PHYSIOLOGY AND HYGIENE

TAUGHT OBJECTIVELY.

INTRODUCED BY

ELEMENTARY LESSONS ON SCIENCE.

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SUGGESTIVE, NOT EXHAUSTIVE.

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PREFACE.

This book is the direct outcome of work done in the schoolroom. It has been tested for years, both by the author and by other teachers whose work could easily be supervised.

It is objective in its methods, *wherever possible and practicable*, leads up from observations and experiments to theories and laws, and aims to teach as nature might teach a bright child under happy influences.

The so-called "New Education", which advocates objective teaching, has found numerous adversaries, because inexperienced teachers, full of idealistic views on the value of objective methods, have made shocking blunders in applying them in large classes. Some, for instance, have tried to teach classes of fifty or sixty pupils as they would a few bright children supplied with all modern appliances. But when, toward the end of the term or school year, principals or superintendents have asked for results, the misapplications of the teachers' methods have become painfully evident.

In order to satisfy the claims of both—the advocates of the principles of sound, objective teaching and the supervising educators looking for results—this book proceeds on the following plan: First, it either recalls to pupils former experiences or introduces them to new observations; second, it incites them to express the facts deduced in correct language; and third, it presents, for memorizing, a concise statement of the facts, laws, or theories in question.

To avoid an undue extension of the book, the introductory, methodical work required for each paragraph has been condensed into a few leading questions or statements; only in the first six paragraphs have the methods herein recommended been exemplified in all their fullness, in order to serve as a guide for the teacher.

It teaches Science in connection with Physiology and Hygiene. The latter two are the principal topics; the chapters on Science are auxiliary.

Before learning of respiration the pupil is taught to observe the properties of air (expansibility and pressure); before finishing this chapter, combustion is treated and the products of respiration and combustion compared. Similarly levers and bones, pumps and the heart, electric wires and the nerves, sound and the ear, light and the eye, are taught together. Chapters on water and heat precede the study of Physiology proper.

It is not a scientific book in the common sense of the word, that is, it does not commence with the basis or the elements of a scientific system in accordance with the present comprehensive ideas about the universe. The elements here presented are selected with a view to didactic or pedagogical principles, the foremost of which are: proceed from the easy to the difficult, from the simple to the compound, from the known to the unknown.

There are numerous excellent books written in the deductive, strictly scientific style and suited to the intellect of mature pupils. This book, however, is intended for children, who, for the first time, receive elementary lessons in natural sciences; together with t... ...ng, and arithmetic. Children of this age (11 to 14 yea... ... require the strictly logical, systematic lectures of the college or university professor. What they need is a live teacher able to interest them in the work, able to ask proper questions and elicit correct and complete answers, and a book containing the most important and most useful facts arranged in a manner facilitating reviews.

It is written in simple language, adapted to the understanding of children of average capacity.

Many books on physiology contain a great number of scientific terms that children learn with a great expenditure of energy and retain with difficulty. Whenever opportunity has offered, the pupil has been assured that mere names, dates, numbers, and unintelligible statements are worth less than nothing, burdening, as they do, the mental storehouse, obscuring the intelligence and weakening the energy.

It throws the main work on the pupil; the teacher's task is to guide and direct. Thus the pupil, learning through his own exertions, becomes interested in the work and strives for progress.

All children are eager for knowledge and desirous of exerting their faculties in the investigation of nature. They know they cannot do this without labor; they desire and need early and continued effort; nevertheless, they feel the need of guidance in their first attempts, and it is one of the most important duties of the teacher to save the waste of time in blundering into needless toils.

A suggestive, not an exhaustive treatment of the subject, has been the author's aim.

As a consequence, pupils using this book intelligently are likely to apply for themselves laws and theories they have learned to understand, and to classify facts which they know with those named in this book.

The subject matter is divided into paragraphs, in each of which the main thought or fact is expressed in concise language.

This allows teachers to omit those parts which they consider of minor importance, and to select the most suitable work for individual needs. At the same time it facilitates reviews.

The author would take this occasion to acknowledge most gratefully his indebtedness, for valuable assistance during the progress of the work, to: Miss Mary Maher, Miss Lutie Stearns, Mrs. E. Rissmann, Mr. Sanford A. Hooper, Mr. Wm. E. Anderson, and, especially, to Miss Julia A. Koerner, who has given much time to the correction of the proof and the designing of the illustrations.

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METHODICAL TREATMENT OF INTRODUCTORY LESSONS.

It will now be shown how to teach in accordance with the methods recommended in this book.

¶ 1. **USE OF THERMOMETER.** The teacher places on a suitable table an alcohol lamp, a tripod, a piece of wire netting, a flask, and a thermometer.

Teacher (holding up a flask). "What is this?"
Pupil. "That is a glass bottle."
T. "Is it such a bottle as you have at home?"
P. "It is a bottle made of thin glass."
T. "We call it a *flask*. What is this (holding up the lamp)?"
P. "That is an alcohol lamp."
T. "What are the parts of an alcohol lamp?" (Teacher assists by holding up the separate parts.)
P. "The parts of an alcohol lamp are a glass vessel, a wick of cotton, a wick holder, a cap or cover, and alcohol."
T. "What is this?"
P. "That is a three-legged iron stand, a tripod."
T. "This?"
P. "That is a piece of wire netting."
T. "What am I doing?"
P. "You pour water into the flask, you place the flask upon the wire netting, which rests upon the tripod, and put the alcohol lamp below."
T. "I want you to observe what happens when water is heated. You might have performed the same experiment in your kitchen. Why did I not use the same materials that are used there?"
P. "We can see the water in a flask better than in a kettle. Glass is transparent, iron is not."
T. "That you may know how warm the water is, I will place this thermometer inside." (See figure. The thermometer is thrust through a flat piece of cork, which rests lightly on the neck of the bottle.)
"What does the thermometer hanging there tell us?"
P. "That thermometer tells us how warm the room is."
T. "Does it tell how warm the wall, or the chair, or the floor is?"
P. "It does not; it tells us how warm the air in the room is."
T. "How do you know?"
P. "It is surrounded by air."
T. "What surrounds this thermometer?"
P. "Water surrounds it."
T. "At least it surrounds the lower part where you find the substance that indicates how warm anything is. When does a thermometer tell how warm the air is, and when does it tell how warm the water is?"
P. "A thermometer tells how warm the air is when it is surrounded by air; it tells how warm the water is when it is surrounded by water."
T. "You may say: A thermometer tells the *temperature* of the surrounding air, water, or other substances. By temperature we mean the degree of heat which a substance has."
"Write the words 'thermometer, temperature, degree', on the blackboard. Spell them."

While some of the pupils are engaged in writing and spelling these words, others are invited to come to the table and tell how many degrees the thermometer shows. Their attention is called to the fact that the eye must be at the same height as the top of the mercury in the thermometer is. The teacher must give plenty of time to the introductory exercises, in order that pupils may thoroughly understand how all the objects are used in combination.

¶ 2. **AIR IN WATER.** The lamp is lighted. Pupils are invited to come to the table, one by one, notice the rise of temperature and make the result of their observation known to the class.

T. "What change do you see in the water?"
P. "Bubbles appear at the bottom and sides, and rise to the surface."
T. "Of what do the bubbles consist?"
P. "Bubbles consist of air."
T. "What makes the bubbles appear?"
P. "The heat does."
T. "Then what does the water contain?"
P. "Water contains air, and the heat drives the air out."
T. "Why does air rise in water, why does it not sink there?"
P. "Air is lighter than water; water is heavier than air."
T. "Suppose there were no air in water, how would that affect the fishes?"
P. "They would die if there were no air in water."
T. "Which contains more air, cold or warm water?"
P. "Cold water contains more air than warm water, because heat drives the air out."
T. "Let somebody at home give you a cup of boiling water and place it where it will cool off. You will then have water like this, which I have prepared for you. How does it taste?"
P. "It tastes flat."
T. "What gives a fresh taste to water."
P. "Air does."
T. "See what a great quantity of air is driven out. How many degrees does the thermometer show?"

¶ 3. **VAPOR.**

T. "What is this?" (pointing to the upper part of the bottle.)
P. "That is moisture."
T. "Is moisture air or water?"
P. "Moisture is water."
T. "From what place did this moisture come?"
P. "This moisture came from the water below."
T. "Did the water run up there?"
P. "It cannot run up; water always runs down."
T. "But how came it up there?"
P. "It came up with the air."
T. "Can you see it coming up with the air?"
P. "We can not."
T. "What substance in this room cannot be seen?"
P. "Air cannot be seen."
T. "What do we call substances which cannot be seen?"
P. "Substances that cannot be seen are called **invisible**."
T. "As, for instance, what substance?"
P. "**Air** is invisible."
T. "What substance came up with the air?"
P. "Water came up with the air."
T. "As you cannot see this water, what kind of water must it be?"
P. "It must be invisible water."
T. "We call this invisible water **vapor.**"

¶ 4. **SINGING WATER.**

T. "Now, I want you to be very quiet, and listen to the water. What do you hear?"
P. "The water grows noisy; it is singing."
T. "And what do you see?"
P. "There are bubbles at the bottom of the bottle, which do not come to the surface, but disappear."
T. "You see the air rising to the surface in a great many small bubbles, which look almost like dust or smoke, but the large bubbles at the bottom look different. These bubbles cannot be air. What are they?"
P. "They consist of steam."
T. "Where is the water warmer, near the bottom, or near the surface?"
P. "The water is warmer near the bottom."
T. "Why?"
P. "Because it is nearer the fire."
T. "Where must the first steam bubbles appear?"

P. "Near the bottom."

T. "Into what water do the steam bubbles come when they rise?"

P. "They come into colder water."

T. "And the colder water changes the steam back to water. Where does the steam appear, and where does it disappear?"

P. "The steam appears near the bottom, in the warmer water, and disappears near the surface, in the colder water."

T. "Where does the water change into steam, and where does the steam change into water?"

P. "Near the bottom the water changes into steam; near the surface the steam changes into water."

T. "So the steam appears below, and disappears above. There is a conflict between the warm water below and the cold water above; the warm water will change into steam, and the cold water will not; therefore the noise.

I want you to watch the warm water in your kitchen, and tell me next time whether you heard it singing."

¶ 5. BOILING POINT.

T. "Now the steam bubbles grow larger, they rise higher, and the singing becomes louder. How warm is the water now?

After some time, the steam rises to the surface, and there are billows and waves. Now the whole mass of water is hot enough to change into steam, and you tell me that the thermometer shows 212 degrees.

We will leave it boiling, and after some time you may again notice how warm it is. It is always 212 degrees. It remains at 212 degrees as long as the water boils.

212 degrees is the temperature of boiling water. We call this temperature the boiling point of water. How is boiling water affected when the heat of the fire is increased?"

¶ 6. VAPOR IN BREATH.

T. "Does the air in this room contain vapor?"

P. "It does."

T. "How do you know?"

P. "We know it, because we breathe it out."

T. "If somebody should say that we do not breathe out vapor, how could you prove that we do? Can you show the water breathed out by you?"

P. "Yes, we can; when we breathe into our hands, we feel the moisture, and this moisture was contained in our breath."

T. "How can you quickly show the moisture in your breath to the whole class?"

P. "By breathing against the blackboard."

T. "One cold day in winter I heard a boy say that he had seen horses smoking. He said the smoke came from the nostrils of the horses. What did he mean?"

P. "The horses breathed out vapor, and the vapor changed to fog—not smoke—in the cold air."

T. "Correct. You see the fog escaping from the nostrils of horses, from your own nostrils, and from those of other animals during winter. In what countries might a person detect the presence of large animals by the fog they breathe out?"

P. "In cold countries."

T. "As, for instance, in King Williams Land. There the Esquimaux are able to detect the presence of reindeer at a distance of six miles. They see a cloud rising at a distance, a little cloud in the clear and cold atmosphere, and presently they know that this cloud arises from a herd of reindeer. Some Esquimaux are able to distinguish reindeer and musk-oxen by the fog or cloud rising from them, and this cloud enables them to pursue the path of the animals without looking at their tracks.

What other large animal, living in the ocean, is detected by the water and fog thrown out?"

P. "The whale."

T. "High up on the mast of a whaling vessel, in a place called the crows-nest, is a sailor always watching for the little fountain of water and fog arising from the head of a whale. As soon as he sees this, he calls "spout!" boats are made ready, and the hunting commences in earnest. Thus the reindeer, the musk-ox, and the whale are detected by their breath."

P. "Near the bottom."

T. "Into what water do the steam bubbles come when they rise?"

P. "They come into colder water."

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ERRATA.

Page 1, ¶ 2, line 7, read *retains* for may contain;
" 3, " 12, " 1, " *retains* for may contain;
" 4, " 15, " 3, " *it* for is;
" 8, " 26, " 5, " *river water* for rain water;
" 8, " 27, " 12, " *remains* for remain;
" 16, " 47, last line, insert "*the*" between "of" and "cold";
" 20, " 55, line 5, omit "*a*" between "what" and "large";
" 25, " 67, " 11, read *globes* for tubes;
" 37, " 91, " 10, " *than* for then;
" 43, " 104, " 10, *omit* the question;
" 71, " 161, " 9, read *exclusively* for conclusively;
" 113, " 235, last line, read *pictures* for picures.

ELEMENTARY SCIENCE AND PHYSIOLOGY.

CHAPTER I.

WATER.

SECTION I.

VAPOR, STEAM, FOG.

1. USE OF THE THERMOMETER. A Thermometer shows the temperature of the surrounding air, water and other substances.

If we wish to know how warm the air in a room is, we look at a thermometer kept in the room. It may tell us that the air has a temperature of 60 or 70 degrees. The degree of heat in the air is called its temperature.

The temperature of water is the number of degrees which a thermometer shows when placed in it.

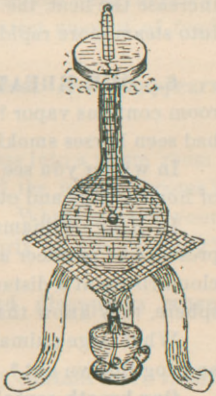

Fig. 1.

2. AIR IN WATER. Describe Fig. 1. What change do you see in the water after the lamp is lighted ? What causes the bubbles to appear ? Of what do the bubbles consist ?

WATER contains air. Heat drives out the air (expels it). Cold water may contain more air than warm water. Cold water containing no air tastes flat or insipid.

3. VAPOR. When the water is heated, the upper part of the flask grows wet, or is covered with moisture. Whence does this moisture come ? Can you see it coming up ? Where was it before it settled on the flask ?

VAPOR is invisible water forming part of the air.

A bottle half filled with water contains vapor in the other half. This vapor cannot be seen.

4. SINGING WATER. Where do the first steam bubbles appear? Why? Where do they disappear? Why? Into what does the water near the bottom change? Into what does the steam change when it comes near the surface?

Water produces a singing noise when the lower portions are warm enough to change into steam and the upper portions are not.

5. BOILING POINT. When the heating is continued, the steam-bubbles grow larger and rise higher. At last they rise to the surface, and there are billows and waves.

212 degrees is the temperature of boiling water. This temperature is called the boiling point of water.

The temperature of boiling water does not change. If we increase the heat, the water will boil more vigorously and change into steam more rapidly.

6. OUR BREATH. How can you prove that the air in this room contains vapor? One cold day in winter a boy said that he had seen horses smoking. What did he mean?

In winter you see fog passing from your nostrils and from those of horses, dogs and other animals.

In King Williams Land the Esquimaux are able to detect the presence of reindeer at a distance of six miles. When they see a cloud rising at a distance, a little cloud in a clear and cold atmosphere, they know that it rises from a herd of reindeer.

What large animal living in the ocean is detected by the water and fog thrown out?

Our breath contains vapor. Some of this vapor changes into moisture when it touches a cold object and to fog when in cold air.

7. STEAM. Fill a flask half with water and boil it. What is above the boiling water? Is steam visible or invisible?

Steam and vapor are invisible and aeriform.

Aeriform substances are substances having the form of air.

8. STEAM AND FOG. What do you see above the opening of a bottle or kettle containing boiling water? Does this fog remain visible? What becomes of it? What change do you observe in the fog that rises from the steam-escape of locomotives, steam-vessels or fire-engines? or from the chimneys of houses in winter?

Steam changes into fog when it enters the atmosphere; fog changes into vapor in clear air.

9. STEAM AND VAPOR. What qualities are common to steam and vapor? What difference is there between the two?

Steam rises from boiling water; vapor rises from water not boiling.

Steam and vapor are essentially the same, both being aeriform water. Steam is hot, vapor is cold. Vapor is the aeriform water that forms part of the atmosphere.

10. FOG. Sometimes fog collects in enormous masses, fills the air as far as we can see, and surrounds us everywhere. It gathers in the meadows as if great masses of smoke were collected. At what times of the day do you see the greatest amount of fog? At what times during the year?

Fog appears when the air grows colder and disappears when it grows warmer.

11. MOISTURE. Bring a cold, dry glass into a warm room. What change do you observe? Whence did the moisture come? What causes vapor to change into moisture? What parts of your sleeping room are covered with moisture early in the morning? Explain.

Moisture appears on cold objects and disappears when they grow warm.

12. VAPOR AND AIR. Warm air may contain more vapor than cold air.

We seldom see fog when the air is very warm because the heat changes the fog into vapor, and warm air may contain a great amount of vapor.

13. FOG AND CLOUDS. To learn the relation between fog and clouds, we should observe the atmosphere in mountainous countries or hear what is said about them by persons who have gone up in a balloon. The moment a rising balloon seems to disappear in a cloud, the persons in it find themselves surrounded by fog.

A cloud consists of fog high up in the air. Fog is a cloud near the surface of the earth.

14. RAIN. As long as the particles of fog are few and small, they float in the air as dust does—the slightest wind carries them along. But when they increase in size and number, and there is not much wind, they will meet, form drops, and fall.

Rain is caused by increased fogginess.

SECTION II.

THE CIRCULATION OF WATER.

15. SOLUTIONS. Prepare a clear solution of salt-water and ask a school-mate of yours what it is. If he is thoughtless or ignorant, he will call is water, because he cannot see the salt. What must he do to ascertain the nature of the liquid? What is a liquid called in which something is dissolved? Sugar, salt, saltpeter, alum, slaked lime, potash, green vitriol and blue vitriol are some of the substances that dissolve in water. Most of these solutions can not be distinguished by their looks, but may be, by their taste.

A solution of a white substance is transparent, that of a blue substance, bluish.

16. TO DISSOLVE AND TO MELT. Name substances that melt. What is needed to melt a substance? What is needed to dissolve a substance? Does sugar dissolve or melt in coffee?

To dissolve means to unite with a liquid; to melt means to become liquid by heat.

17. SATURATION. What will take place if we take too much blue vitriol, or too much salt? We may help the substance dissolve by shaking or stirring the water, but at last we must give it up, as the water becomes completely filled with the substance.

A liquid is saturated with a substance when it can not dissolve any more of it.

18. EVAPORATION. How can I change a glass of water to vapor (not to steam) before school closes to-day? Instead of "change to vapor" we may use the word "evaporate." Where does water evaporate more quickly—in an open bottle or on the floor? In what kind of weather does the washing dry quickly? When do wet sidewalks dry quickly? Name three causes of quick evaporation.

Water evaporates quickly, when it has a great surface, when it is exposed to wind, or when the air is warm and dry.

For the next lesson you may prepare solutions of salt, alum, and blue vitriol, put them in flat dishes, and keep them open in a moderately warm place. We will see what becomes of them.

19. CRYSTALLIZATION. What do you see in the three dishes in which we had the solutions of salt, alum and blue vitriol? Compare the little regular bodies with each other. Would you recognize the little bodies of salt and alum, if they were brought to you from another place? Look at the table salt, which was obtained from the grocery. Do you recognize the form of the little bodies which we obtained by evaporation?

Crystals are the regular forms that substances tend to assume when changing into solids. Crystallization is the process by which a substance assumes the form of crystals.

The more slowly crystallization proceeds, the larger will the crystals become. Druggists sometimes exhibit beautiful large crystals of colored salts. Large mineral collections also contain a variety of fine crystals, such as rock crystal, topaz, ruby, emerald, sapphire, amethyst, diamond, etc. In winter you may see beautiful crystals in many places. They cover the windows; they fall from the sky; they hang on boughs and branches, and form pretty coverings on exposed metal. Rivers and lakes are even full of them. If you measure the angles formed by the lines of these crystals, you will find them to be of the same size

Fig. 2.
SNOW CRYSTALS.

always; they never show a right angle, only such angles as occur in a regular hexagon and a regular triangle.

20. DISTILLATION. Distillation is the process of separating a liquid from substances held in solution, by changing the liquid into steam and the steam into a liquid.

The glass vessel *a* is called a retort; the glass vessel *b*, a receiver. The water in *a* is changed into steam. The steam passing into *b* is

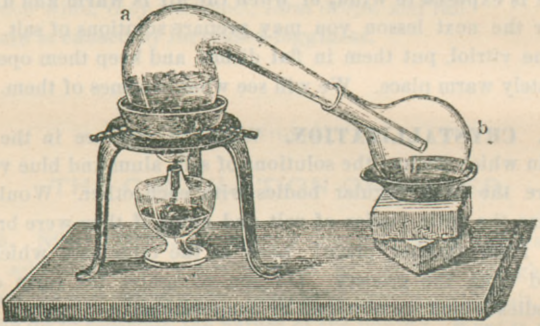

Fig. 3.

cooled off by means of cold water and changes back into water. Water thus obtained is called distilled water. Shorten the definition of distillation by using the words evaporation (change of a liquid to steam or vapor) and condensation (change of steam or vapor to a liquid).

21. DISTILLED WATER is used by druggists in the preparation of medicines, which are often solutions of certain substances. Why do not the druggists use common water, such as we get from a river or lake? What makes this water impure?

Distilled water contains no substances in solution; drinking water usually does.

22. RAIN-WATER. Compare the appearance of rain-water with that of our drinking water. What makes it impure? How can we purify it? May druggists substitute filtered rain-water for distilled water? Why is it that rain-water is free from dissolved substances, while the water of rivers and lakes is not?

Rain-water is condensed vapor; distilled water is condensed steam.

23. SPRINGS. What becomes of the rain-water that falls upon the surface of the earth? Does it remain in the ground? Where are there the greater number of springs, in level or in hilly places? Are they in low places or in high places?

Springs are streams of water issuing from the ground.

How does spring-water taste? Some spring-water is called **hard water;** it contains lime, gypsum, and other substances. Where did these substances enter the water?

24. WELLS. Describe a well that you have seen. On what does it depend whether the well-water contains dissolved substances or not? Many times it has happened that persons have been poisoned by drinking well-water, though no one had purposely thrown poison into the well. Many fatal cases of typhoid fever are occasioned in this way. How this may happen the accompanying figure, **which represents facts,** will tell. Describe it.

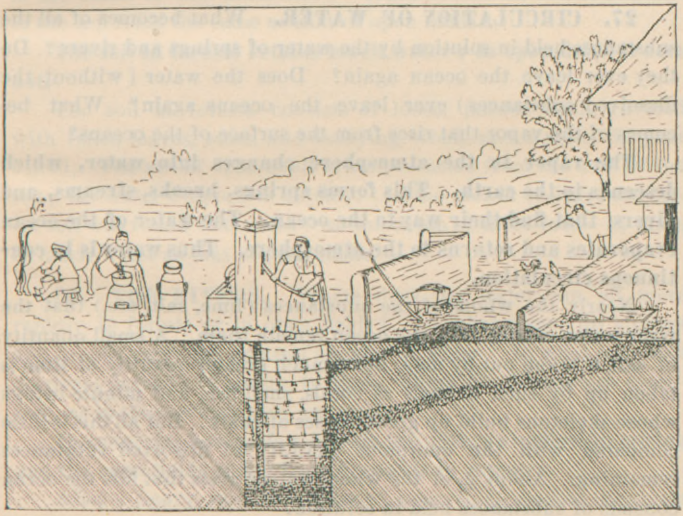

Fig. 4.

The lesson to be learned from this picture is, that every dairy furnishing milk for sale, ought, by law, to be under sanitary inspection. Not long ago a well was found in a cemetery, in close proximity to the ground in which dead bodies were deposited.

