that this connection is maintained by means of the brain and the nerves. You there learned, that all the knowledge which the mind gets of the world around it comes from the senses by means of the nerves; and also that the only way in which the mind communicates its knowledge to others is by means of the nerves that excite the muscles to action. In the chapters following that on the Nervous System, we considered the instruments by which the brain and nerves operate in thus connecting the mind with the world around it. These instruments are the muscles and bones, and the organs of the senses, the eye, the ear, the nose, the mouth, and the skin. In this chapter I wish to carry you on a little farther, and show you more than I have yet done in regard to the manner in which the mind uses these instruments by means of the nerves.

2. The mind is connected with every part of the body. It therefore feels what is done to any part, and it can move the muscles everywhere by willing to have them moved. But the mind, though it is connected with every part, is not in every part. If you pinch your finger the mind feels it as readily as if it

Give the summary, in §1, of what has been already said in regard to the connection of the mind and the body. How do you know that the mind is connected with every part of the body?

were itself in the finger. So, also, it can move the finger as easily as if it were really there among the muscles. But if the hand be palsied, feeling and motion are gone in the part; and yet the mind may be active, and move other parts that are not palsied, and feel what is done to them.

3. The mind, then, is not, as life is, all over the body. It is in the brain. This is its central office, the nerves being its communicating wires. We seem to know very early in life that the mind is in the brain. The child is conscious that he does his thinking in his head. But besides this consciousness, we know some facts that prove that the mind resides in the brain. Thus, if a man be knocked down senseless by a blow on his head, the mind feels nothing, and can move no part, because the mind's organ, the brain, is so much affected by the blow. He breathes still, and his heart beats, because the mind, as you saw in § 33 in the chapter on the Muscles, does not control these operations. If the blow break the skull, and the broken part be pressed in upon the brain, the man will not think, and feel, and move, until the surgeon remove the pressure by raising the broken piece.

4. The brain is shown to be the organ of the mind by the manner in which the mind is affected by disease in the brain. Fever causes delirium by disordering the brain, and a violent inflammation of the brain produces fierce delirium. We sometimes see the mind blotted out, step by step, by slow disease in the brain,

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How do you know that the mind is not in every part? What is said of the consciousness that the mind has its seat in the brain? What fact can you cite that proves that it has its seat there?

so that the strong-minded man becomes gradually like an idiot.

5. You see, then, that the mind or soul, so long as it remains in the body, is dependent upon the brain. *It can act only by means of this organ.* If the brain be disordered in any way, the mind acts in a disordered manner. If the brain be much pressed upon, the mind cannot think, nor feel, nor move any part of the body. The mind is still there, but it is torpid. When the pressure is taken off, it comes out of this torpid state.

6. As the brain is the organ with which the thinking is done, we find that those animals that think much have larger brains than those that think but little. A frog thinks very little, and he has a small brain. An oyster thinks still less, and it would be hard to make out where his brain is. But such animals as the canary-bird, the dog, and the horse, that know so much, have brains of considerable size. Man has a larger brain in proportion to his body than any other animal, because he has to think so much more than other animals do. And men that think much have larger brains than the stupid and ignorant.

7. The mind in the infant is feeble, just like its body. It knows but little. But as the body grows, the mind grows also, and continually adds to its knowledge. I wish to show you now *how* it does this.

8. If you look at a very young infant, you will see that it does not know as yet how to use its muscles at all well. It moves its hands about awkwardly.

How does disease sometimes show that the mind resides in the brain? What is said of the size of the brain in different animals and in man? What is said of the mind of the infant?

It cannot even hold any thing in them. It does not use its eyes well. It cannot turn them so as to look directly at any thing, but they roll about in their sockets irregularly. It does not see any thing clearly.

9. The mind, you see, then, has to learn to use its instruments, the senses and the muscles. And the more it learns how to use them, the more knowledge it gets of the world around it. It learns, for example, to use the muscles and the nerves of touch, so as to know hard things from soft, rough from smooth, &c. In these ways it is continually learning more and more about the world of things with which it is surrounded.

10. In learning to use the senses, the mind makes one sense help another. Thus, the child sees a thing held before it, but as he reaches out his hands to touch it, it is plain that he does not know at first how far off it is. But after a while, by touching it again and again, he knows where it is. That is, by his sense of touch he *corrects* the report which the sense of sight makes to his mind. He makes many such corrections every day, and after awhile becomes able generally to estimate at what distance objects are the moment he looks at them. Just so the infant has to learn to use its ears as well as its eyes. It knows nothing at first of the direction of sound, or of the distance from which it comes.