The water in wells in the neighborhood of decaying animal substances is poisonous.

25. RIVERS AND LAKES. What becomes of the water of springs? Whence does all the water of rivers and lakes come? At what times are the rivers low? When do rivers overflow?

All the water of rivers and lakes descends from the atmosphere.

26. SUBSTANCES DISSOLVED IN RIVER-WATER. Suppose there is a great quantity of salt not far below the surface. What kind of river-water may you expect in the neighborhood? Give a similar instance.

Salt, lime, and other substances dissolved in rain-water are obtained from the soil through which the water soaks before it enters the river.

27. CIRCULATION OF WATER. What becomes of all the substances held in solution by the water of springs and rivers? Do they ever leave the ocean again? Does the water (without the dissolved substances) ever leave the oceans again? What becomes of the vapor that rises from the surface of the oceans?

The vapor in the atmosphere changes into water, which descends to the earth. This forms springs, brooks, streams, and rivers, that find their way to the ocean. The water of the ocean evaporates and returns to the atmosphere. Thus water is in continuous circulation.

Nearly the whole of the substances (lime, salt, etc.) that the river-water carries into the ocean remain there. A small quantity of **salt** is taken out by men, but a much greater quantity of **lime** is taken up by such animals as corals, shell-fish, and minute beings whose skeletons build up great masses of chalk. But all this is little compared with the enormous quantity of dissolved substances remaining. About $\frac{1}{30}$ of the whole watery mass that fills the ocean consists of substances held in solution.

SECTION III.

THE VALUE OF FORESTS.

28. FORESTS AND RAIN. What changes occur in countries in which the amount of rain becomes less from year to year? How does this affect farmers? How the inhabitants of cities?

Countries with few forests have but little rain.

In former years the forests of Spain, Greece, France, Palestine, Egypt, Switzerland, and other countries covered more ground than they do now. The disappearance of forests was accompanied by the disappearance of rain. The greater the forests that were destroyed, the greater were the droughts in the countries thus made bare. Some states in the Union are having this experience.

29. THE SOIL. It is not difficult to see why the amount of rain must depend upon the extent of forests. You have been in forests in summer — in the months of July and August. How did you find the ground, as compared with that of open fields? What is the cause of this difference? What covers the soil of forests? Is the soil itself the same as that of open fields?

The soil in forests retains much water; in open fields it does not.

The soil in forests consists of loose, porous earth, covered with fallen leaves, moss, and decaying wood, and is moist the year round. The soil of open fields is not protected from the heat of the sun; the water evaporates quickly. In the month of July, the forest soil was found to contain — to the depth of three feet — 3½ times as much water as that of open fields.

30. THE RIVERS. Where does the water run off more rapidly, in forests or in open fields? In what season do springs and brooks carry the greatest amount of water? In what countries do rivers overflow in spring, in those where the forests are extensive, or in those where they are scarce?

In countries having few forests the rivers overflow in spring and the open fields suffer from droughts in summer.

After a heavy rain the water of open fields reaches the rivers in a very little while. The highest water-mark of the Seine in France is at present thirty feet above the lowest, while in former centuries there was hardly any difference between the two. The

Ohio sometimes becomes so high that hundreds of people lose their property or their lives.

31. FORMATION OF CLOUDS. The water contained in the soil of forests enters the roots of the trees and ascends the trunks and branches to the leaves, where it evaporates. The vapor rising from forests forms clouds.

Without forests, rivers overflow and rains become scarce. With forests, rivers keep their height the year round, and there is sufficient rain to make the crops grow.

This is not the only benefit forests confer. They equalize the temperature; they protect the country from excessive heat; they break the power of hurricanes and cyclones, and protect the valleys of mountainous countries from avalanches and earth-slides.

CHAPTER II.

HEAT.

SECTION I.

RADIATION.

32. HOW ROOMS ARE HEATED. The amount of heat varies at different times and places. Sometimes a place is warm, sometimes it is cold. This room was colder last night than it is now. Whence did the heat come into this room?

We are sitting at different distances from the stove. Do all of us receive the same amount of heat? How do we protect ourselves from too much heat? How do ladies walking in the sunshine protect themselves from the light and heat of the sun? What similarity is there between a parasol and a screen?

Rooms receive heat from the stove and from the sun.

33. RAYS OF HEAT. How does the sun heat the room? What are those brilliant lines sent by the sun called? How do the rays sent by the stove differ from the rays sent by the sun?

Rays of heat are straight lines in which the heat moves. The rays of the sun contain heat and light; those of the stove contain heat only.

34. HEAT OF OBJECTS. Objects are distinguished as hot, warm, or cold. What objects are called hot? What, warm? What, cold? Sometimes one person calls a room cold, while another at the same time pronounces it to be very warm. How is this difference of opinion caused? What is the real difference between a warm and a cold body? May a cold object become colder? What does an object lose when it becomes colder?

All objects have heat, because all objects may become colder. They become colder by losing heat. Hot objects have much heat; warm objects, some; cold objects, little.

There is only the difference of more and less among hot, warm, and cold objects. It is about the same as the difference between great and small things. Both possess size or volume, the one much, the other little.

35. EXCHANGE OF RAYS. We have learned that stoves send out rays of heat. At what times do they send them out? Is it probable that they do this at all times? May they grow colder at all times? There is no reason to doubt that stoves, like all other objects, throw out rays of heat at all times. Our own bodies throw out rays of heat. Perhaps you have felt the heat given out by persons near you, or have seen how the ice on a window-pane is affected by a finger or hand in its neighborhood.

All objects throw out rays of heat. A hot object throws out more heat than a warm object; a warm object more than a cold object. All objects receive rays of heat.

The more rays an object throws out, the colder it grows. The more rays an object receives, the warmer it grows. If an object receives more rays of heat than it throws out, it grows warmer; if it receives fewer rays of heat than it throws out, it grows colder.

To radiate is to throw out rays; to absorb is to take up rays. Radiation is the process of radiating; absorption is the process of absorbing.

36. REFLECTION OF RAYS. Hold a piece of glass before the face, and go near a fire. What do you observe? Why is your face not struck by the radiated heat of the fire? Feel the glass. Is it very warm? Did the glass take in (absorb) all the rays?

Some of the rays falling on objects are absorbed; some are reflected.

To reflect is to throw back. Rays of heat are reflected from glass as marbles rebound when thrown against a wall.

37. INFLUENCE OF CLOUDS. Does our earth radiate heat or does it keep all the heat that it receives from the sun? Where do the rays radiated by the earth go? How is the earth affected by the radiation of heat? At what times of the day is the cold resulting from radiation felt most? Why?

Sometimes we have clear nights, sometimes cloudy nights. Which are generally colder? What have the clouds to do with the rays of heat sent forth from the ground below?

Clouds reflect the heat radiated by the earth.

38. DEW AND FROST. What do we sometimes notice early in the morning, when we look at the grass and other plants? At what times does the dew cover plants and other objects, when the air is clear or when it is cloudy? When do plants lose more heat, in clear air or in cloudy air? At what times is the air surrounding the plants colder, when the sky is clear or when it is full of clouds? Which air is unable to hold much moisture, the cold or the warm?

Grass, leaves, wooden sidewalks, and iron railings radiate a great deal of heat during clear nights. The air surrounding them grows cold and is unable to hold much vapor. The vapor thrown out (ejected) by the air condenses and covers the objects in the form of dew or frost.

Grass directly under benches or tables is not usually covered with dew; the lower surface of the benches and tables has reflected the rays of heat. There is no dew or frost when the sky is cloudy. When does dew change to frost?

Dew is beneficial to the growth of plants, as it comes when the weather is clear and rain is scarce. There are countries, for instance, those west of the Andes in South America, where vegetation would not exist if it were not for the dew. Name those countries.

39. INSULAR AND CONTINENTAL CLIMATE. There is a great difference between the climate of islands and that of regions far from oceans, as, for instance, England and the North Central Plain of America. Where is the air generally clearer? What substance impairs the clearness of the air? Where does the greater number of fogs occur?

Countries in which the air is usually clear have a changeable climate ; countries in which the air is usually full of vapor and fog, have a temperate climate, without extremes of heat or cold. The former climate is called continental, the latter, insular.

The rays of the sun do not freely penetrate the moist air of islands ; they cannot heat the ground excessively, and the summers are moderately warm. The rays of the earth cannot pass freely beyond the air ; the ground does not cool off excessively, and the winters are mild.

In countries having a dry, clear atmosphere, the heat of the sun is not checked, the ground becomes immoderately warm and the summers are torrid. The heat of the earth radiates without much obstruction, the ground cools off excessively, and the winters are very cold.

In some parts of Australia, where the air is excessively dry, the daily range of temperature is sometimes from 70 to 80 degrees. In the desert of Sahara, where "the ground is fire and the wind is flame" the nights are often cold enough to cause a thin sheet of ice to form on the surface of water.

SECTION II.

EXPANSION.

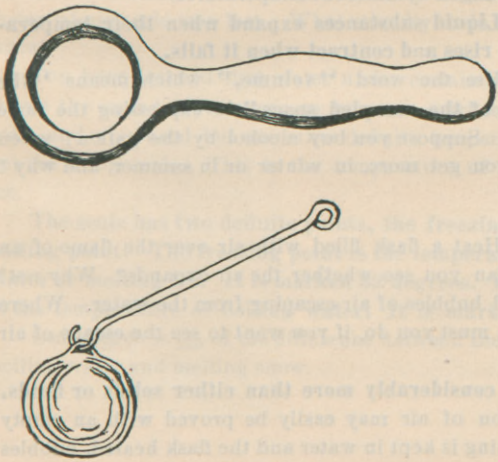

Fig 5.

40. IRON. Examine the effect of heat upon an iron ball just large enough to slip through a metal ring. (See Fig. 5.) Heat the ball over the flame of an alcohol lamp. What effect has the heat upon the iron ? Let cold water run over the ball. How is it changed ?

Iron is expanded by heat and contracted by cold.

In what season are things made of iron large? In what, small? How are nails in stone walls affected by heat and cold?

41. SOLIDS. Not only iron, but also copper, silver, lead, gold, platinum, and all other metals are expanded by heat, and contracted by cold. What is the cause of the cracks or fissures sometimes seen in the ice of skating rinks and rivers?

All solid substances expand while growing warmer and contract while growing colder.

A thick piece of glass held over a flame cracks because the heat does not readily pass through the glass, and the lower surface expands while the upper does not. A thin piece of glass held over a flame does not crack, because the upper surface has nearly the same temperature as the lower.

42. LIQUIDS. Connect a glass tube by means of a perforated cork with the neck of a flask completely filled with water. (See Fig. 6.) Mark the height at which the water stands, and heat the flask over an alcohol lamp. What do you observe? Surround the flask with very cold water. What do you expect to see now? State how the water is changed by different temperatures.

Fig. 6.

Liquid substances expand when their temperature rises and contract when it falls.

Use the word **"volume,"** which means **"the size of the occupied space"** in expressing the same law. Suppose you buy alcohol by the gallon; when do you get more, in winter or in summer, and why?

43. AIR. Heat a flask filled with air over the flame of an alcohol lamp. Can you see whether the air expands? Why not? Once you noticed bubbles of air escaping from the water. Where was that? What must you do, if you want to see the escape of air from the flask?

Air expands considerably more than either solids or fluids.

The expansion of air may easily be proved with an empty flask. If its opening is kept in water and the flask heated, bubbles will be found to escape from it. What happens if the lamp is taken away and the flask remains in its place?

Why does wood make a crackling noise after it becomes heated? What makes chestnuts jump off the pan, when they are roasted?

44. THE THERMOMETER. What three parts has a thermometer? Describe the glass-tube. What fluids are used? What causes the fluid to rise or to fall? Why must there be a globe or bulb at the lower end of the tube? Why is the upper end of the tube closed?

A thermometer consists of a glass tube, a fluid, and a scale. The tube has the same width throughout, is closed at the upper end, and is connected with a globe at the lower. The fluid is usually mercury. The scale consists of a series of numbers.

Sometimes colored alcohol is used instead of mercury.

45. THE SCALE. Suppose you have a thermometer whose scale is lost. How could you restore it with the help of another? How many times would you have to compare the two thermometers and mark the height of the mercury in the incomplete one?

But suppose you could not get hold of another thermometer, or were, like Robinson Crusoe, on a desolate island with a thermometer whose scale was lost. What would you do to prepare a new scale?

You have learned that water under certain conditions always shows the same temperature; so you can mark **one** point of the scale and you need but one other definite temperature in order to get the whole scale. This is the temperature of melting snow or ice.

The scale has two definite points, the freezing point and the boiling point. The freezing point is the temperature of freezing water or melting ice. It is marked 32 degrees. The boiling point is the temperature of boiling water. It is marked 212 degrees.

One degree is $\frac{1}{180}$ of the difference between the temperatures of boiling water and melting snow.

SECTION III.

CONVECTION.

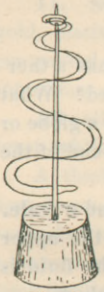

Fig. 7.

46. CONVECTION IN AIR. What is represented by Fig. 7? How can you make such a piece of paper revolve on its axis? Is there a difference in the motion of the paper, when blown at from above or from below? Hold the paper above a heated stove or a warm pipe. Explain the motion. How does the heat cause the air to rise? What takes the place of the air rising from the stove? Show this in a drawing.

Convection is the transmission of heat by means of currents. The air above a hot stove (or steam-pipe) rises, because the heat expands it and makes it lighter than the surrounding air. It ascends to the ceiling, where it spreads, cools off, and descends to the stove.

The air in heated rooms is in constant motion. There are upward currents of warm air and downward currents of cold air. Describe how a furnace heats rooms.

47. WINDS. Open the door of your room slightly and place a lighted candle in the opening, first near the bottom, then near the top and lastly in the middle. What do you notice? What pushes the flame in different directions? Where do you feel the draughts when a door leading to a cold hall is opened, at the head or at the feet?

Wind is air in motion. An open connection between a cold space and a warm space produces a cold current entering the lower part of the warm space, and a warm current entering the upper part of cold space.

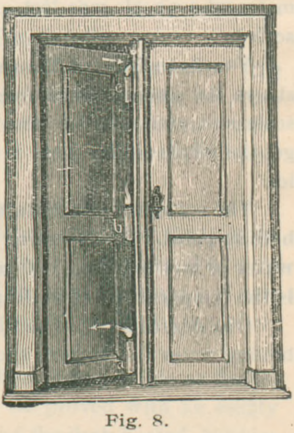

Fig. 8.

Fig. 9.

48. CONVECTION IN WATER. Put sawdust or indigo into a flask filled with water and heat the water by means of an alcohol lamp. What do you observe? (See Fig. 9.) What causes the water to move in this way? What is accomplished by this motion? Fill a test tube with water and hold its upper part in the flame of an alcohol lamp. (See Fig. 10.) **Water heated from below shows convection; water heated from above does not.**

Fig. 10.

SECTION IV.

CONDUCTION.

49. PROTECTION FROM COLD. As winters are quite severe in the northern part of the United States, the people use various means to protect themselves and their property from the cold. Name some of these means of protection. Name substances we use to keep things warm. Which of these substances are warmer than their surroundings? Describe how a hot-bed is made and how it works. Does the manure used in a hot-bed change while it is warm? Does fuel change while it heats? Does fur change while it keeps our bodies warm?

Suppose you feel both surfaces of a fur coat worn by a person in winter. Is the outer surface just as warm as the inner? What makes the inner surface of the coat warm? Does the fur coat produce heat like fuel, which burns, or manure, which crumbles to pieces? If it does not produce heat, how can it keep us warm?

To keep things warm we use fuel, clothes, fur, straw, manure, etc.

Burning fuel and decaying manure keep their surroundings warm, because they are warmer than those; **they produce heat.** Fur, clothes and straw are not warmer than their surroundings;

they do not produce heat. The former **change** while they produce heat; the latter do **not change** while they keep things warm.

50. MAMMALS. What animals yield the best fur? In what climate do these animals live? What benefit do they derive from their fur? Of what does fur consist?

Animals having hair in the skin are called mammals. Our blood, and that of all other mammals, has a temperature of about 99 degrees. If, from any cause the temperature rises or falls a few degrees, disease or death is the consequence. What is the disease when the blood becomes too warm? When it becomes too cold? If we had no means of protecting ourselves from the cold we should die. Is the same true of all animals living in the Frigid Zone? Can any mammal that is not very well protected from the cold live in the Frigid Zone? Is the whale a mammal or a fish, and why? How is it protected from the coldness of the surrounding water?

Mammals are warm-blooded animals having hair in the skin. Their blood has a temperature of about 99 degrees. They are protected from the cold by fur or fat, or both.

Seals, otters, beavers, foxes, bears, reindeer, musk-oxen and other mammals living in a cold climate yield the best fur.

51. BIRDS. What birds live in cold climates? What is the difference between mammals and birds? How are geese, ducks, and gulls protected? How penguins and auks? Does the great amount of fat in the bodies of the latter prevent them from flying? How do their wings look?

Birds are warm-blooded animals covered with feathers. Their blood has a temperature of 100 to 104 degrees. They are protected from the cold by feathers or fat, or by both.

52. OTHER ANIMALS. All animals need protection from cold and die when their blood grows colder than water changing to ice.

Reptiles and amphibians protect themselves by burrowing into the earth or mud. Fish are protected by the ice at the surface. Flies live in warm rooms or hide in cow-sheds and stables, between straw and manure; fallen leaves in the woods protect beetles, spiders, centipedes, wood-lice, caterpillars and others; earth worms go deep below the surface; mosquitoes hide in mud; bees crowd together and the heat of their bodies is generally sufficient to keep the temperature in the hive at about 80 degrees.

53. CONDUCTORS. Poor conductors are those substances which do not allow the heat to pass through them; good conductors are those which allow the heat to pass.

Fur, hair, feathers, fat, straw, wool, cotton, linen, wood, glass and paper are poor conductors; metals are good conductors. Water is a poor conductor, because it may be heated at one place and remain cold at another (see ¶ 48). Air is a poor conductor, and may be used to protect us from the cold. (Notice this in the case of double windows, doors or walls, and air between our clothes.)

Suppose we put a piece of ice into a feather bed, or wrap a woolen sheet about it. Will it melt or remain solid, and why?

CHAPTER III.

DIGESTION.

SECTION I.

INTRODUCTION.

54. OUR WEIGHT. Why must we eat and drink? What would be the consequence if we should not eat or drink for a week or a fortnight? What do you call such a death? How does a starved person look? How does a person change in appearance when he does not eat or drink for three days? How does his weight change during that time? In what way could he regain his weight?

The weight of a person increases during his meals and decreases in the times between his meals.

The loss of weight is caused by loss of substance. The body is constantly losing some of its substance.

55. WHY THE WEIGHT OF THE BODY CHANGES. Since the loss of substance is continuous, it must be caused by some continuous action or movement of the body. Try to find this movement. Sit quietly, do not speak or think of anything else, but observe attentively what a **large** part of your body is moving. Try to stop these movements. Do not breathe for five minutes. Can you do it? Do you breathe while you are asleep? Are there any persons who can stop breathing for an hour or so?

We have now learned two facts: first, we continually lose some of the substance of our bodies; second, we are continually breathing. The coincidence of these two facts suggests the thought that they belong together, that the loss of substance is **caused** by breathing.

What two opposite actions do you perform while you are breathing? Is the air taken in the same as that breathed out?

We lose weight because we breathe out more air than we breathe in. We must eat and drink to make up for the loss of substance caused by breathing.

It follows that our food changes to the substance that we lose by breathing—**changes to air.** This is a wonderful, nevertheless true fact; most (not all) of the food we eat and drink is finally changed into air.

56. THE COURSE OF THE FOOD. The first place to which the food is taken is the mouth. From here it moves to the stomach, then enters the intestines, and from the intestines is sent through the whole body till it finally changes to the air that we breathe out.

Our work will be to follow the food in its course, learn what **changes** it undergoes everywhere, **by what means** the changes are made and how we may **help** or **hinder** the changes. The knowledge of all this is **useful,** because it teaches us how to remain healthy. Ignorant persons become the victims of humbugs and quacks.

57. ORGANS. The tongue, the teeth, and the stomach are organs. Name the organs of plants. Animals and plants have organs, while stones have not. Stones consist of parts, but these parts are not called organs.

Organs are parts that perform functions. Animals and plants are organisms or organized beings, while stones are inorganic substances.

Functions are actions peculiar to organs. Name the functions of some organs of animals and plants. It is a very interesting and important work to investigate the functions.

58. THE MOUTH. The parts of the mouth are the lips (upper and lower), cheeks (right and left), teeth (upper and lower), jaws (upper and lower), tongue, palate.

The lips are at the entrance of the mouth—one above, one below; the cheeks are at its sides; the jaws are the bones covered by the soft parts of the mouth; the teeth are partly in the jaws, partly above or below them; the tongue is in the middle of the mouth; the palate is at its upper end. For what are these organs used, or what actions are assisted by them?

SECTION II.

THE TEETH.

59. KINDS. Examine a collection of human teeth.* How do they look and feel? Are they all of the same form? How many have a single root and how many have more than one root? How

Fig. 11 *a.*

Fig. 11 *b.*

Fig. 11 *c.*

many have a cutting edge, and how many are pointed at both ends? Into how many classes may we separate the thirty-two teeth properly, and how many belong to each class?

A full-grown person who has lost none of his teeth, usually has thirty-two of them—eight cutting teeth (incisors), four eye

* A collection of teeth may be obtained from an obliging dentist.

teeth (canines), and twenty grinding teeth (premolars and molars).

The cutting teeth have single roots and sharp cutting crowns; the eye teeth have single roots and pointed crowns; the grinding teeth have more than one root and round crowns.

60. USE. Why would it not be just as well, if all our teeth were of the same size and form? What work have they to perform when, for instance, you eat an apple? Are these two actions performed by the same teeth? What is the use of the eye teeth?

Let us compare our teeth with instruments used for similar purposes. Biting is similar to cutting. What instruments are used for cutting? Are our cutting teeth similar to knives or scissors, and why? Close and open your mouth several times and observe how the cutting teeth move. Do the grinding teeth move in a similar way, when you open and close your mouth? How do the grinding teeth move when you chew? What tools or instruments move in the same way?

The cutting teeth are used to cut off pieces of food—they resemble a pair of scissors; the eye teeth are used to fasten themselves into pieces of food—they resemble nails; the grinders are used to grind the food—they resemble mill-stones.

Rabbits, squirrels, and other gnawing animals have large cutting-teeth, which they use for gnawing; cats and other flesh-eating animals have large eye-teeth, which they use for tearing; cows, sheep and other hoofed animals have large grinders, which they use for crushing and grinding.

61. PARTS. Each tooth has a root, a neck, and a crown.

The root is in the jaw-bone; the neck is covered by the gum; the crown projects into the mouth.

62. SUBSTANCES. Look at the surface of the parts of a tooth. Touch them. Is there a difference? Try to cut them with a knife. The smooth, shiny, hard substance of the crown is called **enamel.** The dull and less resistant substance of the root and neck is bony and called **cement.**

Enamel is the hardest of all the substances in our body, so hard that it will strike a spark with steel. Try it.

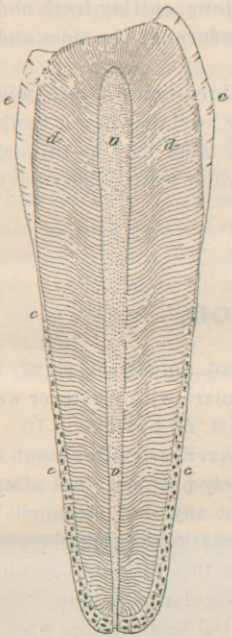

Fig. 12.

The accompanying figure shows a longitudinal section of a cutting tooth. Describe it. The white substance that forms the largest part of the tooth (*d*) is called **dentine** or **ivory.** By what is it covered? The cavity of a dead tooth is empty; in a living tooth it is filled with a soft pulp, full of blood-vessels and nerves. Examine the end of the root· What do you notice? Why must there be an opening?

Each tooth is composed of enamel, cement, dentine, and pulp, the latter consisting of blood-vessels and nerves.

The enamel is the covering of the crown; the cement is the covering of the root and neck; the dentine is below the surface of the tooth. The blood-vessels and nerves enter the tooth through a small opening at the end of the root.

63. CAUSE OF HOLLOW TEETH. What have your parents told you about the treatment of your teeth? Why is it necessary to clean them twice a day? What makes the teeth unclean? Sometimes when cleaning your teeth you find little pieces of meat or other food between them. How do these pieces smell? This putrid smell it caused by decay. The pieces of food have changed, have become sour and corrosive, and in this state dissolve that part of the tooth with which they are in contact.

To find out the effect of a sour substance upon teeth, put a tooth into vinegar. When it has been there for two days, you can easily scratch off some of the enamel with your pocket knife. In a week it will become as soft as lime-stone.

I knew a little girl one of whose upper cutting teeth had a little cavity in the middle of the cutting edge. This was not caused by remnants of food, but by biting thread. We learn from this instance that it is not well to bite hard substances; cracking nuts may seriously injure the teeth.

Teeth not properly cleaned become hollow; cutting teeth and eye teeth become hollow at the sides, grinders, at the sides and on the grinding surfaces.

Children who visit a dentist twice or three times a year, will very seldom, if ever, have toothache; neither need they have a tooth pulled nor will they have bad teeth. The teeth may be injured otherwise, nevertheless out of a hundred hollow teeth, eighty have become hollow from insufficient cleaning.

SECTION III.

CHANGES OF FOOD.

64. SALIVA. Which is better, to eat quickly or slowly? Why? What is there in the mouth that mixes with whatever we chew?

Once, when I was very hungry, a person near me took out a sweet, juicy orange, peeled it, and deliberately put one piece after another into his mouth. He did not offer me any of it, although I expected him to do so. Now, something remarkable took place in my mouth. What was it? We learn from this that our mouths fill with saliva at particular times, or on particular occasions; that there is not a constant, even flow of saliva, but that it comes whenever we think we need it.

When food is eaten or chewed, the mouth fills with saliva. Saliva mixes with the food and thus enables us to swallow dry food.

65. STARCH.* Saliva is necessary for the digestion of bread or anything containing starch. Starch is an important article of food; it is contained in nearly all plants.

Rice, wheat, Indian corn, and rye contain a great amount of starch, more than half of their weight; buckwheat, pea- and bean-meal about two-fifths of their weight; potatoes about one-third.

* How to obtain starch. Scrape a potato, mix the pulp with water, and squeeze it through a piece of clean linen cloth. Let the liquid that passes through the cloth stand in the glass till a white powder has settled. Pour the water off and dry the sediment. It is starch. How does it look? Touch it with your fingers and rub them against each other. How do they feel?

Any kind of flour will yield starch when mixed with water and treated in the same way as the pulp of potatoes. Beans, pease, and seeds of similar plants, after having been soaked in water for several days, may be crushed or pounded in a mortar to a fine pulp and then made to give up their starch.

When you consider that all kinds of bread and all root crops contain starch, you will call starch an almost indispensable article of food. It is for the digestion of this substance that saliva is necessary.

66. CHANGE OF STARCH. Does starch dissolve in water? It is necessary that food be dissolved, in order to be digested. Whatever is to be digested must be liquid; changes do not take place as long as a substance is solid. We can not even taste a substance when it is solid. Try it. Wipe your tongue dry and put a piece of loaf sugar on it. What do you observe?

The change of starch into a soluble substance is accomplished by saliva.

Starch surrounded by saliva changes into sugar.

67. SALIVARY GLANDS. Saliva is made (or secreted) by organs called salivary glands. Two of them are placed in front of and a little below the ears; others lie between the halves of the lower jaw-bone.

Fig. 13.
A BRANCH OF A SALIVARY GLAND.

Salivary glands resemble grapes in their structure. They consist of numerous little globes, each of them at the end of a little tube. The walls of the tubes contain blood-vessels. The saliva is drawn from the blood and fills the globes; from there it is sent into the little tubes. The little tubes connect with larger tubes, and the last and largest of them sends the saliva into the mouth. What parts of the grapes correspond to the tubes?

68. THE FOOD-PIPE. Through what tube does the food pass when it moves from the mouth to the stomach? Is the large tube whose hard walls we feel in the front of our neck, the food-pipe? Which of the two tubes is nearer to the mouth? Where is the upper opening of the wind-pipe? The back part of the mouth is a spacious cavity into which several tubes or other cavities open. It is called the **throat** (pharynx). Name these tubes and cavities.

One day some one at our dinner table told a funny story, which made every one laugh. Suddenly my neighbor was seized with a coughing fit. When he had recovered from it, he said that something had "gone the wrong way," and that he had to send it the right way by coughing. What did he mean?

The act of swallowing, or the process of sending food or drink into the stomach, is quite complicated and must not be disturbed. While we swallow, the opening of the wind-pipe is closed by a cover or lid (the epiglottis), the nasal cavities, by a fleshy membrane (the soft palate,) and the opening between the throat and mouth, by all the soft surrounding parts. The only way food can go now, is into the food-pipe.

Examine the food-pipe of a calf, pig, or sheep. Is it a wide open channel, like the wind-pipe, or is it a narrow passage? Of what

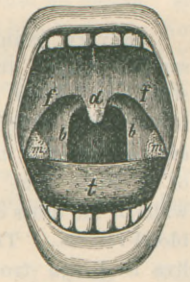

Fig. 14.

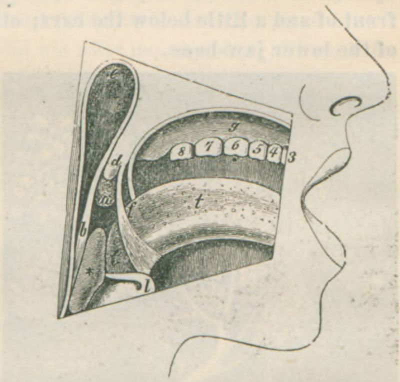

Fig. 15.

do the walls consist? The flesh (muscles) of this tube pushes the morsels of food along, toward the stomach.

What animals swallow food while their heads are near the ground, lower than the stomach? What can you learn from this fact? Then it must also be possible to push the food the other way—from the stomach to the mouth. What animals do this regularly?

The food-pipe (oesophagus) is a narrow, fleshy tube, through which the morsels of food are pushed toward the stomach. It is located close behind the wind-pipe.

69. THE TRUNK contains two cavities, the chest and the abdomen. They are separated by the midriff (diaphragm.) The chest is the cavity above the midriff; the abdomen is the cavity below the midriff.

The diaphragm is stretched across the trunk. It has the form of an inverted wash-basin. Where is the uppermost part of the diaphragm? Where is the lowest? In which of the two cavities is the food-pipe.

70. THE STOMACH is a somewhat conical or oval bag placed transversely in the upper part of the abdominal cavity. Its widest part is at the left side. It has two openings, one through which the food enters, and one through which it passes out.

The opening on the left side is connected with the food-pipe, the opening at the right side with the intestines. The "pit of the stomach" is a slight depression in the skin over the lower end of the breast-bone, directly in front of the stomach.

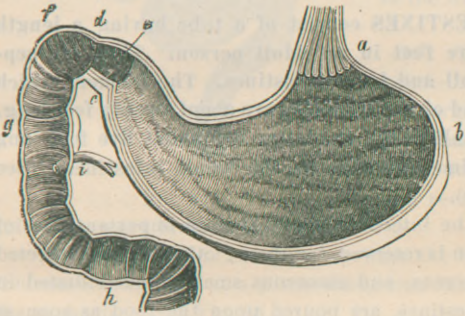

Fig. 16.

71. THE FOOD. When food enters the stomach, the opening at the right side is closed and remains closed for more than an hour. This is necessary that the food may be changed in the stomach.

Substances may be changed in three different ways: they may be reduced to smaller pieces; they may be dissolved; they may be affected by heat. Is all this done with the food in our body?

72. THE THREE COATS OF THE STOMACH. When the stomach is empty, the inner surface is pale and slightly moist, but on the entrance of food it becomes very red, and over all the surface the gastric juice, a clear, sour, and colorless liquid, trickles out like sweat on the skin of a perspiring person. At the same time the walls of the stomach commence to move in and out. Why?

The stomach has three coats, or layers: an outer coat, a middle coat, and an inner coat. The outer coat is smooth and moist, in order that friction with neighboring organs may be prevented; the middle coat consists of muscles, by which the movements of the stomach are performed; the inner coat lies in little ridges, or folds, and contains the gastric glands, which secrete the gastric juice.

The outer coat is called the serous coat; the middle, the muscular coat; the inner, the mucous coat.

73. PROTEIDS.* Gastric juice dissolves the substances, called proteids or albuminous substances. There are four kinds of proteids: albumen, gluten, fibrine, and casein.

Albumen is found in the white of eggs, gluten in flour, fibrine in meat and blood, casein in cheese and milk.

74. THE INTESTINES consist of a tube having a length of about twenty-five feet in an adult person. They are separated into the small and large intestines. The former, which commence at the end of the stomach, are about twenty feet long, and an inch and a half wide; the latter are about five feet long and two or three times as wide as the small intestines. (See Fig. 17 on next page).

The length of the intestines shows that an important part of the work of digestion is reserved for them; other liquids, secreted by the liver, the pancreas, and numerous small glands situated in the walls of the intestines, are poured upon the food as soon as it leaves the stomach.

75. THE LIVER is an abdominal organ lying near the diaphragm, at the right side of the body. It is large and of a reddish-brown color. It consists of a substance softer than meat.

All animals with bones (vertebrate animals) have a liver. The human liver weighs from three to four pounds and contains numerous blood-vessels.

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* How to obtain albumen and gluten. Rub raw potatoes on a grater, so as to get a fine pulp, inclose the pulp in a piece of linen, place it in water and squeeze it. Pour the turbid water in a glass, let the starch settle at the bottom, and heat the clear upper water in a test tube, The albumen coagulates in the form of loose, flaky particles of grayish color.

Mix a spoonful of wheat flour with enough water to make a thick dough, enclose the dough in a piece of linen, place it in water, and squeeze or knead it. Continue the squeezing or kneading till the water, which you may renew several times, no longer appears milky (from starch). The substance remaining in the linen is gluten.

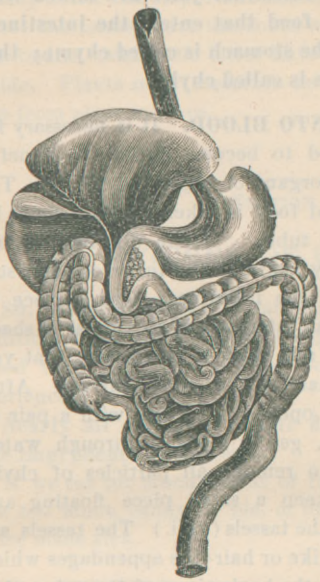

Fig. 17.

76. THE GALL-BLADDER is a pear-shaped bag fastened to the under side of the liver; it contains the bile, or gall, a dark-greenish liquid of bitter taste.

Bile is the secretion of the liver. It accumulates in the gall-bladder and is emptied into the small intestines when food enters them. From what substance of the body is the bile secreted? Why are there numerous blood-vessels in the liver?

77. THE PANCREAS or sweet-bread is an elongated, soft organ, about as large as a hand. It is situated close behind the stomach, and secretes the pancreatic juice, a watery looking liquid.

The pancreatic juice, together with the bile, is emptied into the small intestines, at a place about two inches from the end of the stomach. (See Fig. 16, i.)

78. INTESTINAL DIGESTION. When the food leaves the stomach, it consists of a soft, half digested mass, called **chyme.** Bile, pancreatic juice, and intestinal juice now begin their work and complete the changes. Any particles of starch or of albuminous substances that have escaped the action of saliva and gastric juice, are finally digested. Fat and oily substances are prepared for absorption. The latter are acted upon in a double way; a small part of the fat is changed into a kind of soap, which is easily dissolved and the remainder is separated into very minute particles, which float in the liquid contents of the intestines.

The result of the combined action of all the digestive juices is a liquid of a creamy color, called chyle.

Bile, pancreatic juice, and intestinal juice are mixed with the soft, half digested mass of food that enters the intestines. The mass of food contained in the stomach is called chyme; that contained in the small intestines is called chyle.

79. CHANGE OF FOOD INTO BLOOD. It is necessary for the food to become liquid (to liquefy) in the organs of digestion. Why? The liquefied food is taken up (absorbed) by narrow tubes. Where do they begin? Do they begin at the inner or outer surface of the intestines? Get a piece of the small intestines of an animal (a sheep or calf) and open it lengthwise, that you may examine the inner surface. After having opened the piece with a pair of scissors, gently move it through water, so as to remove all particles of chyle. Then keep a small piece floating and notice the tassels (villi.) The tassels are thread-like or hair-like appendages which contain the beginnings of the tubes that receive the liquid food. You can not see the liquid tubes because they are too small, but Fig. 18 shows how they look when sufficiently magnified.

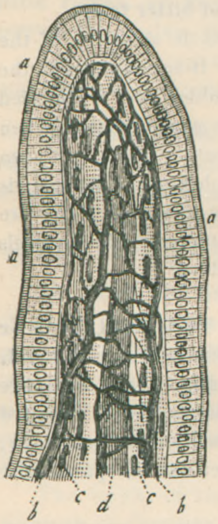

Fig. 18.
a, lining membrane built of cells; b, small blood-vessel; d, narrow tube absorbing chyle.

The chyle is taken up (absorbed) by milk tubes* located in the tassels of the intestines. The milk tubes unite into wider tubes and these finally empty into one of the blood vessels, where the chyle undergoes further changes, and is soon converted into blood.

The contents of the milk tubes are white and milky looking. What parts of plants resemble the vessels and milk-tubes of the body—take up liquid food and carry it along? What is the name of the fluid that moves in plants? What fluids in plants and animals have the same functions, resemble each other, and why?

*Milk tubes, or lacteals, from a latin word (lac) meaning milk. These and other terms are omitted in the text, because children do not easily remember them, frequently confuse them with other scientific terms, and because they do not necessarily help the understanding of the processes of digestion and assimilation.

We may notice this important distinction between most animals and plants; the former have the tubes which absorb the food **inside** of their bodies, while the latter have the absorbing organs (cells) **outside.** Plants must therefore be stationary, while animals may move from place to place.

SECTION IV.

HYGIENE OF DIGESTION.

80. DISORDERS. What changes did you notice in your condition, when your digestive organs were out of order? What caused these disorders? What ought you to learn from these experiences?

Nearly all disorders of our digestive organs are caused by some imprudence of our own.

If we eat too much, or eat of food that does not agree with us, have too much candy or pie, or too many figs, or rich cakes, etc., we are made sick.

81. CHEWING. Suppose you bolt lumps of bread; why may that be a cause of disorder? Or you swallow big pieces of meat; why is that hurtful? Upon what part of a piece of bread or meat do saliva or gastric juice act? Upon what part do they not act? Which has a greater surface — one whole piece or the same piece cut into several pieces? How is your food usually reduced to small pieces?

Name some articles of food that are reduced to small pieces before they are eaten. Is it better to have this grinding and chopping done outside of the mouth, or inside? Is anything wanting, if the chewing of the food is done away with?

What food should not be eaten without chewing? What food might, without much loss? How will it affect our health, if the teeth are unfit to chew the food, or if we have lost them, so that we are obliged to eat soft substances only? Is there a way to avoid these evil consequences? What benefits are derived from a set of artificial teeth?

The food must be sufficiently chewed; otherwise it will not be well digested.

The digestive fluids act only upon the surfaces of solid food; the saliva does not penetrate through lumps of bread which are bolted (swallowed without having been chewed); the gastric juice does not reach the interior of large pieces of meat.

82. EATING TOO MUCH causes an unnatural enlargement of the stomach.

We should not continue to eat when we feel that we have had enough. If we do so, we feel uncomfortable, and lose strength. If we do it often, the enlargement of the stomach becomes permanent, and we lose not only the power to tell how much food we need, but also, in time, may become the prey of dyspepsia, which, in many cases, begins with an unnaturally enlarged stomach.

83. THE INTERVAL between meals should be at least three hours.

A ring of muscle at the outlet of the stomach prevents the passage of food before it is fit to enter the intestines. About an hour after a meal this muscular ring commences to relax a little and allows portions of the food to pass. It then closes again, opens in another half hour, and thus continues, till in three or three and a half hours the stomach is empty.

84. NOURISHING FOOD. You mentioned that you had eaten food that did not agree with you, such as rich cakes, hot bread, a great quantity of raisins, figs, candy, ice-cream, etc. It is true that experience will in time teach us what to avoid and what to use; but in most cases this experience is bought at too great an expense. It is better to know beforehand the consequences of eating improper food. For this purpose we shall have to study the various articles of food systematically, to learn whether they are valuable or not.

Nourishing food is food that is nutritious and digestible.

Nutritious food is food containing a great number of substances that the body needs. Digestible food is food that is easily dissolved in the stomach and easily prepared to enter the blood.

SECTION V.

VEGETABLE FOOD.

85. BREAD. Wheat is the most nourishing food. It contains from ten to fifteen per cent. of gluten, from sixty to seventy per cent. of starchy substances, a small quantity of fat, and useful minerals. Rye, rice, Indian-corn, and other grains are not quite so nourishing as wheat.

Wheat ranks first among all vegetable food-stuffs; it is highly nutritious and easily digestible. With the exception of milk, there is no single article of food that approaches more closely an ideal, or normal, diet than wheat. Bread is made from wheat or other grains.

Valuable as wheat is, it may be the means of weakening the stomach, if prepared or used improperly. It is improperly prepared if, in the form of dough, it is mixed with too much fat or too much sugar, as in fried cakes, tarts, or sweetmeats; it is improperly used as bread, if it is eaten either too fresh or too old, or if taken in too great quantities.

Bread fresh from the oven frequently forms big lumps in the stomach, which are almost impenetrable to the digestive fluids, and may, therefore, cause serious consequences, particularly to persons with a weakened stomach. Old bread is unwholesome when it is moldy; the mold may cause dysentery or dyspepsia.

86. VEGETABLES are built up of cells containing starch, albuminous substances, and other materials. The walls of the cells must be crushed and the cells opened to give up their contents.

Cells are found in all the parts of plants; they constitute the elements (the building-stones) of all plant-structures. Every part

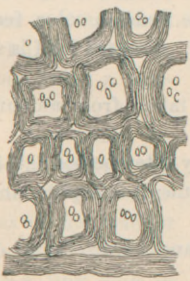

Fig. 19.

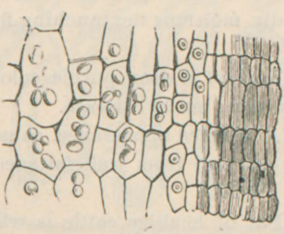

Fig. 20.

CELLS OF PLANTS.

of a plant is built up of cells. What difference do you see in the walls of the various cells represented? Which substances are more easily digested — those made up of cells with thick walls, or those made up of cells with thin walls? Give the reason why. What do we do to open the cells? How do we assist the work of the teeth? When vegetables are boiled, the cell walls are affected in two ways. Name them.

87. SUGAR is a healthful, nutritious, and easily digestible substance, particularly when forming a part of other dishes. Persons eating too much sugar have bad teeth, and become weakened in health.

Put sugared water or a sweet juice in a warm place for a few days. What change will occur? How do the remnants of sweet substances change in the mouth? How do sour substances affect the teeth?

If the stomach is overloaded with sugar, as in persons who daily indulge in candy and other sweet substances, it will become diseased and the appetite for simpler, more wholesome food will lessen.

SECTION VI.

ANIMAL FOOD.

88. ROAST BEEF is more digestible and nutritious than boiled beef as usually prepared. The quality of beef depends, firstly, on the condition of the animal from which the meat is taken; secondly, on the piece obtained; thirdly, on the skill of the cook.

In the selection and preparation of beef we should be guided by the following rules:

1. Good, healthy beef is of a pale, reddish color, feels firm, and hardly moistens the touching finger; diseased beef is soft and slimy.

2. Beef of a deep purple color is taken from an animal not killed by man, but by disease.

3. A marbled appearance, caused by interspersed fat, is found in beef obtained from well fattened cattle; it is healthy and nutritious.

4. Fat of healthy cattle is white and hard; fat of diseased beef is yellow, watery, or gelatinous.

5. Good beef has little odor; diseased beef has a rank smell.

6. Before roasting or boiling beef or any other kind of meat, do not wash it, because water removes good juices from near the surface—it is sufficient to wipe it with a clean linen cloth.

How long a roast should be on the fire depends on its size. Thus pieces of tender beefsteak should remain on the fire but a few minutes, while roasts weighing from ten to fifteen pounds should be on the fire till a crust is formed, which may take from ten to fifteen minutes, and after this be kept in an oven for about three hours. The inside of the roast should remain red and contain blood. If the roast is overdone, it is hard, tasteless, and indigestible.

89. SALTING AND SMOKING. Salt beef and salt pork have less nutritive value than roast beef or pork, and are less digestible. Smoking makes the fibres hard and dry.

The brine in which meat is salted extracts most of the valuable juices. Smoked beef can be well digested by a healthy stomach.

90. RAW MEAT is less digestible than roasted meat, and may be the means of bringing parasites into the body.

Parasites are animals living in or upon the body of others —feeding on the substance of the animals they inhabit. The most frequent parasites introduced by raw meat are the **tape-worm** and the **trichina.**

Fig. 21. Bladder worm.

Tape-worms are introduced by beef and pork, mostly by pork. The pig is sometimes infested by a small animal called the tailed bladder worm. Its body consists of a small head, a short neck, and a trunk formed of a yellowish-white bladder filled with a fluid substance. If the **head** of this worm be introduced into the human stomach, it will soon lodge a tape-worm.

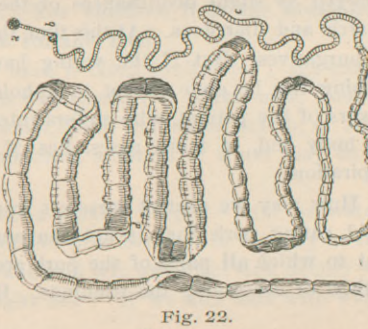

Fig. 22. Tape-worm.

The tape-worm inhabits the intestines. Its head, which is quite similar to that of the bladder worm, fastens itself, by means of a tiny ring of hard, strong hooks, to some place on the soft inner surface of the intestines. Its body consists of hundreds of joints, the last of which contain numerous eggs. They detach themselves and are ejected from the body with the waste products of digestion.

The tape-worm, though troublesome, and disturbing the health of persons infested by it, seldom causes serious consequences.

The **trichina**, however, is dangerous, and has frequently caused death. It is dangerous for two reasons; first, because the parasite is so small and transparent that it can be detected only with the microscope; and secondly, because it is usually introduced in great numbers, which further increase in the human body.

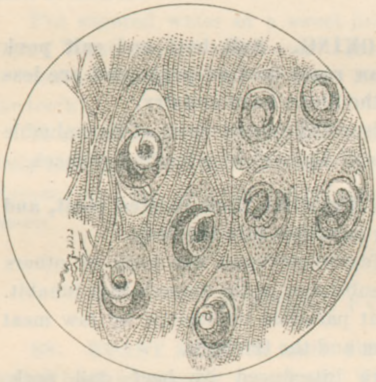

Fig. 23. Trichinae.

Figure 23 represents the parasite as seen in pork. Describe its appearance. The pouch, or bag, consists of a membrane containing lime. If introduced into the stomach, the sour gastric juice dissolves the membrane, and the parasite is set free. It now feeds on the contents of the stomach and intestines, and soon brings forth about 200 living young, which are carried by the blood to every part of the body. They finally lodge in the muscles, where they form coils like those represented in figure 23.

A few days after eating meat infested by trichinae a person is annoyed by slight disturbances of the digestive organs, such as catarrh and diarrhoea. At this time the trichinae may be ejected by purgatives. But if the young have commenced to wander, nothing can be done except to uphold and strengthen the vital powers of the patient, who suffers intense pain in various parts of the body and, in many cases, dies of paralysis of the muscles of inspiration.