What is said of the use which the infant makes of the muscles and the senses? What is said of its learning to use them? Illustrate the fact that the mind makes one sense help another in learning to use the senses?

11. It is a long training that the mind has to go through in learning to use the muscles. The hand of the infant is of little use at first, but after a time he learns to hold things in it. And from this the mind goes on to use the muscles of the hand more and more, till, in some cases, as in the skilful engraver or penman, it acquires wonderful skill in the movement of these muscles. The child learns to perform many different motions before he comes to try that very general motion of the muscles of the body, creeping. And then, in learning to walk, all the muscles that move the body, the head, the legs and the arms, are exercised in balancing movements, day after day, for a long time, before he can acquire such skill in the use of the muscles as to walk off readily and with scarcely thinking of what he is doing.

12. In learning to talk and sing, the mind learns how to use muscles, just as in learning to walk. These are nicer and more difficult operations, and so it takes the mind longer to learn them than to learn to use the muscles in walking. Especially is this true of learning to sing. The mind is obliged to practice a long time on the muscles of the larynx, in order to use them skilfully in singing.

13. In training the muscles of the voice in speaking and in singing, the ear acts as the teacher. It is only by the hearing that we know that we make the right sounds. When the child begins to talk, he makes various trials of the sounds that he wishes to utter, his

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What is said of the time required for learning to use the muscles? What is said of learning to talk and sing? Why does it take longer to learn to do these than to learn to walk?

ear all the time listening, that his mind may know when he utters them correctly. So, when one is learning to sing, the ear listens to inform the mind when the note is properly sounded. In learning both to talk and sing, the ear is thus continually correcting the mistakes which the mind makes in using the muscles of the voice.

14. So necessary is the ear in the training of the muscles of the voice, that these muscles are never used in a child that is born deaf. In almost all the deaf and dumb there is no defect in the organs of the voice. The apparatus is all there—the articulating parts, the tongue, palate, &c., the larynx with its vocal ligaments, and the muscles that tighten them, so that they may vibrate, and the muscles of the chest that force out the air to strike upon them. And the mind has its nerves running from the brain to all parts of the apparatus. But the mind does not work the apparatus, or play on the instrument, as we may say, simply because it has no guide in doing it. There being no hearing, the mind has no means of knowing when the right sound is uttered, and therefore it utters none. The deaf and dumb are dumb because they are deaf.

15. If a child, instead of being born deaf, becomes deaf while it is learning to talk, he will remember the motions of the muscles of the voice by which he uttered some words, the names of common objects, such as hat, watch, &c. He can therefore pronounce these words, but he does it very awkwardly, because there is no hearing to guide the voice.

What acts as the teacher in learning to talk and sing? Illustrate this. What is said of the deaf and dumb? What is said of children that become deaf and dumb while learning to talk?

16. I have thus told you how the mind uses the muscles of the body. It is a very complicated machinery that the mind works. There are over four hundred muscles in the body, and the mind works them by a multitude of nerves that go from the brain to them.

17. Observe, now, that the mind in most cases knows nothing about all this machinery of the muscles. Your mind wills that your hand be raised, and it is instantly done. You may not know what muscles do this, and if you do you cannot perform the motion any better than if you did not know. The anatomist that knows the names of all the muscles, and understands how they are arranged, cannot use them any better than those who know nothing about this. The skilful balancer would not be any more skilful, if he had all the knowledge which the anatomist has. The famous singer could not sing any better if he should know how the little muscles in his throat work in producing the different notes.

13. When man works any machinery that he has made, it is necessary that he should understand its various contrivances. Thus, the sailor cannot guide the ship unless he knows all about its rigging. But it is not so, as you have seen, with the machinery that the mind works in the body. The mind does not look at the hundreds of muscles that it works, as the sailor looks at the various ropes with which he man-

What is said of the muscular machinery that the mind works? How much does the mind know about this machinery? Could it work any better if it knew all about it? State the comparison given in regard to machinery made by man.

ages his vessel. And when it wishes to perform any motion, it is not obliged to consider what muscles it must put into action. It simply wills that the motion shall be done, and instantly something, we know not what, goes along a multitude of nerves to a multitude of muscular fibres, and they contract just enough to perform the motion.

19. For every different motion a different message, as we may call it, is sent along the nerves. If you raise your hand, a message is sent through the nerves to the muscles that do it. Now, if you raise it again, but in a little different manner, a little lower or higher, or a little more to one or the other side, a little different message is sent along the nerves to those muscles. And the same can be said of the muscles of any other part of the body. You see, then, that while any machinery made by man can perform but a few motions, this machinery of the muscles can perform motions of any variety.