How may we protect ourselves from this danger? We should avoid eating pork that is not **thoroughly cooked.** The intense heat to which **all parts** of the pork are subjected, is the only sure method of destroying the trichinae. Roast pork that is still red inside, may contain living trichinae. Salting and smoking does not kill them—sausages made of smoked pork may contain them alive.

91. MEAT GENERALLY. The flesh of mammals is more nutritive than that of most birds. The flesh of fish contains more water than that of mammals or birds, but is easily digested, and should not be left out of our diet.

Veal is not so nutritive as beef, but is more tender, and, when of good quality, more easily digested. Good **mutton** is nearly as good as beef, but harder to digest. **Pork** has less nutritive value than beef or mutton, and is harder to digest than either. The flesh of **deer, rabbits, hares,** and **squirrels** is less nutritive than beef or mutton, but more easily digested then these. The meat of **chickens, turkeys,** and **pigeons** is more easily digested than that of **geese** or **ducks. Crabs** and **lobsters** are not easily digested. **Oysters** are considered wholesome, and are most easily digested when eaten raw.

92. EGGS. Can you give a reason why eggs must contain most or all of the substances that the bodies of animals contain ?

Eggs are nutritious food, because they contain much albumen and fat.

In what condition are eggs most easily digested ? It is not advisable to eat hard boiled eggs. The white is almost indigestible, though the yolk offers no difficulty in this state.


Fig. 24.
Milk Tester.

93. MILK. In what respect do eggs and milk resemble each other ?

Milk contains albumen (casein), sugar, fat (butter), salts, and water. For children it is the healthiest, cheapest, and most suitable food.

Unfortunately milk is often adulterated ; the cream, which contains the wholesome fat, is skimmed, and the milk mixed with water, flour, rice-water, starch, or other substances. A fraudulent addition of water may be detected.

Which fluid has a greater weight—milk or water ? In what does an object float better—in a heavy or in a light fluid ? In what fluid will an object sink deeper—in a heavy or in a light one ? If we mix milk with water, does it become heavier or lighter, and will an object sink deeper or less deep in it than in pure milk ?

A milk tester (lactometer) consists of a short, upright glass tube with a heavy globe attached to the lower end and a very narrow glass tube above. When using the instrument one must be careful in his judgment, because different cows give different milk and the weight of different kinds of milk is not always the same. But when the tester shows as much as one-third or one-fourth of water added, one may be sure it is an intentional mixture.

94. FAT. How do persons look who are fond of eating fat, and how is their health ? Sometimes a physician tells parents to have their children take cod-liver oil daily. Why ? In what climate do persons eat great quantities of fat ? How do those persons look ? Do they suffer much from colds ? Is it healthful to eat fat ?

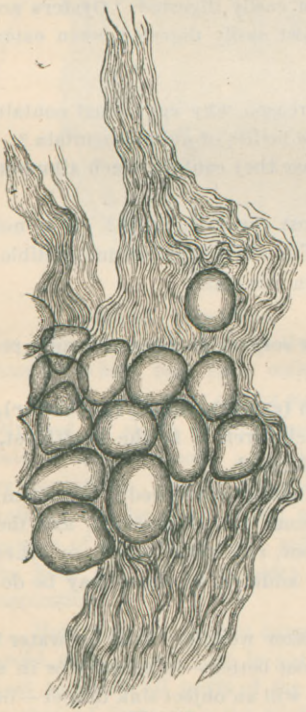

Fig. 25.
Fat cells in loose connective tissue.

You should make it a rule to eat some fat daily. You are doing so when you eat bread with butter, which is the most digestible of all fats. It is a fact that persons who eat and **digest** a sufficient quantity of fat very seldom suffer from cold, and are less liable to fall victims to the dreadful disease, consumption. What is the use of fat in our bodies ? At what place in our bodies will the fat, as a protection from the cold outside, be of greatest use ? What effect has it upon the looks of persons ?

A third use of fat is seen when, after a long sickness, in which most of the fat has disappeared, a person tries for the first time to stand on his feet. The weight of the body resting upon the soles **produces pain.** In a normal state, the fat cells between the skin and the inner part of the soles act like a number of rubber balls, which, while being pressed together, lessen the pressure of the body upon the sensitive parts of the skin.

Suppose a person grows too fat; how can he rid himself of the superfluous quantity? Nature does not allow an excess of wealth without punishing the offender. A person who is too fat is weak in many respects and may easily sicken.

The cause of this inconvenience is, sometimes, a hereditary disposition; in other cases, it is the habit of eating too much and too rich food, and not exercising enough. Indulgence in alcoholic drinks is likewise a frequent cause of an unhealthy accumulation of fat.

Persons fond of eating fat and able to digest it well, are strong and healthy. Fat protects us from colds; it improves our looks; and it lessens the pressure of the body upon the sensitive parts of the skin.

95. CHEESE contains casein, fat (butter), fatty acids, and salt. It is very nutritious, but exceedingly hard to digest.

There are but few articles of food so hard to digest as cheese. A person with a weak stomach should avoid its use entirely. Dry cheese should be grated before being eaten.

Section VII.

ARTICLES OF RELISH.

96. SPICES AND CONDIMENTS. Name the spices and condiments. What do your parents tell you about the use of pepper, mustard, pickles, vinegar, etc.? How do you feel if you take much of them? Mustard is sometimes used as a poultice. What effect has it upon the skin? What effect, therefore, must it have upon the inner, sensitive membrane of the stomach, if taken in great quantities?

Spices and condiments are injurious to health, if taken daily or in great quantities. A small quantity, just enough to give relish to other dishes, is sufficient to stimulate the digestive organs.

Vinegar, in small quantities, may assist the work of the gastric juice in promoting the digestion of albuminoids. Pepper increases the flow of saliva and gastric juice in a marked degree. Mustard is a gentle stimulant, but none of these substances should be taken every day. If that is done, their effect is lessened, and if, to produce the usual effect, their quantity is increased, various disturbances — constipation, indigestion, dyspepsia — are the inevitable consequences. Spices are to the digestive organs what the whip is to the horse ; the less you use the whip, the more sensitive is the horse ; the more you use it, the more callous and obdurate the horse becomes.

97. TEA AND COFFEE are not articles of food ; they are stimulants. Stimulants are substances that excite the organs, and increase their vigor and activity.

What was mentioned in regard to spices is true of coffee and tea; they are beneficial when used in moderate quantities, but destructive to health, if used to excess. Both contain a deadly poison. Chocolate is similar to tea and coffee in its effect upon the system, but preferable to them on account of its high nutritive value. Coffee and tea, as generally prepared, contain no nourishing substances except the sugar and milk that are added. *

CHAPTER IV.

RESPIRATION AND COMBUSTION.

SECTION I.

PROPERTIES OF AIR.

98. AIR SPREADS (expands) in every direction — it tries to fill all the spaces it can reach. Air has the quality of expansion.

Air is found in all the places where we are ; it comes and it goes out through every little opening; it is in the earth into which we dig; it finds its way into substances like a sponge or a powder; it surrounds the whole earth. The whole mass of air surrounding the earth is called the **atmosphere.**

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*An exposition of the dangerous effects of alcohol and tobacco will be found in ¶ ¶ 302-315.

99. HEIGHT OF THE ATMOSPHERE. Is there a limit to this expansion? Does the air spread from the earth to the moon, and the sun, and the stars? Is the whole universe filled with air? What have you heard about the air on high mountains?

It is believed that the air does not extend beyond the solid earth higher than one hundred miles.

100. PRESSURE OF AIR. The air accompanies the earth in its course through space, just as we do ourselves, and as all objects found on the earth do. Air is attracted by the earth, as everything else is; it follows that it must press upon other bodies.

Immerse a glass in water, turn it, and lift it, upside down, so that the bottom is above the surface. Why does the water not fall out? Put one end of a glass tube in water; can you take away the air in the glass tube and make the water rise? What causes the water to rise? Fill a glass with water, cover it with a piece of paper, turn the glass upside down, and slowly remove your hand. Does the paper hold the water in its place by its own force? In what direction does the air press? Roll a piece of paper into the form of a tube, close one end by pressing the tube together, take the other end in your mouth, and exhaust the air. What happens? What is the cause of this motion?

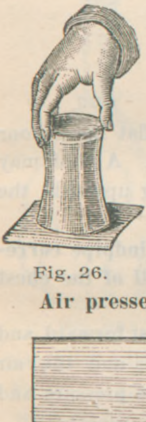

Fig. 26.

Air presses in all directions.

101. WHY THE LOWER AIR IS DENSE. Suppose our room, or a very high hall, were filled with loose cotton; would the upper cotton differ from the lower? Why?

The lower air is denser than the upper, because it is pressed upon by the latter.

The air near the surface of the earth is dense and heavy, while the air in the upper regions is rare and light.

Fig. 27.

102. A PAIR OF BELLOWS consists of two boards of equal size, connected at their edges by a wide piece of leather. At one end there is a tube leading from the outside to the inside; at the opposite side there are two handles.

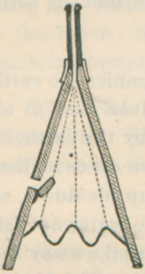

Fig. 28.

There is, besides, a valve in one of the boards, but we will not consider the valve for the present. How is the inner space changed, if you separate the boards from each other? How does that change the air inside? Where is now the dense air, inside or outside? What takes place if you push the boards towards each other? How does that change the inner space? The inner air? What motion of the air is caused by the approach of the boards toward each other?

SECTION II.

RESPIRATION.

103. THE CHEST. Place your two hands flat upon your chest, draw a breath, and forcibly breathe out again. A pupil may put the bellows before you with the tube pointing upwards, the movable board in front, and set it in motion.

The chest acts like a pair of bellows. The windpipe corresponds to the tube of the bellows, the movable wall of the chest to the movable board of the bellows.

When a person moves the front wall of the chest forward and upward, the space inside the chest grows larger, and the air contained there, thinner. The air outside has more pressure and forces its way in through the windpipe.

When the front wall of the chest moves back, the space inside becomes smaller and the air contained there, denser. This dense air has more pressure than the air outside; it therefore forces its way out.

104. BREATHING. Sit straight for a few moments and direct your attention to the act of breathing. Try to keep the front wall of the chest perfectly quiet; what other part of your body is moving instead? You will understand what this part has to do with breathing, if you remember what you learned about the two cavities in the trunk. What is the name of the partition between the two cavities? We can not feel the movements of the midriff, as we can those of the front wall of the chest, but we must take it as a fact that the midriff moves down when the front wall of the abdomen moves forward. Why does it move in this way ?

We can breathe in two ways; either by moving the front wall of the chest, or by moving the front wall of the abdomen. The latter movement is caused by the movement of the midriff (diaphragm).

There is nowhere an empty space in the cavity of the abdomen. When the diaphragm moves down, it presses upon the soft organs contained in the abdomen, and these affect the movable front wall.

105. LUNGS AND RUBBER BALLOONS. For this lesson we need a rubber balloon attached to a wooden tube. Blow air through the tube. What takes place? What takes place when you stop blowing? What widens the balloon? What causes the balloon to collapse? What two forces change the form of the rubber balloon? Suppose several of these rubber balloons were connected in such a way that the air could freely move from the inside of one balloon to that of any other; would the same two forces be able to make the same two changes ?


Fig. 29.

Our lungs consist of a number of such balloons. It is true that their walls do not consist of rubber, but the substance of the walls has the essential quality of rubber — elasticity. A great number of balloons with elastic walls, in fact, several millions of them, are connected in such a way that the air contained in one may freely pass to all the others. They are not nearly so large as a rubber balloon, but their size does not change their quality; they act exactly like a number of large balloons connected in the same way.

Fig. 30
Air Cells of the Lungs.

A rubber balloon is widened by the pressure of air and narrowed by the elasticity of the

rubber walls. Our lungs are composed of a great number of similar balloons, which are called air cells. Their walls consist of elastic tissue.

Examine the lungs of a rabbit. You can not see the air cells, because they are very minute, but you can see them act. Blow into the windpipe. What change do you see in the lungs? Stop blowing. What change do you now see in the lungs? What produces these changes?

106. COLOR OF THE LUNGS. The lungs of a rabbit are of a roseate color, which they take from the blood they contain. The lungs of human beings are of a darker color.

The dark color of our lungs is due to dust, the great enemy of health, which we can not keep out of the houses and streets of cities and towns. If you had lived in fresh air all your life, your lungs would be as beautiful as those of animals, and you would be free from many serious diseases.

107. STRUCTURE OF THE LUNGS. Our lungs are separated into the right and left lung, each of which has several lobes. The two lungs are connected by the windpipe, which is first divided into two, then into many smaller branches. The sub-divisions of the windpipe are called bronchi (singular: bronchus.) The windpipe and bronchi consist of cartilaginous rings, connected by membranous tissues. *

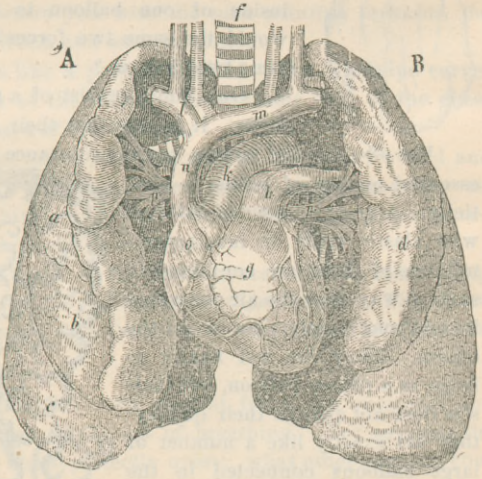

Fig. 31.
Lungs and Heart.

* Do not study this lesson without having seen and touched the objects mentioned.

When you have an opportunity, compare the rings in the windpipe of a turkey or chicken with those of a rabbit or squirrel. Compare the structure of the lungs with that of a tree, or with that of a bunch of grapes.

SECTION III.

COMBUSTION.

108. A BURNING CANDLE. To learn more about the nature of air, we will examine it in connection with a burning candle. Place a short candle upon the table, light it, and put a glass chimney over it. What happens? What is the cause of the extinction? It can not be that air is wanting, because there is air all around the light—the chimney is filled with air. Why are the flames in lamps with chimneys not extinguished? Arrange your candle and chimney in such a way that the light will not be extinguished.

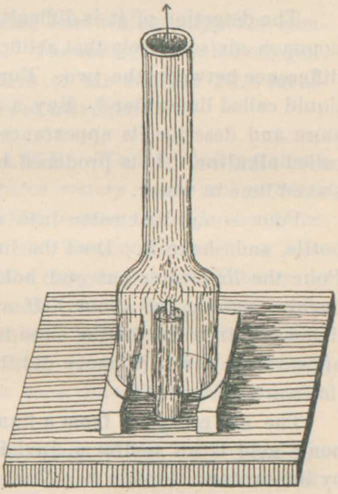

Fig. 32.

A burning candle needs a constant supply of fresh air. The fresh air enters the flame from below and from the sides; the hot air escapes upward.

A candle or a lamp burns brightly when enclosed by a chimney, because then the hot, light air forms a column which moves quickly upward. The chimney of a stove or a fireplace acts in the same way. The greater the draft, the greater the amount of fresh air that reaches the burning substance, and the brighter the fire.

109. WATERY VAPOR IN THE AIR ESCAPING FROM FLAMES. Place a glass chimney over a light and closely observe whether it changes its appearance. What do you see? What substance makes it dim? Place a flask filled with cold water over a flame and watch its lower surface. What do you see?

The air escaping from a flame contains watery vapor.

A kettle shows big drops of water on its lower surface shortly after being placed on the fire. A chimney grows dim from moisture shortly after it is placed over a light. When the kettle or the chimney becomes hot, the moisture evaporates.

110. CARBONIC ACID IN AIR ESCAPING FROM FLAMES. We shall now try to find another substance in air escaping from flames, but it is somewhat difficult and you would probably never learn anything about it without being told. A hundred years ago or longer, it was not known to anyone that this substance is contained in air.

The detection of it is difficult, because the substance resembles common air so closely that artificial means must be used to find a difference between the two. For this purpose we make use of a liquid called limewater.* Buy a small quantity of it at the drugstore and describe its appearance and taste. Its peculiar taste is called **alkaline.** It is produced by dissolving a small quantity of slaked lime in water.

Pour some limewater into a wide-necked bottle, close the bottle, and shake it. Does the limewater change its appearance? Pour the limewater out and hold the bottle upside down over a burning candle for about half a minute, pour a small quantity of limewater into the bottle, close it, and shake. Does it change its appearance now? Whence did the substance come that makes the limewater milky?

The air escaping from a flame contains carbonic acid. Carbonic acid is an aeriform, invisible substance, which is detected by limewater.

111. AIR A MIXTURE OF OXYGEN AND NITROGEN. For this experiment we need a plate with water, a tumbler, and a piece of tissue-paper. Light the paper, throw it quickly into the tumbler, and place the tumbler upside down on the plate, in the water. What happens? With what was the glass filled before it was placed in the water? With what is it filled now? Measure the quantity of air and water in the tumbler.

*How to make limewater: Throw a spoonful of slaked lime (the white substance that masons mix with sand to form mortar) into a bottle of water, shake well, and let it stand a few hours. When the upper water is clear, pour it off carefully.

Not taking into account a few bubbles that escaped through the effect of heat, we find that one fifth of the air disappeared while the paper burned. You learned some time ago that a burning substance needs fresh air. This experiment teaches the same, and at the same time shows us that about one fifth of the air is used up by a burning substance. Does the remaining air support the burning of the substance?

Suppose I place some substance in the manger of a hungry horse, and I find that the horse eats but one fifth, though I know he is still hungry; what must I think about the nature of the substance placed in the manger? Did it consist of equal parts or of unequal parts? Apply this to air.

Air consists of two substances, one which supports combustion, and one which does not. The former is called oxygen, the latter, nitrogen. 100 measures of air contain 20.8 measures of oxygen, and 79.2 measures of nitrogen.

112. A REMARKABLE CHANGE. We have learned that a flame consumes oxygen and produces watery vapor and carbonic acid. Nitrogen is not changed while passing through the flame; it is neither consumed nor produced. Two questions must arise from these facts: 1. Where does the oxygen go? 2. Whence do the watery vapor and the carbonic acid come? Oxygen can not be destroyed, that is, changed to nothing; vapor and carbonic acid can not be created, this is, arise from nothing. We should add another fact to be explained at the same time: the consumption of the candle itself.

When a candle burns, the substance of the candle and the oxygen disappear, while carbonic acid and watery vapor appear. This shows that the substance of the candle and the oxygen CHANGE into carbonic acid and watery vapor.

Section IV.

RESPIRATION AND COMBUSTION COMPARED.

113. TEMPERATURE. In studying the process of respiration more thoroughly, we may now make use of what we have learned. How warm is the air expired? Hold the bulb of a thermometer in the hollow of your hands and breathe against it. Where does the air increase its temperature ?

The interior of our bodies has a temperature of about 100 degrees, and the air we expire, or breathe out, is nearly as warm.

114. VAPOR. What substance do you notice when you breathe into the hollow of your hands ? Which air will hold more vapor, warm or cold (see ¶ 12) ? This tells very clearly which air contains more vapor, the inspired or the expired air.

The air which we expire is usually saturated with vapor.

115. CARBONIC ACID. You have learned how to detect carbonic acid ; see whether or not the breath contains it.

The air which we expire contains the same amount of nitrogen as the air which we inspire, but has lost a considerable quantity (4.782 per cent.) of oxygen, and gained almost as much (4.35 per cent.) of carbonic acid.

116. RESPIRATION AND COMBUSTION. What do our bodies lose through the process of respiration ? What other process produces heat, vapor, and carbonic acid ? Is the air which supports a flame the same as that which enters our bodies when we breathe ?

The inspired air is identical with the air which moves toward a burning candle ; the expired air is similar to the air which leaves a burning candle.

This makes it probable that a process similar to the burning of a candle takes place in our own bodies.

Section V.

VENTILATION.

117. CONFINED AIR. Recall the time when you were present at a lecture or an entertainment, when a large hall was crowded with several hundred people. How did you feel toward the end of the lecture or entertainment ?

The air in a room occupied by persons loses oxygen, grows warmer, and takes up vapor and carbonic acid. Hot air filled with vapor and carbonic acid is unhealthful.

Type-setters and printers, tailors and shoemakers, persons in factories, and others who live indoors almost constantly, look pale and are weak. **"The air of closed rooms brings about the greatest part of human misery that is the result of disease."**

118. FRESH AIR. What persons live in fresh air most of their time? How do most of them look and how is their health? What makes them strong, and what makes those living indoors, weak?

Fresh air is the chief preserver of good cheer and health; it lessens the danger of nearly all diseases.

Farmers, hunters, sailors, and others who live in fresh air almost constantly look fresh and are strong.

The effect of fresh air is very great indeed, greater than most persons think. Animals that live in fresh air all their lives, are seldom sick; but if we house them or imprison them in cages, they are attacked by numerous diseases, just as we are.

The mere desire to breathe fresh air is not sufficient; the fulfillment of this wish is difficult and requires knowledge and energy. We must first learn what makes the air impure, secondly, what impurities are the most dangerous, and thirdly, what are the best means of purifying the air.

119. VAPOR. What do we call air containing much vapor? Is the air on small islands dry or moist? What kind of air do sailors and fishermen usually breathe? Are sailors and fishermen strong and healthy or not?

In summer the air is sometimes exceedingly moist and warm, and has hardly any motion — there is scarcely any wind. We do not like to move about then. Why not? In which air does the sweat evaporate more freely, in dry or in moist air? What air do we call close and sultry?

A moderate amount of vapor in the air which we breathe is healthful; a great amount is unhealthful.

120. CARBONIC ACID. This is a **poisonous gas.** Fresh air contains $\frac{4}{100}$ per cent. of it, or ten thousand measures of fresh air contain four measures. Two measures in one thousand measures of air ($\frac{1}{5}$ per cent.) cause headache and dizziness. Four per cent. of carbonic acid in the air (or the amount contained in our breath) is dangerous.

In fresh air carbonic acid is found in a greatly diluted state, and does not affect our health. When its amount increases, it injures the health.

121. ORGANIC SUBSTANCES CONTAINED IN EXHALED AIR. Until now we have mentioned vapor and carbonic acid as the only substances our bodies give out. Can we detect their presence by the sense of smell? Is the air of a closed room in which many persons breathe, inodorous? In view of these facts exhaled air must contain other substances.

The air exhaled by persons contains organic substances. These substances have a musty or fetid smell. Infectious diseases (small-pox, scarlet fever, measles, diphtheria,) spread from one person to another by means of exhaled organic substances.

Organic vapors and minute solid particles are thrown off from the lungs and skin. When we are sick, or when the body is very active, as during vigorous muscular exercise, the amount of these substances is greatly increased. You will have noticed a peculiar sour smell near persons exercising vigorously. The air of sick-rooms or hospitals is very offensive to the smell, if nothing is done to improve it.

Think of the smell of your own sleeping room. You do not observe it in the morning, when you rise and dress; but if you return to the room after having been outside for a few minutes, what do you notice? If you send this air through pure water by means of a pair of bellows, the water will soon become highly disgusting. Or simply blow your breath through a glass of pure water, and you will have the same result. Do you consider such water fit to drink? If you stop to think of it, you do not care to take this highly disgusting air into your lungs, perhaps over and over again; or you do not care to breathe in what your neighbor has breathed out.

What is done with the bed-clothes during day-time, and why? Wool, feathers, articles of dress, bed-clothes, wall-paper, and damp walls absorbe these organic substances very readily and keep the peculiar fetid smell for a long time.

Sometimes the same disgusting, musty smell is noticed in a school-room, partly caused by the clothes of some boys who are not well cared for at home, or are too lazy to attend to their personal neatness. What have these boys neglected to do? How should the clothes be cleaned? On what day of the week should the clothes be thoroughly dusted and aired?

Are there any decaying substances in your own house? It is frequently the case that vegetables kept in the cellar, such as potatoes, cabbage, carrots, or bulbs of garden plants (dahlias, begonias, cannas) decay without the knowledge of the inmates of the house; or that the remains of the meals are kept in some corner of the dwelling-house where they exhale a putrid smell.

The belief that this foul air does not affect the health of the inmates of the house, because they seldom enter the basement, is wrong. It is true that they do not often go there, **but the air comes to them.** Air is a very movable and penetrating substance, easily passing through the ceilings and floors, particularly in winter, when the heat expands it and causes it to rise. Dangerous fevers have frequently been caused by the foul air of basements.

122. AMOUNT OF FRESH AIR NEEDED. We must find means to supply our rooms with fresh air, and to expel the bad air; in other words, we must find means to ventilate our rooms.

A comparison will make the nature of this work clearer. Suppose a large barrel or cask filled with water is blackened by a thin but steady stream of ink. We want to purify the water. If we could empty the cask, and fill it anew, we should need a comparatively small amount of water. But this can not be done. The cask has to remain full at all times, and the stream of ink can not be checked. What are we to do? We must throw in a large and steady stream of pure water, and provide for the overflow. In this way we shall not rid ourselves of all the ink, but we shall keep its amount within certain bounds or limits. The greater the supply of pure water, the less ink that remains.

The purification of the air in a room is a similar process. In order to estimate the amount of fresh air that should be brought in, we should compare the amount of carbonic acid in the air we breathe out with the amount of carbonic acid in fresh air. (See ¶ 115). How much carbonic acid is contained in a mixture of one measure of exhaled air and 100 measures of fresh air? The correct answer to this question proves that even this great amount of fresh air would keep the air of a room only about half as pure as the air outside. Practical experiments have shown that a sufficient purification of the air can not be obtained unless the amount of fresh air brought in is from 130 to 140 times as great as the air exhaled.

At least 2000 cubic feet of fresh air per hour and person must be sent into a dwelling-room to counteract the evil effects of exhaled air.

2000 cubic feet is a great amount. At first sight it seems almost impossible to comply with this demand without expensive machinery. But nature will assist us, if we only understand its laws.

123. VENTILATING FLUES. The opening of windows or doors for the purpose of ventilation is accompanied by two evils: firstly, it causes draughts, which are injurious to health; secondly, it requires constant attention.

A perfect ventilation should, firstly, cause no dangerous draughts; secondly, work without requiring much attention; thirdly, be inexpensive. All these requirements may be fulfilled.

Since most rooms are heated by stoves, we will consider how the latter can be used for the purpose of ventilation. The fire in a stove is similar to the light of a lamp. How many and what currents of hot air does the light of a lamp produce? How many and what currents does the heat of a stove produce? Of what do the walls of a chimney consist? What is the temperature of the walls? This heat may be used to produce another outward current of air. It is only necessary to double the chimney, that is, to build two passages for the out-going air, one for the smoke and the other products of combustion, and one for the foul air of the room; or the chimney may be built of double width, and divided by a partition-wall. Should this partition-wall be thick or thin, and why?

A flue separated from the chimney by a thin partition affords an excellent means of producing an outward current of air in a room. The inner surface of the flue should be smooth, so as not to impede the air current.

If the inner surface of the ventilating flue is rough, or clogged with mortar or pieces of brick, it will not work well. The cost of this arrangement is slight, if made at the time of building the house. The opening of the ventilating flue should be near the floor and provided with a register. One ventilating flue may be used for several adjoining rooms on each floor, in the same way that the chimney may be used.

Since only a few houses are ventilated in this way, it will be useful to show how the chimney itself may be utilized for the purpose of carrying out the foul air. Explain Fig. 33.

The ventilating flue (v.f.) should consist of a tin or sheet-iron pipe, from six to ten inches in diameter, according to the size of the room. The arrangement is cheap and useful and should not be omitted in any room heated by a stove.

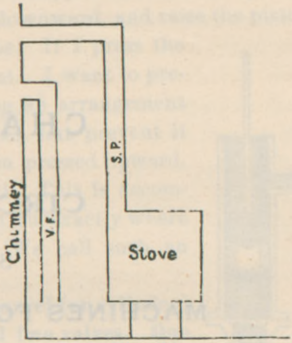

Fig. 33.

124. ADMISSION OF FRESH AIR. A well ventilated room has special arrangements for the admission of fresh air. A wooden tube, six or eight inches in diameter, commencing on the outside of the building, extending under the floor and ending in an opening behind the stove, affords an excellent means for that purpose.

How will the air of this tube move when the stove is heated? How is this current of air produced?

A simple mode of admitting fresh air without causing draught is to raise the lower window sash from four to eight inches, and to close up the space below with a board. By this means a draught in the lower part of the room is avoided, and through the opening thus made between the upper and lower sash, a current of air is directed upward, toward the ceiling, where it diffuses throughout the room; or several small elbow-tubes may be fitted into the wall and turned upward in the room.

Some persons may object to these means of ventilation on account of the cost. They will find, however, that the cost is much lower then they upon first thought suppose. The stove may need a little more coal, but good ventilation will improve the health of all the inmates of the house, and money will be saved that otherwise might be spent for drugs and the doctor.

CHAPTER V.

CIRCULATION.

SECTION I.

MACHINES FOR MOVING WATER.

125. HERO'S FOUNTAIN. Fill a glass bottle half full with water, perforate a cork and pass a clay pipe or glass tube through the opening. Connect the cork and the neck of the bottle air-tight. How can you test whether or not the two are connected air-tight?

A Hero's fountain consists of a bottle partly filled with water and a tube whose lower end reaches into the water. The neck of the bottle and the tube are connected air-tight by means of a perforated cork.

Blow very forcibly through the pipe or tube, which reaches nearly to the bottom of the bottle. What happens when you stop blowing?

Fig. 34.

126. THE SYRINGE consists of a tube terminating in a small orifice and a piston. A piston is a short cylinder that fits air-tight into a tube.

When the narrow end of the syringe is dipped into water, and the piston moved upward, the space below the piston becomes greater and the air, thinner. The outer air, being denser, forces some of the water into the tube. When the piston is pushed in, the air inside grows denser and throws the water out. (Compare with ¶ 102-3.)

Fig. 35.

Use the word volume, which means **"the space which a thing occupies"** in the above explanation.

127. THE SUCTION-PUMP. Suppose I hold the syringe vertically, with the opening turned downward, and raise the piston so as to get some water into the tube. If I press the piston back, the water will squirt out. I want to prevent this. I want near the opening an arrangement that will allow the water to come in, but prevent it from flowing out; that opens when pressed upward, and closes when pressed downward. This is accomplished by a heavy round object that fits exactly where the tube begins to get narrow. We call such an arrangement a **valve.**

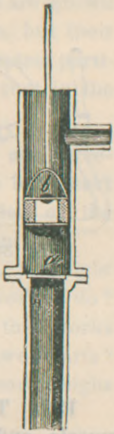

Fig. 36.
Suction-Pump.

The suction-pump consists of a barrel (or cylinder) with a piston, a suction-pipe, and two valves. One valve (b) is in the piston, the other (a) at the upper end of the suction-pipe. Both valves allow the water to move upwards, not downwards.

A valve is an arrangement that allows a fluid to flow in one direction only. How do the valves of the suction-pump act when the piston is raised? When it is lowered? What is the use of the side-tube?

128. THE FORCE-PUMP consists of a barrel (or cylinder) with a piston, a suction-pipe, a side-tube near the lower end of the barrel, and two valves. One valve is at the upper end of the suction-pipe, the other in the side-tube. Both valves allow the water to move away from the suction-pipe, not toward it.

How do the valves act when the piston is raised? When it is lowered?

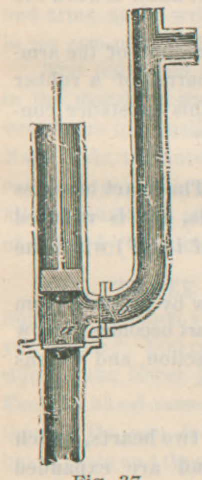

Fig. 37.
Force-Pump.

129. THE RUBBER SYRINGE consists of an oval rubber bag, with two rubber tubes attached. Each tube contains a valve, one of them allowing a fluid to flow towards the bag, the other, from the bag.

Place the end of one tube into water (do not take the wrong tube), and periodically press the bag. What takes place? What makes the bag assume its former shape, after the pressure ceases? What prevents the water from squirting out from the same tube through which it entered? Give a full description of the work of the rubber syringe. Pumps or syringes of this description are used by physicians. We have a similar arrangement in our bodies, an arrangement by whose action a very useful fluid is set in motion. What is its name?

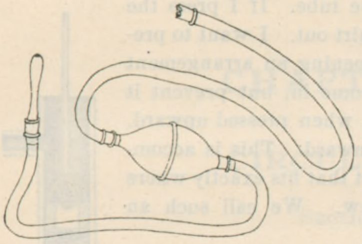

Fig. 38. Rubber Syringe.

SECTION II.

THE BLOOD.

130. THE HEART consists of a barrel, or bag, made of muscle, and tubes leading to and from it. (See Fig. 31.)

Muscle, or muscular substance, is what we usually call flesh. It has a power peculiarly its own, the power to become shorter or to contract. You can feel that, if you place your right hand upon the inner side of the left upper arm and move the left hand toward the shoulder. What do you notice?

The greater thickness is caused by the contraction of the arm-muscle. Now suppose an oval bag, like the barrel of a rubber syringe, were built of muscular substance, and this substance contracted; how would the inner space be changed?

131. MOVEMENTS OF THE HEART. The heart becomes narrow by the contraction of its muscular walls, and is widened (not by its own action but by a power outside of itself) when the contraction ceases and the blood rushes in.

The bag of a rubber syringe becomes narrow by pressure from without and widens by its own elasticity; the heart becomes narrow by its own activity, which is the power of contraction, and widens when discontinuing to contract.

132. TWO HEARTS. Our body contains two hearts, which are grown together, and which contract and are expanded simultaneously.

It is a general mistake to speak of **one** heart, when, in fact, all men, all mammals, and all birds, have two distinct hearts, just as distinct as the two lungs. It is true that the two hearts are grown together, and that they contract and expand in unison, but their interiors are entirely separated from each other by a complete partition, and the blood in one part is widely different from that in the other.

133. LEFT AND RIGHT HEART. Our hearts are force-pumps that drive the blood through the body. The left heart forces the blood through the body (with the exception of the lungs); the right heart forces the blood to the lungs only.

The left heart is sometimes called the **body heart,** the right heart, the **lung heart.** Which of the two has more work to do? How does a muscle that works much, differ from one that works less? What difference, therefore, is there between the two hearts? The two hearts have equal capacities, but the left heart weighs twice as much as the right heart.

134 THE BLOOD-VESSELS. All the blood of our bodies is contained in blood-vessels. Blood-vessels are tubes carrying blood.

You can see or feel blood-vessels on the back of your hands and arms, at the wrist, at the sides of the lower jaw, at the temples, in the arm-pits, at the back of the foot.

The red blood shines through the skin on the cheeks, the lips, in the mouth, in the tongue, and at other places. Here the blood-vessels are too small to be seen without the use of the microscope. Nails, hair, the outer skin, the hard substance of our teeth, and the cartilage are without blood. All the other parts of the body are filled with blood, so that a person can not stick a pin into any part of his body without drawing blood at once.

135. THREE KINDS OF BLOOD-VESSELS. Put your finger on a blood-vessel at the inner side of your wrist. What do you notice? You can feel the same at several other places—at the sides of the lower jaw, at the temples, at the back of the foot, etc. Feel the blood-vessels on the back of the hand or arm. Try to press them. Do you feel the difference between those in which the blood beats and those in which it does not? Examine a blood-vessel that you take from a piece of veal, from a liver, or from a piece of roast. Describe it.

Arteries are blood-vessels with stiff, elastic walls; veins are blood-vessels with thinner and inelastic walls. Capillaries are the narrow blood-vessels between the two.

The blood in the arteries beats or pulsates, that is, the arteries grow periodically wider and longer. This is caused by the action of the heart, which presses blood into the full arteries. The veins are the blood-vessels in which the blood returns to the heart; they do not beat or pulsate. The capillaries connect the ends of the arteries with the beginnings of the veins.

136. NECESSITY OF THE BLOOD. Why is it necessary to have blood everywhere in our bodies? What becomes of the old substances in our bodies? What two duties has the blood to perform? Suppose a muscle has been working continuously for some time, till it has become tired; what important service will now be done by the blood?

Blood is necessary in all parts of the body, because it brings them fresh substances and carries away the old. Every active organ throws off waste material and needs fresh material to work with.

A working muscle is similar to a steam engine, which uses fuel, throws off ashes, and produces motion. Muscles are not the only parts of the body that work and, consequently, need blood.

137. COMPOSITION OF THE BLOOD. Does the blood contain everything that is contained in a muscle? How do you know? The same is true of other parts of the body; consequently, blood contains all the substances of the bones, eyes, tongue, skin, lungs, stomach, liver, heart, throat, teeth, brains, nerves, tendons, hair, intestines, etc. You may shorten the list by using one word.

Blood contains every substance or material in our bodies; it is the liquefied body.

Suppose you visit a large factory, consisting of many rooms containing a great variety of tools. Suppose the factory produces red cloth, white cloth, porcelain knives, stone pillars, shovels made of horn, photographic apparatus, musical instruments, soft brushes, sieves, drop curtains, and many other things. You ask where the laborers are, and are told that there are none, but that there is a curious red fluid carried to every single article, and that this curious red fluid has manufactured all the articles. It is further asserted that not only the articles, but the tubes in which the fluid runs, nay, the factory itself, with all the splendid large rooms, are the work of nothing but this fluid.

You think this is a story from fairy-land, and yet it tells only what may be said of our blood. The factory with its rooms is what? And what are the various articles mentioned?

138. NEED OF MOTION. Put your finger on one of the arteries at your wrist and feel your pulse. Try to count the beats in exactly one minute. Try again. Spend some time in obtaining this number as exactly as you possibly can. **Rise.** Count again. What is the average this time? How many more than at first? **March in place.** Count again. How many more this time?

Suppose you should count while you are running; what would be the result? And if you should lie down on a lounge; what would be the number of beats? What do we learn from these observations?

The blood runs slowly in persons lying down, and gradually increases its speed when they sit, stand, walk, or run. Rapidly flowing blood carries off the old material more thoroughly and brings more fresh material in its place.

Which persons have more blood, are stronger, and enjoy better health, those who lie down and sit much, or those who stand, walk and run more? What causes their better health? Do you really believe that running is healthful? If you train yourselves, you will be able to run a long while without being exhausted.

In ancient Greece every one—man, woman, and child—was regularly trained in gymnasia, and daily exercise was taken in rapid running. Now most persons exercise running only when they want to board a street car. Name a few animals remarkable for their speed. How about elephants, hippopotami, fat hogs, bears, and other heavy animals? What does that teach about fat persons? What do you think about walking matches?

139. FUNCTIONS OF CAPILLARIES. We have heard that blood may be called the "liquefied body", that it carries away old material from, and brings new material to, all the organs of the body. Where may this exchange of material between the blood and the organs take place most successfully—in the arteries, in the veins, or in the small blood-vessels between the two? Why? Will this exchange of material take place more successfully in vessels with thick walls or in vessels with thin walls?

The exchange of substances between the blood and the organs of the body takes place through the walls of the capillaries, which are extremely thin.

All organs containing blood have numerous capillaries. The heart, arteries, and veins have no other purpose than to provide the capillaries with the necessary material.

140. THE TWO KINDS OF BLOOD. An important exchange occurs in the capillaries of the lungs; the air changes and and the blood changes. State the changes of the air. The oxygen lost by the air is taken up by the blood, and the carbonic acid and vapor, which are taken up by the air, are lost by the blood. Accordingly there are two kinds of blood.

The light-colored blood is loaded with oxygen, which is taken from the air; the dark blood is loaded with carbonic acid and water, which are taken from the various organs of the body.

How does the color of the blood change in the lungs? The opposite change occurs in the capillaries of the body. Name the two systems of capillaries and state the change of the blood in each of them.

141. SUBSTANCES FOUND IN BLOOD. Blood consists of a fluid called plasma and billions of solid blood cells. The blood cells have the form of circular discs thin in the middle and thick at the margin or edge.

Fig. 39.
Blood Cells.

Fig. 39 shows how the blood cells look when greatly magnified. A piece of money pressed together in the middle and thickened at the margin, would be a fair representation of their form.

It is remarkable that they are so numerous. There are thousands in every single drop, and thousands of millions in the body of every person.

In a healthy person about one-half of the blood consists of blood cells; the other half is plasma. But the quantities vary. A person who is poorly fed, or one who suffers from want of sleep, has a small number of blood cells. They increase after a meal, after a sound and healthy sleep, and after a long stay in fresh air and sunshine. A look into a person's face usually shows whether he has a sufficient number of blood cells or not. How ?

142. PLASMA consists of fibrin and serum. Plasma is blood less the blood cells ; serum is plasma less the fibrin.

Blood forms a clot over a healing wound. The clot consists of coagulated fibrin and encloses a great number of blood cells. Blood taken from a living body separates itself into a clot containing fibrin and blood cells, and a watery liquid, the serum.

143. THE HEART. We have compared the heart with a rubber syringe. Is there a pulsation in the water which is pressed out of the syringe ? Does the water run in continually, or in successive impulses ?

The heart, too, forces the blood out in successive impulses, just as the rubber syringe does with the water, **but it receives the blood in a continuous stream.**

I wish you to clearly understand this peculiarity of the heart. The blood is forced out in successive beats or impulses, and it flows in without interruptions. Suppose we had the same in a rubber syringe; what would become of the water which runs into *v*, while *h* contracts, (see Fig. 40)?

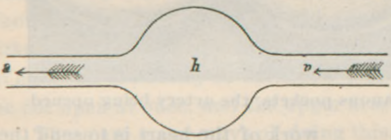

Fig. 40.

If the water **collects** in *v*, the walls have to extend, so that a kind of reservoir or receptacle is formed there. Such an arrangement is found in the heart at the place where the veins discharge their blood. Here it collects while the heart contracts.

Each of the two hearts has a receptacle where the blood collects while the heart contracts.

How many valves are there in the rubber syringe, and where ? The heart has two valves at the same places and for the same purposes; a valve at the outlet, to prevent the return of the blood from the artery when the heart expands, and one at the inlet, to prevent the return of the blood into the receptacle when the heart contracts.

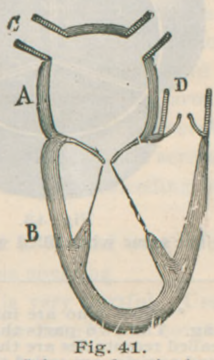

Fig. 41.
Scheme of a single heart.
A, receptacle ; *B*, heart ; *C*, vein ; *D*, artery.

Each heart has two sets of valves, one where the receptacle *opens into it,* and *one* where the artery commences.

144. DISSECTION OF A HEART. You may now examine a real heart. Each pupil must bring a heart from a butcher and do his own dissecting. It does not help you much, if some one else does the work for you. You will have to find and describe the following: the left heart and the right heart; the left receptacle and the right receptacle; the two sets of valves between the receptacles and the hearts; the two sets of valves at the outlet of each heart.

Examine the size of the receptacle; it holds nearly as much blood as the heart itself, but its walls are much thinner. This is because it has less work to do. What is its work? The

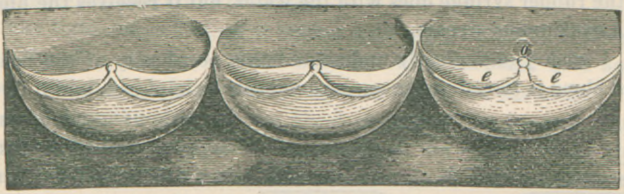

Fig. 42. The three membranous pockets, the artery being opened.

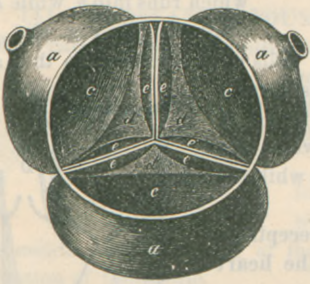

Fig. 43.
The same when filled with blood.

work of the heart is to send the blood a great distance through a system of arteries. Consequently the walls of the heart must be stronger and more muscular then those of the receptacle.

The outlet of the right heart is in front of that of the left heart. The valves at the outlets consist of sets of three membranous pockets. *

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* Those who are interested in scientific names may learn the following. The two parts that we called hearts are the *ventricles;* what we called receptacles are the *auricles;* the flap-valves between the ventricles and auricles are ealled the *bicuspid valve* (left heart) and the *tricuspid valve* (right heart); the sets of membranous pocket-valves are called *semi-lunar valves;* the artery into which the right heart sends its blood, is the *pulmonary artery*, that of the left heart, the *aorta*.

145. HOW TO TREAT WOUNDS. A wound may heal quickly without causing much pain, or the same wound may annoy a person for a long time. Why is this ?

Wounds properly attended to heal quickly, without causing much pain ; wounds not properly cleansed and cared for become inflamed and cause pain.

The first step in the treatment of a wound is to stop the bleeding.

The bleeding of wounds in which the blood is furnished by **capillaries** only will either soon stop of itself, or it will do so if cold water or ice be applied. Bleeding from a **vein** is not usually serious and may also be stopped by the application of iced water or bandages kept cool by ice or soaked with a solution of alum.

But if a larger **artery** should be cut or torn and the light-colored blood continue to flow in spite of pressure upon the wound, there is danger of bleeding to death. In such a case a physician should be called at once, that he may tie up the artery. Meanwhile some person present should try to press upon the trunk of the artery at a place above the wound. If, for instance, the artery at the wrist should be severed, where should you try to press ? At the same time raise the injured arm so that the hand will be above the head. Why ? If the artery in the elbow-joint be cut, the sleeves should be cut open at once, and the upper arm be firmly compressed.

There are many ways of doing this. If you have a long piece of rubber, tie it firmly around the arm several times. If you have a bandage, use it in the same way, always placing one turn directly over the other, then tying the ends together, and pouring water on it in order to make it tighter. Elastic suspenders make very suitable compressors ; soldiers and travelers should have no other kind. If you have only a handkerchief or a towel, tie it around the arm, put a cane, a stick, or a key under it, and twist it around several times ; or tie your bandage over a suitable piece of wood laid across the artery, and do not cease your endeavors, till the bleeding is stopped.

If afterwards a clot of coagulated blood is formed over the wound, do not remove it ; it is the best possible covering.

Remember that dust or dirt in a wound is very hurtful. Use neither shreds of cotton nor linen (charpie or lint)*, nor court-

* Except the antiseptic preparations sold by druggists.

plaster, nor old sponges, dirty linen, spider-web, nor any other possibly dirty object, nor touch the wound with unwashed fingers.

The **least amount** of dirt or dust, even the invisible dust of the air, may cause inflammation, putrefaction, or the production of pus. Everything that touches the wound should be scrupulously clean.

CHAPTER VI.

THE SKIN.

146. QUALITIES. Where is the skin? Can you lift the skin from the organs underneath? What kind of covering, therefore, is the skin?

The skin is a loose, elastic covering of the whole body.

147. THICKNESS. Compare the thickness of the skin on the neck, the throat, and on one of the eye-lids.

As a rule the skin is thin on the front of the body and on the inner side of joints and limbs; it is thick on the back of the body and on the outer side of joints and limbs. On the neck it is about as thick as on a calf— $\frac{1}{12}$ of an inch.

Examine the skin of the hand, the inner side of the fingers, the palm, the outer side of the fingers, the back of the hand. Where do you find numerous folds? Where are they curved, where straight, concentric, parallel, or crossing each other? Where flat? Where deep?

148. WHAT IS FOUND IN THE SKIN. Lift your hand as high as your eyes. What do you find at its surface? The whole skin, except at the palms and soles, is covered with hair. What is found in the skin of the fingers and toes, but not in the skin of other parts of the body? What fluid substance is occasionally found upon the skin? What is the name of the organs secreting sweat or perspiration? Another substance, occasionally found upon the skin, is a kind of oil or fat. You can prove the existence of this substance by touching tissue paper when your fingers are moist with sweat. How does the appearance of the paper change? What is the name of the organs secreting oil? What causes the red color of the skin? How can you prove that there are nerves in the skin?

In the skin, or attached to it, are hairs, nails, sweat-glands, oil-glands, blood-vessels, and nerves.