20. I have already spoken of the variety of motion that the muscular machinery can perform, in the chapter on the muscles, § 12 and § 13, and therefore will not dwell on it here. For all this variety there is a corresponding variety in the messages or impressions sent from the mind to the muscles. Even when the muscles only vary in the *degree* of their action, for every different degree there must be a different message. Thus, if in playing on a piano, you press

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What is said of the different motions performed by muscles? Illustrate by referring to the hand. What is said of the great variety of muscular action. Illustrate this variety as produced by varying the *degree* and the *direction* of the action of muscles?

on the same key twice in the same way, except that you vary the degree of pressure, two different messages are sent to the muscles that make the pressure, telling them in each case how hard to press. Much more, then, must the messages of the mind to the muscles vary, when their action is not only varied in degree, but in *direction* also, as when the hand moves from one key to another in playing on the piano.

21. In the chapter on the Muscles you saw that generally many muscles act together in producing any motion. For the different motions of any part, then, there must be a vast variety of messages sent along the nerves of the muscles in that part. You can get some idea of this variety, if you move your hand about in as many different ways as you can think of, remembering what a number of muscles there is at work while you are doing this.

22. In estimating the variety of the messages sent to the muscles, you are to remember that a separate message is sent to every fibre of a muscle by its little nervous tube, as mentioned in § 9, in the chapter on the Nervous System. How wonderful it is, that in all this multitude of messages that are sent to the fibres of the muscles, there should commonly be no mistake in any of them. In every motion each fibre gets its message correctly, and acts in obedience to it. You will realize how wonderful this is, if you turn back to the chapter on the Muscles, and read again

What is said in §21 of the variety of messages sent by the nerves to the muscles of any part? What are you to remember in estimating this variety? What is very wonderful in regard to this?

all that I say there of the variety there is in the action of the muscles.

23. When the muscles in different parts of the body are at work at the same time, in some general movement, the variety of messages that go to and from the brain is inconceivably great. When one is walking, for example, the mind continually sends a multitude of messages to all the muscles that together perform this general motion of the machinery. At the same time there are messages going to the brain from some of the organs of the senses, perhaps from all of them. But the variety in the messages is more striking when different motions are performed in different parts of the body. Observe one who is playing on a parlor organ, and at the same time is singing. Messages are sent in this case to many different parts for different purposes—to the muscles of the foot that work the bellows—to the muscles of the arm and hand and fingers in playing on the keys—to the muscles of the eyes in moving them to look at the notes—to the muscles of the vocal ligaments in making the different notes—to the muscles of the throat, lips, &c., in articulating the sounds—and to the muscles of the chest in forcing out the air through the windpipe. While all this is going on, the ear is listening to discover if there be any error in the sounds, the eyes are looking at the notes, and the sense of touch is guiding the muscles of the hand in regulating the degree of pressure on the keys of the organ. That is, while messages

What is said of the variety of messages that go along the nerves when one is walking? In what cases is this variety most striking? Give the illustration.

are going *from* the mind with such rapidity and variety to the muscles of the foot, the hands, the eyes, the throat and the chest, messages are coming *to* the mind from the ears, the eyes and the fingers. The communications of the mind with the different parts of the body are in such a case numerous and complicated beyond conception.

24. I have thus shown you how the mind makes use of its instruments, the organs of the senses and the muscles. I have spoken of them as the machinery of the mind, and you have seen that these instruments contain mechanisms that are more perfect and beautiful than any that man ever constructed. You have seen that the body is mostly a collection of machinery for the mind to use, and that the purpose of those parts which the mind does not use is to build those which it does use. The object of one portion of the machinery of the mind, the organs of the senses, is, as you have seen, to enable it to gain a knowledge of the world around it. The object of the other portion of its machinery, the muscles, with the parts that they move, is to use this knowledge gained by the senses in making impressions upon the things and beings with which it is surrounded. It works with the muscles, and with them communicates its knowledge to others.

25. This machinery of the mind is fitted for our present state of being. But this life is short. This body, with all its ingenious and beautiful contrivances, is to be dwelt in and used by the mind but a short period of time. In the life which follows, its ever-

Give the summary in §24. What is said of the instruments which the mind will use in another life?

lasting life, it is to have, as the Bible tells us, a better, a glorified body. It will, therefore, have better instruments to use then than it has now, and so will be able both to know more and to do more than it can in its present state.

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3. Unity of design marks the series.
4. The use of initial letters only.
5. The fact that children delight in them.
6. Their cheapness.