Blood causes the red color of the skin; nerves cause its sensibility.

149. THE TWO LAYERS OF THE SKIN. The skin consists of two parts, or layers—one outside, the other inside. The layer outside is called the scarf-skin (epidermis); the layer inside, the true skin (dermis). The scarf-skin has neither blood-vessels nor nerves; the true skin contains blood-vessels, nerves, and the bases of hairs, nails, sweat-glands, and oil-glands.

We may cut into the scarf-skin with a sharp or pointed knife, or we may tear off a piece with a pin without causing pain. A separation of the two layers is caused by a blister, such as appears after the skin has been scalded or burned.

150. THE-SCARF SKIN. Where is the scarf-skin thick? What persons have a thick and hard scarf-skin on their hands? What persons have a thick scarf-skin on their soles? What causes the scarf-skin to become hard and thick?

We say of persons having a hard skin that their hands are **horny**—we speak of a **horny fist.** An accurate comparison between horn and the substance of the scarf-skin shows that the two are closely allied. The whole body is enclosed by a true horny covering, which, through suitable training, may become an effective protection from blows and similar injuries.

When you tear off a piece, what difference do you observe between the inner and the outer surface of the scarf-skin? How does it affect the outer part of the skin, if you rub it with a rough towel, particularly after a warm bath?

The scarf-skin becomes hard and horny by frequent pressure. Its inner surface is soft and moist; its outer surface is dry and hard.

The scarf-skin continually peels off. The more active the skin is, the greater is the quantity of surface material that may be rubbed off.

151. THE NAILS. Where are the nails? What two parts may be distinguished in a nail? Press that part of the finger that is directly under the nail, on a desk, and try to trace the inner end of a nail. What appendages of cats, cows, and horses correspond to our nails? In what respect are nails similar to claws and hoofs?

We may distinguish two parts in a nail,—the part outside and the part inside (the base.)

152. HAIR. The hair is similar to the nail in having two parts—one longer part outside, and one shorter part inside. In what part of the nails and hair are there nerves and blood-vessels? What is the use of blood-vessels in the bases? The function of the nerves is to regulate the secretion of the material necessary for the growth. Examine Fig. 44 to see how the inner end of a hair is connected with the skin.

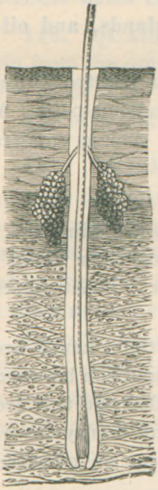

Fig. 44.

The longer part of a hair, outside of the skin, is called the SHAFT, the shorter part inside, the ROOT or BASE. The root is enclosed in a kind of bag formed by the true skin and called the hair-sac. From the bottom of this bag a PAPILLA arises. The papilla is full of blood-vessels and nerves.

Usually two oil-glands open into the hair-sac near its upper end and supply the hair with oil, a kind of natural pomatum.

Baldness may be caused in various ways, and, sometimes, can not be prevented. To avoid it, cleanse the skin of your head carefully, and be temperate in all your habits. Every morning cleanse the scalp with a fine toothed comb. If the hair be dry, use a small amount of oil or fat (pure vaseline is excellent), and occasionally wash the head with soap and water. Do not wear a cap or hat when you can avoid it; the head needs fresh air. Do not have the hair cut too short.

153. THE SWEAT GLANDS. They are found over all the skin. They are very numerous in the palms, where their outlets (the pores) may barely be distinguished with the naked eye.

Examine those at the tips of your fingers with an ordinary lens or burning-glass.

A sweat-gland (see Fig. 45) **is a narrow tube that commences at the surface and penetrates the skin to a depth of about one fourth of an inch. There it coils up into a small bundle, or knot. This is surrounded by a net work of capillaries.**

Why are the capillaries close to the coils of the sweat-glands? What is the use of nerves in the same places? On what occasion do we perspire much? A slight perspiration goes on continually, even when the sweat is not visible. The amount of sweat that we lose in one day varies between one and three and a half pounds. Suppression of perspiration is unhealthful.

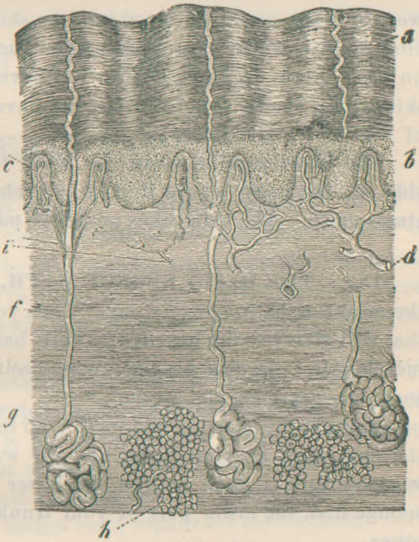

Fig. 45.
a, outer part of scarf-skin; *b*, inner part of the same; *c*, papillæ; *h*, fat cells; *g*, sweat glands; *d*, blood-vessels; *i*, nerves.

154. THE PAPILLÆ. What organs of the skin are connected with nerves? Besides, the skin contains numerous other nerves which are the true organs of touch and feeling. To understand how these are arranged you may examine Fig. 45, which represents an enlarged view of a vertical section of the skin. Show the scarf-skin, the true skin, the sweat-glands, the blood-vessels and the nerves. Describe the surface in which the scarf-skin and the true skin touch each other.

The surface in which the true skin and the scarf-skin touch each other has a great many small elevations called papillæ. * **Some papillæ contain blood-vessels, some, nerves.**

Are there more papillæ with blood-vessels or more with nerves?

* The Latin name for warts.

155. THE NERVE-PAPILLÆ are the organs of touch and feeling.

By means of the nerves in the papillæ we discover whether substances are rough or smooth, hard or soft, warm or cold.

156. BLOOD-PAPILLÆ. What is the use of blood-vessels in the skin? What takes place when blood and air are separated by a thin membrane? Why have some persons a fresh, ruddy, healthy-looking skin, while in others the skin looks faded and sallow? When does the skin look healthier, in summer or in winter? In winter we can not have as much air and sunshine as we desire, but we can bring plenty of blood into the skin, if we are not too lazy. How do you warm your fingers when they feel cold and you have no fire? How do you feel after you have thoroughly rubbed your skin with a coarse towel? Why not have this comfortable feeling of health and strength every day?

The blood-papillæ allow the blood to come close to the outside of the body where it may interchange its gases with the atmosphere. The skin takes an active part in respiration.

157. THE DAILY SPONGE-BATH. Many of you have not the means of bathing every day. Then you may learn of a method that will give you the benefit of a daily bath without any cost worth mentioning. All you need is a wash-basin with water, a piece of soap, a big sponge, and a rough towel.

Early in the morning first wash your face and ears, then undress the upper half of your body, and use water, soap, and towel to wash and rub it, then undress the lower half of your body, and sponge first, the lower part of your trunk, then one leg, then the other.

The rubbing with a coarse towel is necessary and should not be hurried. Even in a cold room you will not catch cold or even feel cold, if you take a sponge-bath; on the contrary, you will feel warm and comfortable, and, what is still better, will harden your body and protect yourself from colds.

What effect has the rubbing upon the scarf-skin? What effect has it upon respiration, if the scarf-skin is thin? What upon the acuteness of touch? Upon perspiration? Upon the amount of blood in the skin?

The daily sponge-bath produces an increase of respiration, perspiration, and warmth, a greater acuteness of the sense of touch, and a healthier look.

Nothing so simple and inexpensive is of equal benefit to your health and energy as a daily sponge-bath of the entire skin. Those who unfailingly take a daily sponge-bath are best protected from colds and infectious diseases.

CHAPTER VII.

EXCRETION.

158. LUNGS AND SKIN. To excrete means to throw off what is useless. What two substances are excreted by both the lungs and the skin ? The skin excretes a small quantity of carbonic acid and a considerable quantity of water. Does the skin excrete the same quantity of water daily, or does it lose much on some days and little on others ?

Lungs and skin excrete carbonic acid and water. The amount of water excreted by the skin varies greatly: we lose much water when it is hot or when we sweat; we lose little water when it is cold or when we do not move about much.

Since there are great variations in the quantity of water that the skin excretes, our bodies need organs for the discharge of the surplus water, or of that amount of water which is prevented from leaving through the skin. These organs are the **kidneys** and the **bladder.**

159. KIDNEYS. Examine a pig's or sheep's kidney. What is its shape ? The human kidney has the same shape. What can you say of its appearance and its other qualities ? At what place is it connected with other organs ? What organs can you distinguish at the concave side ?

Examine the interior; cut through the kidney with a sharp knife; lead the knife all around the margin. The white substance is fat. Try to take away as much of it as you can without injuring the surrounding parts. Notice that there is a small cavity, or basin. Look at the brown substance. Do you see any lines indicating a special arrangement of this substance? Find out what part of the outside is attached to this cavity.

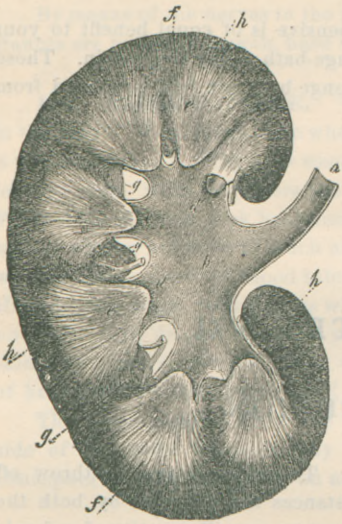

Fig. 46.
Section through the Kidney of a Child.

The kidneys lie in the back of the abdominal cavity, one on each side of the back-bone. Each is of the size of about one half of its owner's fist, has the shape of a bean, is brown in color, smooth, and softer than meat. The interior contains a small cavity or basin located near the concave side.

The light brown substance is separated into a darker part near the outside and a lighter part further on the inside. The latter is again divided into seven or eight conical pieces with the points, or apices, directed toward the cavity. The cavity is continued in a long tube called the **ureter.**

160. THE RENAL* ORGANS. Examine Fig. 47, and name the objects, or organs, represented.

What organs are connected by the ureters? At what place do the ureters unite with the bladder? What is the use of the blood-vessels represented in Fig. 47? It is not pure water which the kidneys excrete, it is urine, a liquid containing about 95 per cent. of water.

The renal organs consist of the two kidneys, several blood-vessels, the two ureters, the bladder, and the urethra.

* Renal means pertaining to kidneys (renes).

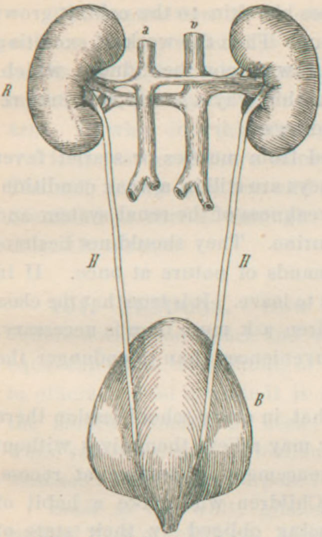

Fig. 47. The Renal Organs.

The kidneys excrete urine from the blood which the blood vessels bring to them ; the urine flows through the ureters into the bladder ; and the bladder discharges the same through the urethra.

A muscular ring at the base of the urethra keeps the bladder closed when no urine is being discharged.

161. URINE contains 95 per cent. of water and 5 per cent. of dissolved substances. The most important of the latter is urea, a substance containing nitrogen.

Substances containing **nitrogen** are excreted by the kidneys almost conclusively. If the kidneys are disordered, if their function is obstructed, and the urea retained, serious consequences follow. If this condition lasts, the person can not live.

162. HYGIENE OF THE KIDNEYS. Why can the kidneys not be spared from the body ? If both kidneys be cut from a living animal, it dies in a few hours from blood-poisoning. What has poisoned the blood ? Is the work of the kidneys the same every day or is it sometimes great and sometimes small ? When does the skin excrete a very small amount of water ? Does more water leave the skin of a person who takes a daily sponge-bath, or of one who does not ? How does dirt prevent the excretion of water from the skin ? Whose kidneys have more work, those of a cleanly or those of an uncleanly person ? Whose skin contains more blood ?

Whatever increases the amount of blood in the skin increases respiration and relieves the kidneys; whatever decreases the amount of blood in the skin decreases respiration and throws work on the kidneys. Imprudent exposure to cold, particularly in the early stages of recovery from measles or scarlet fever, may cause incurable kidney diseases.

If a person imprudently exposes his skin to the cold, it grows pale, because the blood is driven out. Then the work of excreting a sufficient quantity of water is thrown upon the kidneys, which, consequently, are overworked. In this way a severe cold may result in a serious disease of the kidneys.

Children having just recovered from measles or scarlet fever must be careful, because their kidneys are still in a weak condition.

Some children suffer from a weakness of the renal system and often feel the need of discharging urine. They should not hesitate to do so, but comply with the demands of nature at once. If in school, they should ask permission to leave. It is true that the class is disturbed, and that careless children ask more than is necessary. Yet it is better to suffer these inconveniences than to endanger the health of any one.

Children should be reminded that in every school-session there are three distinct times when they may relieve themselves without disturbing the class: before commencement of lessons, at recess, and at the close of the session. Children who make a habit of leaving between times, without being obliged by their state of health to do so, are careless and disorderly.

CHAPTER VIII.

MUSCLES.

SECTION I.

STRUCTURE AND FUNCTION.

163. CONTRACTION. What name is given to muscles by the butcher and the housekeeper? Place your right hand at the inner or front side of your left arm and raise your left hand toward the shoulder. How does the muscle change?

The muscle at the front of the upper arm grows thicker and shorter when the hand is raised toward the shoulder. Muscles contract.

The contraction of the above-named muscle is caused by the will, or energy, which has its seat in the brain. If the will, having its seat in the brain, causes the contraction of muscles situated in the arm, there must be a connection between the brain and the arm. Of what does this connection consist?

It is just as if there were **telegraph wires** between the two. The will, acting upon one end of a nerve, gives a command. The command is carried through the nerve to the muscle, and the muscle contracts.

164. TENDONS. How far does the arm-muscle extend? Where does it commence and where does it end? Is the muscle of equal thickness throughout, or is it thick in some places, and thin in others? Feel it while it is slowly contracting. The middle of the muscle consists of flesh; the two ends are made of a tough, white substance called a tendon. To what are the ends of a tendon attached? For what purpose?

Look at the white glistening pieces sticking out from the severed feet of chickens, geese, and turkeys. They are tendons. Pull one of them. What takes place? Stretch your fingers forcibly, what do you feel near the bases of the fingers? These pieces, too, are tendons; they resemble the white glistening ribbons in the chickens' feet. We may compare the tendons with ropes fastened to a heavy body and pulled by some power placed at the other end. What is the load, and what is the power, when the forearm is bent?

The two ends of the arm-muscle (and of many other muscles) consist of a tough white substance and are called tendons. The tendons connect the muscles with bones. When the muscles contract, the tendons pull the bones.

165. CONNECTIVE TISSUE. (See Fig. 25.) Get the leg of a rabbit, squirrel, or any other small animal. Carefully remove the skin. The substance found close under the same is called the connective tissue. What does it connect? It is also found between the muscles. It forms a sheath, or envelope, for every muscle.

Connective tissue is a loose, white substance found throughout the body. Not only the muscles, but also the nerves, bones, and blood-vessels, the heart, lungs, and all other interior organs are surrounded by membranes consisting of connective tissue. At other places it has the office of packing material, filling out the spaces between adjoining organs.

Without connective tissue, the relative position of our organs would change continually. It keeps the organs and the various parts of each organ in their places, and prevents a dislocation of any part inside of our body.

Muscles, nerves, blood-vessels, and the other parts of our body are kept together and in their places by a white, loose substance called connective tissue.

166. FIBRES. To see a muscle in its whole extent, tear the connective tissue all around it, or cut and remove it. What shape has the muscle? How does it look and feel at the surface?

The elements of a muscle extend lengthwise. They are called fibres.

Fibres are from a half to one and one half inches long, and are placed regularly alongside of and behind one another.

167. CONTRACTION AND EXPANSION. Let us return to the above-mentioned muscle of the upper arm. Suppose it has contracted and the fore-arm is bent; how is the arm made to take its former position? You may discover it by slowly bending and forcibly stretching your lower arm about twenty times. At what place do you feel your upper arm grow tired? How is that caused? How is the upper arm made to perform the two opposite motions of bending and stretching?

The only active work of the muscles is their contraction; their expansion is passive. Muscles contract and are expanded.

What adjective may we use to denote the ability of muscles to contract? Change this word to a noun.

168. ATTACHMENT OF MUSCLES. To what are the muscles of the fore-arm attached? Those of the neck? Are the two ends of a muscle attached to the same bone or to two bones, and why? Are bones the only parts of the body moved by muscles, or can you name other parts moved by them, while the nearest bones remain in their places?

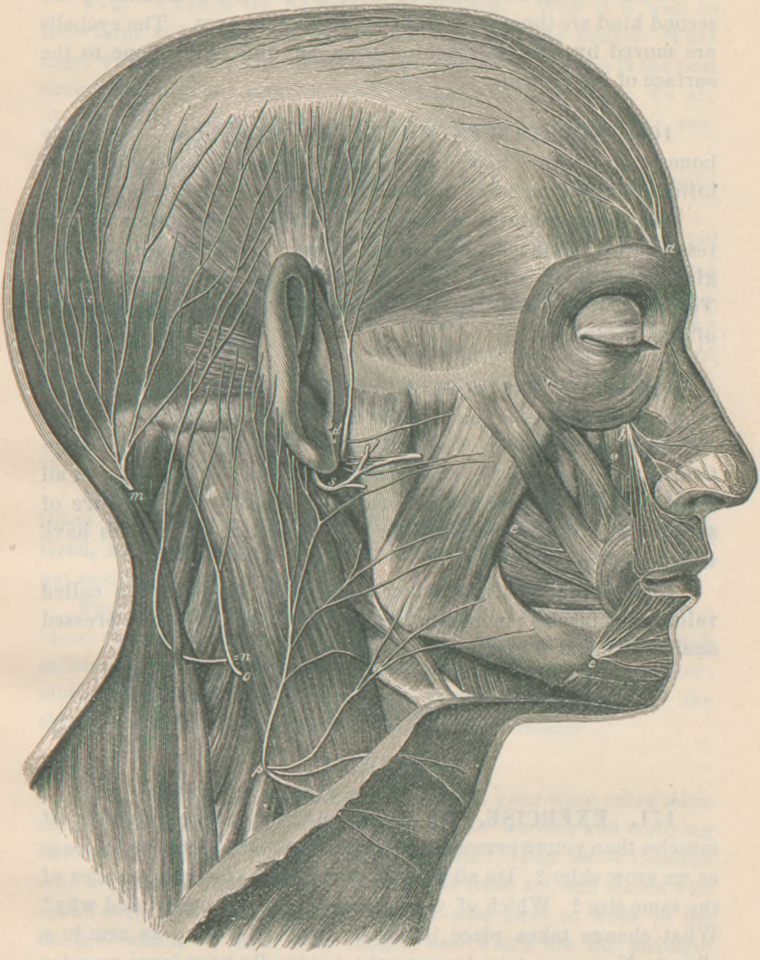

Fig. 48.
Muscles and Nerves of the Head.

Many muscles are attached to two bones and move one bone toward or away from the other. A few muscles connect two places in the skin, or they reach from an underlying bone to the upper soft parts.

Muscles of the first kind are those of the limbs ; muscles of the second kind are those around the mouth and the eyes. The eyeballs are moved by muscles reaching from an underlying bone to the surface of the eyeball.

169. SUBSTANCES MOVED BY MUSCLES. Not only bones and skin are moved by muscles, but also foreign substances introduced into our body from without are moved by them.

Our body contains a number of tubes and hollow organs (esophagus, stomach, intestines, heart, tubes connected with glands, etc.) in which various substances are moved along. This motion is caused by the contraction of muscles in the walls of the organs.

170. TWO KINDS OF MUSCLES. When do the muscles of the esophagus contract ? Food widens the esophagus ; it exerts a pressure on its walls. The muscles of the stomach contract when food enters ; the heart contracts when it is filled with blood. In all these cases the contraction of muscles is caused by the **pressure** of substances. What two causes for the contraction of muscles have we mentioned ?

Muscles that contract when directed by the will are called voluntary muscles ; muscles that contract when they are pressed against are called involuntary muscles.

SECTION II.

HYGIENE.

171. EXERCISE. Do old persons have a larger number of muscles than young persons ? Does the number of muscles increase as we grow older ? Do all persons of the same age have muscles of the same size ? Which of your arms is usually stronger, and why? What change takes place if one is obliged to carry an arm in a sling ? Name some tradesmen who habitually have large muscles in their arms. What is the cause of the large size of their muscles? Why have storekeepers, teachers, merchants, and others smaller muscles ?

Muscles grow large and hard when they are used frequently and forcibly.

172. VALUE OF STRONG MUSCLES. Why is it well to have large and strong muscles in every part of the body? What must we do to have strong muscles everywhere? When is the best time to develop our muscles, when we are young or when we are old, and why? Name some exercises that you like and often perform, and the parts of the body they strengthen.

Do you perform any exercises that tend to strengthen your chest, your back, or your sides?

In most children the muscles of the neck and back are too weak to carry the head erect and to keep the shoulders and arms back. They need **suitable exercises** to strengthen these muscles.

A strong and wide chest is not the only benefit to be gained by daily exercise. What effect has exercise upon the current of blood? What functions of the blood are performed more thoroughly, if it runs quickly through the whole body?

How does exercise affect respiration? How does it affect the skin? How does it affect the appetite?

Persons with large muscles are stronger and healthier than those with smaller muscles. They feel better, are not easily tired, have sound sleep, enjoy their food, digest it well, and are not easily affected by cold.

Proper exercises increase our health and our well-being. The blood carries off the waste more thoroughly and brings more fresh substances to the organs; the breathing is deeper and quicker; more carbonic acid is thrown off, and more oxygen taken in; the skin becomes warm and ruddy; the appetite increases.

173. WORK AND SLEEP. When did your sleep bring more energy and vigor, when it followed a day of writing and studying indoors, or a day of lively exercise outside? You know children who are seldom allowed to enjoy play and fresh air, and others who spend every spare moment out-doors, or who have to work in the fields, — which of them sleep longer, and which are the stronger and healthier?

Persons who use their muscles vigorously do with less sleep, and are more refreshed by it than persons whose muscles are usually inactive.

Laborers, farmers, tradesmen, housemaids, and others who are used to hard labor, usually do not sleep so long as persons who have little muscular exercise. The less a person is used to hard labor, the more easily he is tired.

174. IMPROPER EXERCISE. A word of caution is necessary before we close this chapter. Some of you may think that, as exercise increases a person's strength and well-being, you should take it on every occasion and as much of it as you possibly can. But there is such a thing as over-work. Nature has put a limit to the amount of work that each person can do, and it is well to respect this limit. How do you feel after vigorous work ?

If you feel exhausted, it is but natural that you should rest. Exhaustion is the warning sign of nature. Stop your work and rest till you feel strong again. If you exercise regularly every day, you will soon be able to work a long while without feeling exhausted. Persons who do not stop when it is necessary, may be affected by valvular diseases of the heart. If they do it often, the whole body may prematurely decay.

Furthermore, the time immediately after a hearty meal is not suitable for muscular exercise; we feel disinclined to work then. If we overcome our disinclination, and work on, our food will be imperfectly digested.

Do not exercise when you are exhausted ; do not exercise immediately after a hearty meal.

CHAPTER IX.

LEVERS AND BONES.

SECTION I.

LEVERS.

175. THE SCALES. Examine a pair of scales, such as a grocer or a druggist uses. Show its essential parts. Which of these parts are movable ? Describe the motion of the iron beam.

The essential parts of a pair of scales are: the TWO SCALES; the IRON BEAM that supports the scales; the BASE, which supports the iron beam. The two halves of the beam are

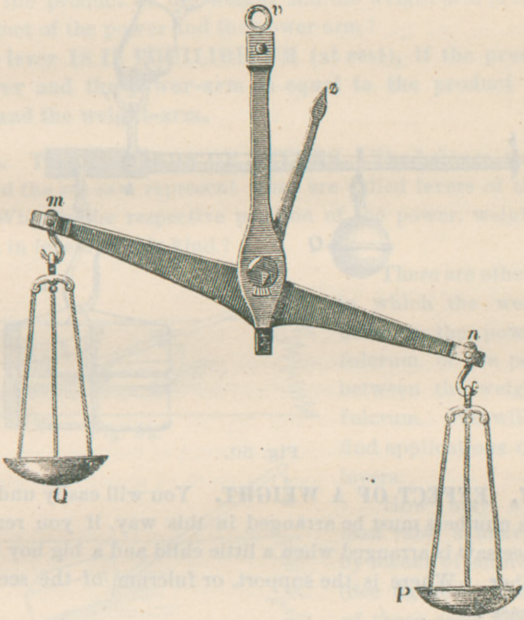

Fig. 49.

called the ARMS; the middle of the beam is called the FULCRUM; the beam itself is called a lever.

When is the beam or lever in a horizontal position?

176. THE STEELYARD is a lever with two unequal arms. Its fulcrum is the point about which it turns.

Butchers use a steelyard to find the weight of a pig or calf. The animal is hung on the short arm, and a ring to which an iron ball is attached, is placed over the long arm. The iron ball is put at the place where it balances the weight of the animal, and the number at this place tells its weight.

In what order are the numbers arranged on the long arm? Where are the lower numbers? What increases with the distance from the fulcrum?

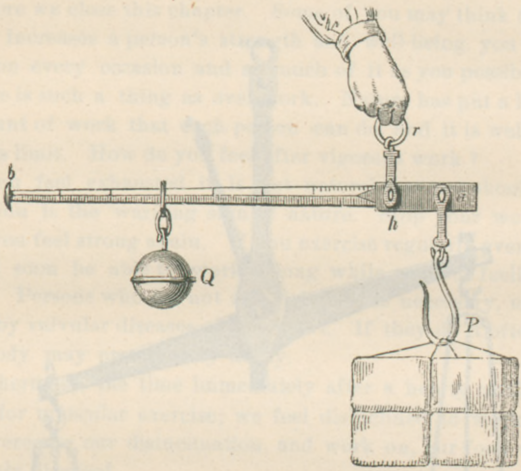

Fig. 50.

177. EFFECT OF A WEIGHT. You will easily understand why the numbers must be arranged in this way, if you remember how a see saw is arranged when a little child and a big boy balance each other. Where is the support, or fulcrum, of the see-saw in such a case?

A weight has more effect on a long arm of the lever than on the short arm.

178. THE LAW OF THE LEVER. We shall be better able to express the law of the lever, if we distinguish the two weights as **power** and **weight.** Suppose we have a lever whose arms have a respective length of four and eight inches; what power will balance a weight of ten pounds at the end of the shorter arm? Show this in a drawing. Demonstrate it with a

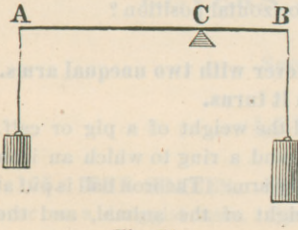

Fig. 51.

few small weights and a strong ruler supported by the top of a chair. What two pairs of these numbers must be multiplied together to obtain equal results? Substitute words for the numbers of the equation which you obtained. Which of the two arms may be called the power-arm? Which, the weight-arm? What takes place if the product of the weight and the weight-arm is equal to the product of the power and the power-arm?

The lever IS IN EQUILIBRIUM (at rest), if the product of the power and the power-arm is equal to the product of the weight and the weight-arm.

179. THREE KINDS OF LEVERS. The balance, the steelyard, and the see-saw represent what are called levers of the first kind. What is the respective position of the power, weight, and fulcrum in levers of this kind?

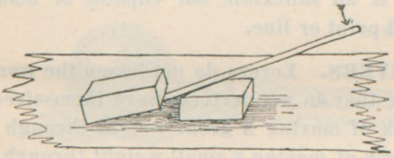
Fig. 52.

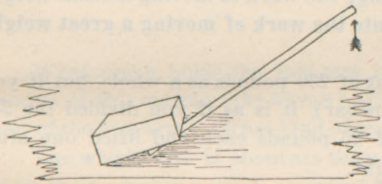
Fig. 53.

There are other levers in which the weight is between the power and fulcrum, or the power is between the weight and fulcrum. We will try to find applications of these levers.

How may a workman raise a heavy stone by means of an iron bar? (See figures). In which of these cases have we a lever of the first kind? The other case represents a lever of the second kind. Define it. What, then, is a lever of the third kind? An example of the last kind is a fishing rod held as the following figure shows.

Describe it. Suppose the fish weighs five pounds, the weight arm is eight feet, and the power-arm, two feet; how great must the power be to balance the weight of the fish?

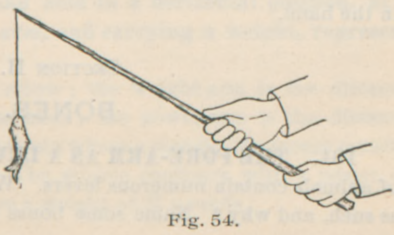
Fig. 54.

Twenty pounds will balance the fish in the air. While in the water, the fish uses its muscular power to pull with a much greater force. Anyone who has had a big fish on a line will remember that it took both power and skill to overcome the resistance.

A lever of the first kind is one with the fulcrum between the power and the weight; in a lever of the second kind, the weight is between the fulcrum and the power; in a lever of the third kind, the power is between the fulcrum and the weight.

What kind of lever is represented by a ladder raised by taking hold of one of the rounds while placing the foot against the end? What kinds are represented by a door pushed very near the hinges? By a door taken hold of at its edge? By a spade? A wheel-barrow? A chopping-knife? An oar? A sling for throwing stones? A pump-handle?

Definition. A lever is an inflexible bar capable of being freely moved about a fixed point or line.

180. WORK OF LEVERS. Levers do not lessen the work that is to be done, because they do not perform work themselves; but they change the work of moving a great weight through a short distance into the work of moving a small weight through a great distance, or they change the work of moving a small weight through a great distance into the work of moving a great weight through a short distance.

You cannot lift a weight of 250 pounds as a whole, but if you use a suitable lever (a crowbar), it is as if you divided the 250 pounds into 10 weights of 25 pounds each and lifted one after another to the required height.

You cannot move a stone lying in your hand with great rapidity, but by the use of a suitable lever (a sling) you increase the rapidity of the stone while exerting more muscular power. The same amount of muscular power would move a heavier stone lying in the hand.

Section II.

BONES.

181. THE FORE-ARM AS A LEVER. Our bodies and those of animals contain numerous levers. Which of our organs may act as such, and why? Name some bones and tell about what points they may be moved. Suppose the fore-arm and hand are in a horizontal position, at a right angle to the upper arm, and that they carry a weight of 25 pounds. Where is the fulcrum and where the weight-arm ?

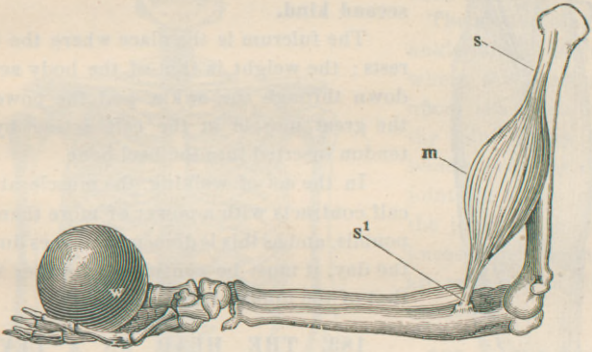

Fig. 55.

What organ holds the fore-arm in its place ? Where is the tendon of this muscle (the biceps) attached ? What is the power-arm of the fore-arm ? What kind of lever is the fore-arm, and why ?

The weight-arm is about six times as long as the power-arm. How great a power must be exercised by the contracting muscle in balancing 25 pounds ?

If we substitute a mechanical arrangement for a muscle, we should need this weight.

The fore-arm and hand held in a horizontal position, at a right angle to the upper arm, and carrying a weight, represent a lever of the third kind.

The fulcrum is at the elbow ; the weight-arm is the distance between the elbow and the hand ; the power-arm is the distance between the elbow and the space where a muscle (the biceps muscle) is attached to the bone. The muscle contracts with a power of about 150 pounds to balance a weight of 25 pounds.

182. THE FOOT AS A LEVER. Another instance of the use of a bone as a lever is found in the act of rising on the toes of one foot. What represents the lever, its fulcrum, weight-arm, and power-arm ?

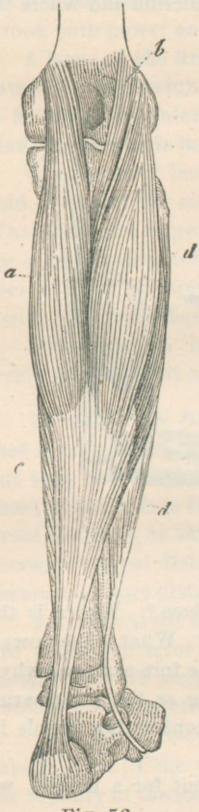

Fig. 56.

When we stand upon the toes of one foot, the foot represents a lever of the second kind.

The fulcrum is the place where the foot rests ; the weight is that of the body acting down through the ankle, and the power is the great muscle at the calf acting by its tendon inserted into the heel bone.

In the act of walking, the muscle at the calf contracts with a power of more than 100 pounds, and as this is done many times during the day, it must be considerably larger than that of the upper arm.

183. THE HEAD AS A LEVER. What position does the head take when no active, or muscular, power is exerted, as, for instance, when a person falls asleep in a sitting position ? How is it brought back into its erect position ?

In the movement of nodding, the head represents a lever of the first kind.

The fulcrum is the place where the head rests on the back-bone ; the weight is the fore part of the head (or the excess of its weight over that of the part behind the fulcrum) ; the power is the muscle of the neck acting by its tendon inserted into the back of the head.

What kind of levers are represented by the parts of our upper and lower limbs ? By the lower jaw ? Which teeth exert a greater pressure, the cutting teeth or the grinders, and why ? Why have cats and lions shorter jaws than oxen and horses ?

184. JOINTS. We will now examine the places that we have recognized as the fulcra of bones. Name those places. What name is applied to all of them? Name other joints in the body. What office, or function, have joints?

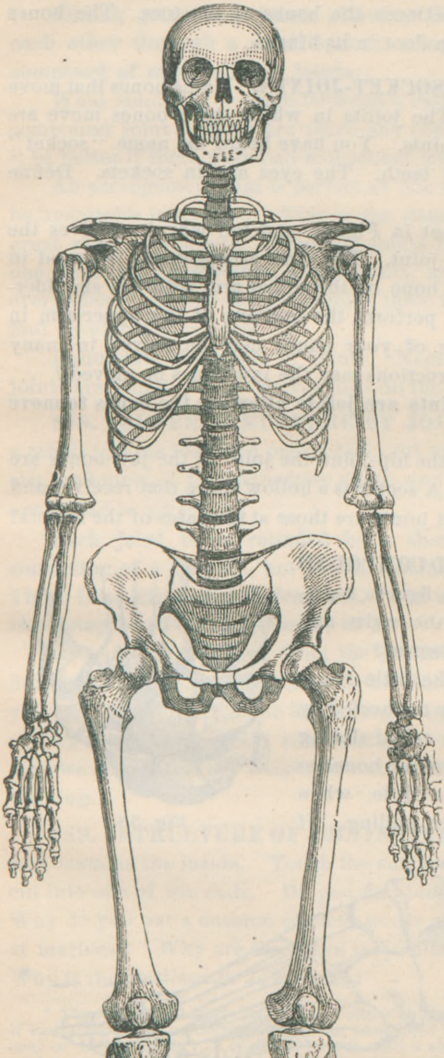

Fig. 57.

Joints are the places where two bones meet and where they can be moved about each other.

The elbow-joint, the ankle-joint, the place where the head rests upon the back-bone, the joint of the jaw-bone, the shoulder-joint, the finger-joints, the joints at the hips, knees, wrists, and toes, are examples of different joints.

185. HINGE-JOINTS. Examine the movements of the fore-arm. Name other joints that allow the bones to be moved like the fore-arm — in one plane only. What movable objects in your room are moved in the same way — in one plane only? What is the name of the mechanical appliance that allows these movements?

Hinge-joints are joints that allow movements in one plane only.

The fore-arm moves

in one plane only—in that of the upper arm; the elbow-joint is a hinge-joint. Other hinge-joints are the knee-joints, the finger-joints, and the joints between the bones of the toes. The bones move in the joints like a door in its hinges.

186. BALL-AND-SOCKET-JOINTS. Name bones that move in many directions. The joints in which these bones move are called ball-and-socket-joints. You have heard the name "socket" in connection with the teeth. The eyes are in sockets. Define socket.

Examine the hip-joint in Fig. 57, and tell why it receives the name of ball-and-socket-joint. The same arrangement is found in the joint connecting the bone of the upper-arm with the shoulder-blade. Enumerate and perform the motions of the upper-arm in this joint. What parts of your hands may be moved in many directions? In what directions may the jaw-bones be moved?

Ball-and-socket-joints are joints allowing the bones to move in many directions.

The shoulder-joint, the hip-joint, the joint of the jaw-bones are ball-and-socket-joints. A socket is a hollow space that receives and holds something. What joints are those at the bases of the fingers?

187. SLIDING AND COMPOUND JOINTS. Examine the figures representing the bones of the wrist and ankle. What do you observe?

Wherever two of the little bones face each other, they are connected by joints. These joints are called **sliding joints,** because they allow the bones to slide over each other a little, when subjected to pressure or pulling. If

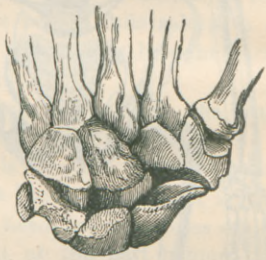

Fig. 58.

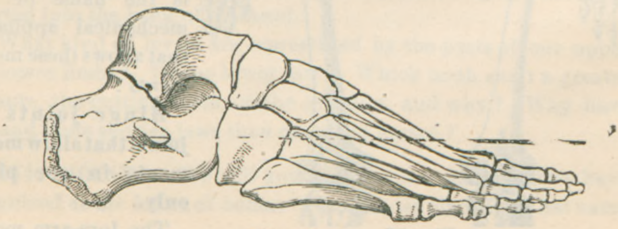

Fig. 59.

we consider the wrist or the ankle as one joint, we call it a **compound joint.**

Sliding joints are joints allowing the bones to slide over each other through a small space; compound joints are joints composed of many sliding joints.

What similarity is there between a ball-and-socket-joint and a compound joint? Why are there any compound joints? Would it be better if there were ball-and-socket-joints instead?

An arrangement that is perfect at one place in our body, may be unsuitable in another. This is the reason why there is such a great variety of joints. Even the joints that are classified under one head, as, for instance, hinge-joints, are not exactly the same everywhere. If you should examine them more closely, you would find peculiarities in each.

Enumerate the kinds of joints. Name the places where these joints are found. What movements do they allow?

188. OUTER STRUCTURE OF JOINTS. From the leg of a rabbit (or the foot of a pig or calf,) cut away the skin, the muscles, and most of the connective tissue, and examine how the bones are united in a joint.*

Each joint is surrounded by a short, air-tight cylinder, consisting of a flexible, but tough membrane, called a capsule. There is no air below the capsule. The union of bones in joints is accomplished by the pressure of air.

Rise and lift one foot from the ground. The leg which now hangs down from your trunk has a weight of 15 to 25 pounds. Do you feel this weight? The leg is carried by the air—the air presses the leg into the hip-joint and carries it. This is also the reason why we do not feel the weight of our arms and legs when we are walking.

189. STRUCTURE OF JOINTS INSIDE. Open the capsule and examine the inside. Touch the surface of the bones there and cut into one of the ends. Do you find bone or another substance? Why do you put a cushion of cloth under your hand when you play at marbles? Why are the bones in joints covered with cartilage? Why is the cartilage in joints oily?

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* The class will learn better and show more interest and enthusiasm if each pupil can be induced to bring to school a suitable piece of a mammal or bird, further, a plate, a towel, and a sharp knife, and to prepare and examine the joint under the direction of the teacher. Knowledge gained in this way is indelibly impressed on the mind.

The ends of the bones, or the places where the bones meet, are covered by a layer of cartilage, which is lubricated with an oily or greasy substance, the synovia. The synovia is secreted by glands in the capsule.

The cartilage in joints acts like a cushion ; as it contains neither nerves nor blood-vessels (See ¶ 134), it is not hurt by pressure.

190. LIGAMENTS. Look at the joint once more. Try to find some thicker pieces of a tough, tendon-like substance reaching from one bone to another.

Fig. 60. Ligaments in the joints of a finger.

Ligaments are strong bands of an elastic, tendinous substance reaching from one bone to another. Their function is to prevent any too extensive movements.

Ligaments keep the movements within certain limits. Without them the muscles would often perform movements which would bring the bones out of joint.

191. PARTS OF BONES. Compare a fresh bone with an old one, such as you sometimes find in the fields. Feel the surfaces of the two bones and tell how they differ.

Try to pull off something from the surface of the fresh bone. This membrane is called periosteum. It covers each bone, excepting where another bone touches it.

The periosteum contains **blood-vessels,** which send numerous small branches into the bone itself. You can not plainly see these blood-vessels in a fresh bone. But look at the old bone. What do you find on its surface? There are the places where the blood-vessels enter the bone.

The fresh bone is a solid piece, a piece without hollow spaces ; the old bone is **porous ;** it contains large cavities whose beginnings you can see at the surface, and many small cavities, which may be seen with a magnifying glass.

If you touch a piece of paper with a fresh bone, it becomes transparent. What causes the transparency? If a butcher saws a fresh bone, the surfaces of the saw and of the sections are covered with a fatty liquid.

A fresh bone is a solid piece without any pores or cavities. It contains blood-vessels and a fatty liquid and is covered with a thin membrane, called periosteum.

192. SUBSTANCES OF BONES. Prepare two bones in the following way: place one in the bright fire of a stove or furnace; keep the other in diluted muriatic acid for several days. What qualities do the bones show?

The two methods produce diverse results with the bones. The substances burned by the fire are preserved by the acid, and the substances dissolved by the acid are preserved by the fire.

Bones consist of a hard and a soft, flexible substance. The former is called the mineral substance; the latter, the animal substance.* The mineral substance makes the bones hard and strong; the animal substance makes them flexible and elastic.

The bones of old persons contain a great quantity of mineral substance and a small quantity of animal substance. The consequence is that shocks or concussions that do not seriously affect the bones of young persons, result in broken bones in the aged. The opposite is true of the bones of very young children. Their bones abound in animal substances and lack mineral substances. What takes place if they walk at too early an age?

193. WHY LONG BONES ARE HOLLOW. Break a long bone or ask the butcher to saw across the leg of a sheep. Look at the section. What do you see?

Long bones must support the upper body, just as the legs of tables and chairs must support the upper parts. What quality must the legs have that they may be able to support, and not break down?

You probably have seen houses whose ground-floor is used for stores. The fronts of these stores have large show-windows. Directly over these show-windows are the walls and windows of two, three, or four upper stories. How is the front of such a building supported? Are the iron pillars solid or hollow? What resemblances are there between the iron pillars and the long bones of our body? Why do the contractors and builders not use solid iron pillars?

Suppose I have 250 pounds of iron of which I want a pillar made, 16 feet high, and as strong as possible; should it be a solid or a hollow one?

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* The mineral substance is mainly phosphate of lime and carbonate of lime; the animal substance is cartilage.

The long bones in our arms and legs are filled with a kind of fat called marrow. Hollow columns are stronger than solid columns of the same length and weight.

It is easier to break a solid stick than a hollow stick of the same length and weight. Iron pillars that are used to support great weights are hollow. If they were solid and had the same size, they would be unnecessarily heavy and expensive; if they had the same weight, they would not be strong.

194. THE SKELETON consists of the united bones of our body. Its three main parts are the head, the trunk, and the limbs. Its central part is the back-bone. (See Fig. 57.)

Where do you see long bones? Where, flat bones? Where are the most massive bones? Where do you see a number of small bones lying close together?

195. THE BACK-BONE. The back-bone, or vertebral column, consists of many bones placed one upon another. Each of these bones is called a vertebra; it consists of a ring with a body in front and projections at the sides and back.

The upper part of the vertebral column consists of twenty-four vertebræ, seven of which are in the neck, twelve back of the chest, and five between the loins.

The spaces between the front bodies of the vertebræ are filled up by cartilaginous cushions which have the essential quality of India rubber —elasticity. They are pressed together if a weight rests upon them, and expand if this is not the case. Measure your height early in the morning just after rising, and late at night just before going to bed. What do you find?

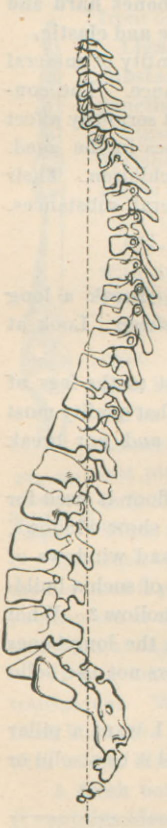

Fig. 61.
Vertebral Column.

196. CURVES IN THE BACK-BONE. Draw a line parallel with the axis of the back bone. Describe this line. What part of the body is in front of the upper convexity? Of the upper concavity? What inconvenience would it be to the chest if these curves were turned in the opposite directions?

There is still another benefit derived from these curves. Tell why the head is jarred when you jump upon the heels while your legs are straight. Do the curves change when you jump or fall upon the feet?

The back-bone has four curves. It is bent forward in the neck and between the loins, backward in the chest and in the lower parts.

The curves in the chest and in the lower part enlarge the size of the cavities in the trunk. The elastic cushions between the bodies of the vertebræ allow slight movements of the back-bone to all sides. When we jump or fall, they cause an increase of the curves. In this way the head is protected from violent shocks.

197. USE OF THE BACK-BONE. Each of the vertebræ has a cylindrical opening. What do all these openings, lying directly one over another, form together? What fills this cylinder in a living person?

The back-bone forms a long hollow cylinder for the protection of the spinal cord. The spines of the back-bone serve for the attachment of muscles.

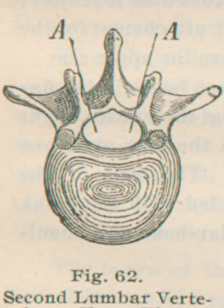

Fig. 62.
Second Lumbar Vertebra. Upper View.

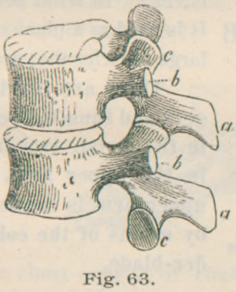

Fig. 63.
First and Second Lumbar Vertebræ. Side View.

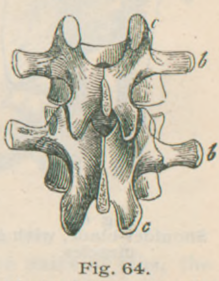

Fig. 64.
First and Second Lumbar Vertebræ. Back View.

The back-bone is sometimes called the **spinal column.** Why is it called spinal? Is there anything in a back-bone resembling spines? Where can you feel the projections, or spines, of your back-bone.

Sit very straight and feel the swelling of muscles on your back. Hold your hand at the loins and feel how the muscles at the two sides alternately swell when you walk.

Remember that the meat taken from the loins of rabbits, deer, oxen, and other animals is very rich and tender, doubtless because the frequent use of these muscles in walking and running draws much blood and nourishment to them.

198. THE BONES OF THE ARM. How many bones can you count in your hand ? Furthermore there are eight bones in the wrist, two in the fore-arm, and one in the upper arm. (Show these bones in Fig. 57.)

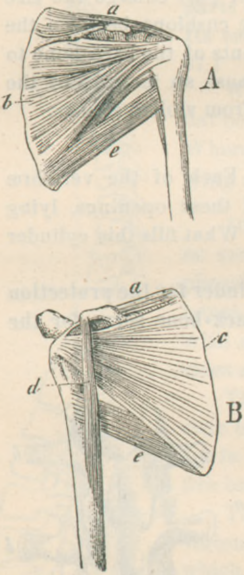

Fig 65.
Shoulder-blade, with its muscles.