The attention of teachers, whose range of subjects includes geography, is respectfully and particularly called to Mr. Olney's Geographical Works. These works, more especially the School Geography and Atlas, have been in use for several years, and so far as the publishers have been able to ascertain, it is the general testimony of teachers that the "Practical System of Modern Geography" is the best work for practical use that has ever appeared. But recent works have been put forth, claiming to be made upon superior principles, and modestly intimating that all previous standard works are so inferior in construction as to render them deservedly obsolete. Indeed it is claimed that there has been no advance in geographical text-books for many years, until suddenly a new Daniel has come to judgment. In looking carefully over the recent inprovements so boastfully claimed, we are unable to discover *any* which have not been substantially drawn from Olney's Geographies.

Mr. Olney commenced the plan of simplifying the first lesson and teaching a child by what is familiar to the exclusion of astronomy. He commenced the plan of having only those things represented on the maps which the pupil was required to learn. He originated the system of classification, and of showing the government, religion, &c., by symbols. He first adopted the system of carrying the pupil over the earth by means of the Atlas. His works first contained cuts in which the dress, architecture, animals, internal improvements, &c., of each country are grouped, so as to be seen at one view. His works first contained the world as known to the ancients, as an aid to Ancient History, and a synopsis of Physical Geography with maps. In short, we have seen no valuable feature in any geography which has not originally appeared in these works; and we think it not too much to claim that in many respects most other works are copies of these. We think that a *fair and candid examination* will show that Olney's Atlas is the largest, most systematic, and complete of any yet published, and that the Quarto and Modern School Geographies contain more matter, and that better arranged, than any similar works. The attention of teachers is again called to these works, and they are desired to test the claims here asserted.

TESTIMONIALS.

From President Humphreys, D. D., *Amherst College.*

Mr. J. Olney.—Dear Sir, I have examined both your improved School Atlas and Modern System of Geography with more than ordinary satisfaction. Your arrangement of topics appears to me better adapted to the comprehension of the child, and to follow more closely the order of nature, than any other elementary system of the kind with which I am acquainted. Instead of having to encounter the diagrams, problems, and definitions of Astromony as soon as he opens his Geography, the young learner is first presented with the elements of the science in their simplest and most attractive forms. His curiosity is of course awakened. That which would otherwise be regarded as an irksome task, is contemplated with pleasure. The opening mind exults in the exercise of its faculties, and in the ease with which it every day gathers new intellectual treasures. The constant use which you oblige the child to make of his Atlas, I consider of a great advantage, and the substitution of initials for the names of countries, mountains, rivers, &c., a valuable improvement. There is, moreover, a condensation of matter throughout, combined with a clearness and simplicity which cannot fail, I think, of being highly appreciated by all enlightened and judicious teachers. Your method of designating the length of the principal rivers is extremely simple and convenient.

From the Connecticut Mirror.

As an elementary work, we certainly never have seen any of the kind that will compare with it. Simplicity is its leading feature, and instruction its real object. It is adapted to the humblest capacity, and may be studied in connection with the Atlas, almost as advantageously by children as by those of a maturer age. We are not accustomed to speak in terms of praise of every new school-book which appears, for it is countenancing the practice of taxing parents, no matter how heavily, for the sake of *change.* But in the case of Mr. Olney's Geography, we are so well satisfied that it is just what is wanted in our common schools, that we really account it our *duty* to aid in introducing it.

I have long thought Olney's Geography and Atlas a *first-rate* school-book, and the publishers of it have certainly given to it an attractive appearance to the teacher and pupil. I have used it, I think, nearly ten years of my teaching, and *always* found the successive editions *reliable* for *accuracy*, and *well up to the times.*

M. F. Cowdery,
Supt. Schools, Sandusky.

Similar memorials have been received from the following gentlemen:

Salem Town, LL. D.	F. A. Brigham, Ill.
Pres. Lord, N. H.	E. P. Barrows, N. Y.
Pres. Bates, Vt.	P. Hardy, N. H.
Robert Vaux, Penn.	R. S. Howard, Mass.
M. L. Brown, N. Y.	E. Kingsbury, "
M S. Hawley, Mich.	E. Hall, Vt.
J. S. Dickson, Mich.	A. K. Slade, R. I.
N. Brittan, N. Y.	J. Alwood, N. Y.
J. N. Smith, Iowa.	J. Estabrook, Mich.
T. S. Bradley, Ohio.	A. D. Sturtevant, Ill.
A. D. Wright, "	A. G. Wilder, "
N. S. Scott, N. Y.	R. C. Corey, Ark.
Isaac Clufton, Ill.	C. B. Crumb, N. Y.

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