Hold your right hand at the upper left side of your chest and move the left upper arm up and down. What do you feel ? This bone is called the **collar-bone.** Its use is that of a brace ; it holds the arm away from the middle of the chest. What other bone moves when we raise or lower the arm or shoulder ?

Describe the form of the shoulder-blade. What part of the body does it cover ? In what persons does it project ? It is used as a place of attachment for the large muscles that move the upper arm.

There are fourteen bones in the fingers and thumb, five at their bases, eight in the wrist, two in the fore-arm, one in the upper arm. The bone of the upper arm is connected with the trunk by means of the collar-bone and shoulder-blade.

199. THE BONES OF THE LEG. There are fourteen bones in the toes, five in the foot, seven in the ankle, two in the lower leg, one in the upper leg. The bone of the upper leg is joined to the hip-bone. A round flat bone on the front side of the knee-joint is called the knee-pan.

How many bones altogether? Which of these bones are smaller and which larger than the corresponding bones of the arm? Is the arm less protected at the elbow-joint than the leg is at the knee-joint? Which bone of the leg corresponds to the bone of the upper arm? The bone of the upper arm is joined to the shoulder-blade; the shoulder-blade connects it with the trunk. What bone corresponding to the shoulder-blade connects the upper leg to the trunk?

The two hip-bones and the lower part of the back-bone form the largest bony structure of the body; it supports the entire upper body and is itself supported by the legs.

200. THE CHEST. Fig. 67 represents all the bones of the chest. It looks somewhat like a basket. How many ribs do you count on each side? Which ribs are long and which are short? Notice that the front parts of the ribs differ from the main parts. These front parts are pieces of elastic cartilage connecting the bony ribs with the breast bone. Is there a piece of cartilage to each rib?

What shape has the breast-bone? With what are the ribs connected in the back part of the chest? Name all the parts of the skeleton contained in the chest.

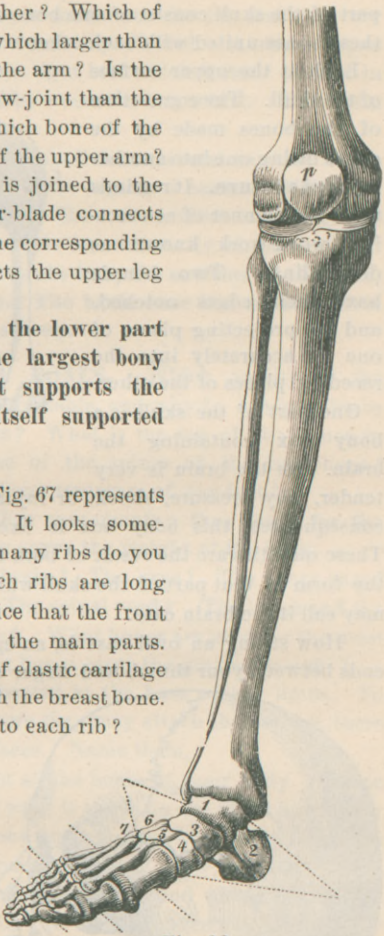

Fig. 66.

The bones of the chest consist of twelve pairs of ribs, the breast-bone, and a part of the back-bone. The upper ten pairs of ribs are connected with the breast-bone by means of elastic cartilages. The two lower pairs of ribs are called floating ribs.

201. THE SKULL. Examine a skull and compare it with Fig. 68. Which bone of the skull is movable? Does the remaining part of the skull consist of one bone or of many bones? How are these bones united with each other?

Look at the upper surface of the skull. The connection of the bones made by the edges fitting one into another is called a **suture.** It reminds us of the manner of connecting wood-work known as dovetailing. Two boards have their edges notched, and the projecting pieces of one fit accurately into the receding places of the other.

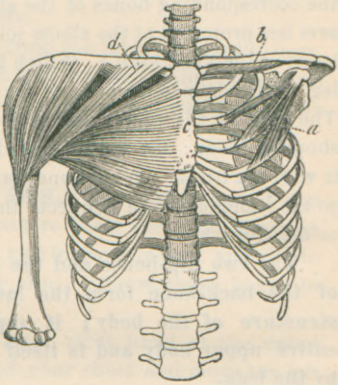

Fig. 67.

One part of the skull is a bony box containing the brain. As the brain is very tender, any pressure, shock, or injury being followed by serious consequences, this bony box is exceedingly firm and strong. These qualities are the result of both form and structure. What is the form of that part of the skull which contains the brain? You may call it the brain case.

How strong an oval case is, an egg may show you. Take its ends between your thumb and finger and try to crush it. Even a strong man would not succeed. Perhaps you can crush it, if you put the ends in your two palms. Try it.

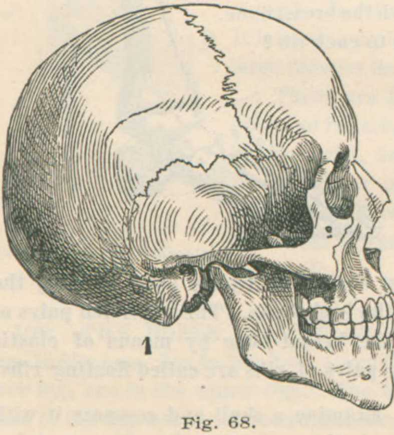
Fig. 68.

The second cause of the strength of the brain-case is its structure. Each bone consists of a smooth layer outside and a smooth layer inside, with a spongy mass between them.

A heavy blow upon the head is received by the tough outer layer; if this should be crushed, the softer middle layer moderates the jar, and the very hard inner layer will seldom be seriously affected. A tender object is well protected if placed in a tight box which is itself packed in hay or cotton and surrounded by a second, larger box. The brain is protected in a similar way.

The remaining bones of the skull form several cavities whose function is to receive and protect the organs of sense. Which are the uppermost of these cavities? Show the cavities of the ears and nose. The jaw-bones surround the seventh cavity of the skull.

The skull consists of the brain-box, the cavities of the eyes, ears, nose, and the jaw-bone. The brain-case has an oval form and is exceedingly firm and strong.

202. FOUR USES OF BONES. Which quality of the bones of the skull is the most valuable, and why? Are long limbs more valuable than short ones? What is the use of the bones in the limbs? What is the use of the spines of the back-bone? What is the main use of the bony structure of our foot?

Bones protect; they allow movements; they serve for the attachment of muscles; they carry the weight of the body.

What bones protect the brain? The eyes? The inner ears? The organs of the mouth? The spinal-cord? The lungs and the heart? The lower intestines? What bones are used for the most extensive movements? What bones carry the greatest weight?

The largest muscles are located at the **base** of our limbs. To give them sufficient space where they may attach themselves, there are flat bones with great surfaces. Name them.

Write a composition about all the bones of your body. Name them in groups or singly, tell what is the main use of each, whether or not they serve more than one purpose, and how their form and structure aid them in the accomplishment of their functions.

Arrange them as long bones, flat bones, and round bones, and tell of what use their form is. In this arrangement consider the ribs as parts of one extended flat bone.

SECTION III.

HYGIENE OF BONES.

203. BROKEN BONES. Perhaps there are children in your school whose arms or legs have been broken. They may tell you how it happened, what the doctor did, and how long it took till the limb could be used again. Have you seen a person whose fore-arm had recently been broken? How had he to keep his arm, and why?

If a person breaks a bone, a surgeon should be called at once. Meanwhile the sufferer should be kept as quiet as possible, and bandages soaked in cold water put around the injured part. If often renewed, they will prevent swelling and inflammation.

When the broken bones are "set", they must be kept perfectly quiet till the pieces are grown together.

An unskilled person, in trying to set a bone, usually does more harm than good, increases the suffering of the person injured, and delays the healing.

204. CROOKED LEGS may be caused in two ways; either by standing or walking at too early an age—before the bones have attained the necessary strength—or by eating food lacking mineral substances.

Suitable appliances (splints and straps) should be used as soon as possible. In some cases such children should be given a more generous diet—should eat more meat and eggs than usual, drink good milk, have plenty of fresh air, and take a daily (sponge) bath.

205. ROUND SHOULDERS AND A CROOKED BACK. What is the cause of a crooked back? At what age is the back most liable to grow crooked? Sometimes before the children go to school they have acquired a crooked figure. Why do older persons not grow crooked?

Most persons of seventy years and over have a round upper back and keep their shoulders bent forward. Both—the danger of a humpback for children, and the round shoulders of old persons—show that the back needs **strengthening** and **protection.** Suitable exercises for strengthening the back (swinging the arms, rowing, sawing wood, mowing with a scythe, pulling a rope, mounting a rope) should frequently be taken, and a suitable rest for the small of the back should be used when persons are obliged to sit a long while. This will enable them to sit straight.

Compare the looks of a person carrying himself straight, with his shoulders kept back, with those of a person bending forward. Are round shoulders a detriment to the health?

Round shoulders and a crooked back make a narrow chest. A narrow chest is accompanied by weakness and debility. A broad, capacious chest is the sign of health and strength.

The ancient statues of gods show physical perfection in the enormous capacity of their chests. Courage, intrepidity, and heroism are said to dwell in the strong chests of warriors.

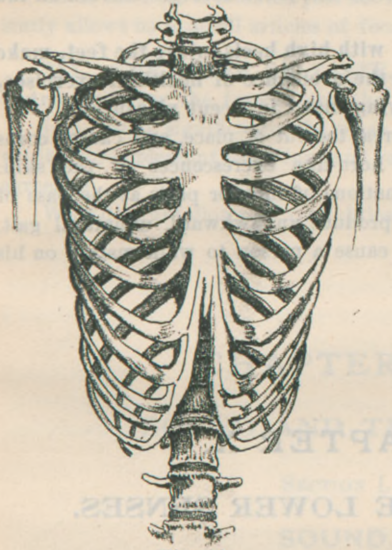

Fig. 69.

We should be desirous of developing strong chests and backs at the right time, in youth.

206. TIGHT LACING. Look at Fig. 69. It represents the bony chest of a woman twenty-three years of age, deformed by tight lacing. What organs are injured by a continuous pressure of the lower ribs?

Tight lacing injures the lungs, the heart, the liver, and the stomach.

Tight lacing makes all healthful exercise impossible. Women indulging in it "get out of breath" easily, the least exertion fatigues them; the heart is pressed against the stomach, the liver is crushed, and weakness of circulation and digestion are the inevitable consequences.

No part of the body can be continually compressed by tight garments without causing lasting injuries.

207. TIGHT SHOES. Look at Figs. 70 and 71, and tell what they represent. What injuries are done by the wearing of tight shoes? How is the ability to walk affected, if the great toe is

Fig. 70.

Fig. 71.

turned out of its place, or if one toe is pressed over the other? What painful excrescences of the skin are caused by the pressure of tight shoes? Which is easier and more natural—to walk on the toes, or on the whole sole?

Tight shoes and shoes with high heels injure the feet, make walking painful, lead to the avoidance of healthful exercises, and prevent us from enjoying many innocent pleasures.

A tight shoe turns the great toe out of place, and causes corns and bunions. Corns are horn-like excrescences of the skin. Bunions are painful inflammations of interior parts at the base of the great toe. High heels produce an awkward, unnatural gait, and induce fatigue. They cause a person to walk mainly on his toes.

CHAPTER X.

THE THREE LOWER SENSES.

208. THE SENSE OF FEELING enables us to perceive, firstly, that an object touches the skin; secondly, that an object is warm or cold; thirdly, that something causes pain.

As a rule, the skin is more delicate on the front parts of the body, and on the inside of joints and limbs, and less delicate on the back of the body, and on the outer side of joints and limbs. The sense of feeling is most acute where the nerve-papillæ (¶ 154) are most numerous.

209. THE NOSE consists of two symmetrical halves. Its partition is bony at the base and cartilaginous in the front part. It contains two cavities, whose openings are called nostrils. These cavities are lined with mucous membrane.

Do we usually breathe through the nose or through the mouth? Do we derive any benefit from this manner of breathing? One benefit is that the air, by passing through the long and intricate passages of the nose, is properly warmed before entering the lungs. Furthermore, it is, to a considerable extent, freed from dust.

210. SMELL is the sensation we experience by means of the nerves distributed throughout the nasal cavities.

Since the nose is situated just above the mouth, it most conveniently allows us to smell articles of food before taking them in.

211. THE SENSE OF TASTE. The nerves of taste are distributed over the tongue and the back of the mouth.

In a certain signification the sense of taste is called the lowest, yet it affords pleasant sensations and renders the daily act of eating agreeable.

What danger follows the thoughtless gratification of this sense?*

CHAPTER XI.

SOUND AND THE EAR.

SECTION I.

SOUND.

212. HOW SOUND IS PRODUCED. Attach one end of a knitting needle to a table and move the other in such a way that it will produce a sound. What organs give us knowledge of this sound?

As your ears are at a distance from the needle, there must be some connection between them. What substance is there between them?

Something must travel through the air from the needle to your ears. What is it? What is sound, or noise, that it can travel from one place to another, through the air? Is it a substance? If it is no substance, and yet travels from one place to another, through the air, what is it?

* The senses of taste and smell are closely connected and often confounded. Many so-called tastes are actually smells, as, for instance, the sensations produced by spices, such as pepper, cinnamon, or onions. When the nose is held tightly closed, or when the nasal chambers are blocked or inflamed by a cold in the head, the "taste" of these spices is not perceived. Normal tastes are: sweetness, sourness, saltness, and bitterness.

If you can not find out, tell what takes place with the needle when we hear the sound. What takes place with the air which surrounds the needle? There is a motion of the air near the needle, a motion called vibration. Can you tell now what travels through the air?

Our ears give us a knowledge of noises and sounds. Sounds are produced by vibrating objects. The motion travels through the air from the vibrating objects to the ears.

How can you prove that the vibrations of the air travel in all directions?

213. SOUND-WAVES. As we can not see the motions or vibrations of the air, it is difficult to get a correct idea of the same. But vibrations similar to those of the air are seen in water when a stone is thrown into it. Describe these vibrations.

The air vibrates in a similar way, except that the waves do not spread in one plane, or over one surface, as those of the water do, but in all directions, up and down, right and left, forward and back, and in all intermediate directions.

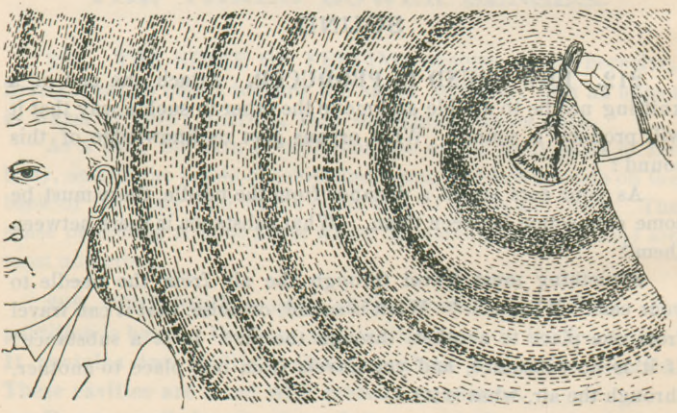

Fig. 72.

Vibrating objects produce sound-waves in the air. Sound-waves spread in all directions. They form spheres; they are spherical.

214. PITCH. How may we produce different sounds with a knitting needle? What difference is there in the tones when longer or shorter portions vibrate? What difference is there in the vibrations themselves when the vibrating pieces are short or long? What can you tell of the vibrating strings of violins, guitars, pianos, etc.?

You saw a musician tune his violin. How did he do it? Does a tone depend on the tightness, or tension, of a vibrating string? What three qualities of vibrating objects decide the height or depth (pitch) of a tone?

Pitch is the degree of height or depth of a tone. It depends on the length, the thickness, and the tightness (tension) of the vibrating object.

Long portions of knitting needles vibrate slowly and produce low tones; short portions vibrate quickly and produce high tones.

Long and thick strings produce low tones; short and thin strings, high tones.

A musician tunes his instrument by tightening or loosening the strings; the tighter a string, the higher the tone.

SECTION II.

THE EAR.

215. STRUCTURE OF THE EAR. The ear is composed of three parts, the outer ear, the middle ear, and the inner ear. The outer ear consists of the CARTILAGINOUS PIECE outside of the head and the PASSAGE leading into the head; the middle ear is an irregular cavity called the DRUM OF THE EAR; the inner ear is an irregularly shaped piece called the LABYRINTH. The outer and the middle ear are separated by a membranous partition called the DRUM MEMBRANE.

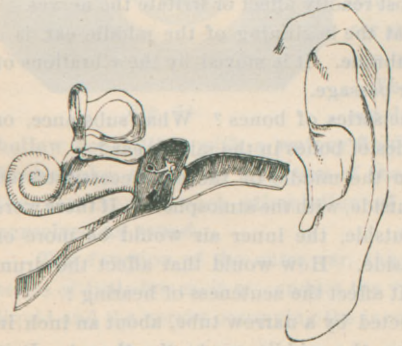

Fig. 73.

The outer and the middle ear are filled with air ; the inner ear is filled with a watery liquid.

There is great difficulty in studying the structure of the ear from nature ; it would be well for you to examine an enlarged model of an ear.

216. THE OUTER EAR. Compare your ear with the ears of other animals. Of what benefit is it to animals to be able to move their ears ? What has the size of the ears to do with the acuteness of hearing ? What, then, is the use of the outer ear ?

The outer ear catches the vibrations of the air and leads them to the middle ear, in a way similar to that in which a funnel carries water in one direction.

Animals able to move their ears bring them into a position where they can best catch the sound ; they turn the opening in the direction from which the sound comes.

217. THE MIDDLE EAR is a cavity through which a series of little bones (the hammer, anvil, and stirrup) extends. The bones are made to vibrate by the drum membrane ; they carry the vibrations further, to the inner ear.

The middle ear is connected with the throat by means of a little tube called the Eustachian tube. (See Fig. 73.)

The outer ear **catches** the vibrations of the air ; the inner ear is a box for the nerves ; the middle ear, or the part between the **catcher** and the **nerve-box,** is especially adapted to the **conduction** of the vibrations of air, enabling them to assume a form, or condition, in which they will most readily affect or irritate the nerves.

The drum membrane, at the beginning of the middle ear, is a tightly stretched thin membrane. It is moved by the vibrations of the air contained in the air-passage.

What is the use of the series of bones ? What substance, or medium, surrounds the series of bones in the middle ear ?

The presence of air in the middle of the ear necessitates an open connection with the outside, with the atmosphere. If there were no connection with the outside, the inner air would be more or less dense than the air outside. How would that affect the drum membrane ? How would it affect the acuteness of hearing ?

The connection is effected by a narrow tube, about an inch in length, which extends from the middle ear to the **throat.** It is called the **Eustachian tube.** You may convince yourselves of the fact that you have two of these tubes in your head. Close your nostrils with your fingers, keep the mouth closed too, and fill your mouth with air; inflate your checks. What do you feel? Make the movements of swallowing.

The disagreeable sensation in your ears is caused by the dense air in your mouth, which penetrates through the narrow tube into your middle ear and presses the drum membrane outwards, thereby hindering the free movements of the membrane and the series of bones. When you make the movement of swallowing, you open the throat-ends of the tubes, and the surplus air escapes.

218. THE INNER EAR. The inner ear is the most peculiarly shaped part of the entire ear. Look at the piece resembling a snail's shell, at the three tubes curved in various ways, and at the wider piece connecting the shell and the tubes. What is the substance of which these pieces are made? What is inside? What part of the middle ear touches the inner ear?

Fig. 74.

The flat part of the stirrup, its footplate, is inserted into the wall of the inner ear, in such a way that its surface touches the fluid. To what part of the inner ear are the vibrations of the stirrup transferred?

The inner ear, or labyrinth, consists of a peculiarly shaped, hollow bone filled with a watery fluid and hundreds of nerves. Each shake, swing, or vibration of the fluid affects or stimulates the nerves, and each stimulation of any of these nerves is perceived as sound.

The function of the outer ear, the drum membrane, and the series of little bones, is to conduct the vibrations of the air to the liquid and the nerves occupying the inner ear.

CHAPTER XII.

THE ORGANS OF VOICE.

219. THE VOICE-BOX (larynx) is the uppermost part of the windpipe. It is felt just below the skin, has a projection in its front and upper part, and is smooth at the sides.

In what direction does the voice-box move ? Is there a difference in the voice-boxes of different persons ? What difference is there in the voices of different persons ? Is there any connection between the size of the voice-box and the height and depth (pitch) of the voice ?

220. THE VOICE-CORDS (or vocal cords) are two delicate bands of elastic tissue. Their bases are at the right and left inner sides of the voice-box. Their upper edges extend from the prominent point of the voice-box to a place directly opposite. The narrow slit between the edges is called the glottis.

The voice-cords are neither drums nor strings, but partake of the nature of both.

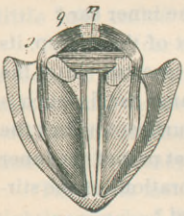

Fig. 75.
Vocal Cords and Glottis.

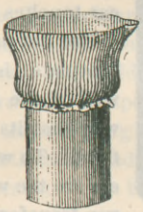

Fig. 76.

Fig. 76 represents a model which may give you an idea of their shape and action. A strip of rubber cloth is laid around the end of a glass tube in such a way that about one inch of the rubber extends beyond the end of the tube.

Take two opposite portions of the projecting rubber between the fingers of your right and left hand, and slightly stretch the rubber. Now blow through the tube. What happens ?

At what place has the air the greatest power, and where, therefore, does it cause the rubber to vibrate ?

The air sent through the vocal cords has its greatest power in the glottis ; it causes the edges, which are thick and round, to vibrate more or less forcibly. Suitable muscles tighten the vocal cords more or less, according to the pitch of the sound which is to be produced.

221. THE MOUTH takes an active part in the production of the voice. Its cavity forms an air-chamber, which has a note of its own ; the lips, teeth, tongue, and palate vary the sound in many ways.

Open your mouth wide and utter the sound of "a" as in "father"; then gradually narrow the mouth and protrude the lips. The sound "a" will change to "o" as in "more" and "oo" as in "food". This proves the activity of the mouth in the production of the voice.

If you desire to learn what organs of the mouth are active in the production of the various sounds, you must carefully observe these organs while you utter the simple sounds. Probably your grammar contains some statements regarding the same.

222. CARE OF THE VOICE. Most good voices are spoiled in early childhood. Children produce loud noises before their vocal organs are strong enough to permit such exertions.

Many persons do not pay proper attention to the preservation of their voices, though the possession of a pleasant voice is a source of much pleasure and benefit, and but little care is needed to preserve its power and beauty. It is true that an excellent singing voice is the gift of nature, but many persons ruin, by improper treatment, what nature has bestowed upon them.

The improper way in which many children scream rather than sing, in school and out, tends to impair the character of their vocal cords, hardens them, destroys their smoothness and uniformity, and makes their voices coarse and disagreeable. Whoever wishes to have a pleasant voice must not scream, wrangle, or sing boisterously at any time, and when the throat is sore from any cause, must exert it as little as possible.

Which persons have larger and stronger vocal organs—women or men? Which, as a rule, have more pleasant voices? How is that caused?

The purity of the voice is further endangered by some gaseous substances. How does it affect you if you accidently inhale the smoke of burning sulphur? How does tobacco smoke affect you?

Habitual smokers seldom possess a clear and pleasant voice. The constant irritation of the pungent tobacco smoke has an injurious effect upon the vocal cords.

CHAPTER XIII.

THE EYE AND LIGHT.

SECTION I.

STRUCTURE OF THE EYE.

223. PARTS OUTSIDE. There are numerous organs in connection with the eyeball. Place a finger on your forehead, just above one eye, and move it downward. What does the finger touch? Draw the line which your finger describes. Compare it with the line in Fig. 77. Name the various parts of this line. Point to the outer surface of the upper eyelid; the upper surface of the lower eyelid; the inner surface of the upper eyelid.

Fig. 77.

A line drawn from the forehead to one of the cheeks, across the eye, touches the eyebrow, the upper eyelid with its eyelashes, the eyeball, and the lower eyelid with its eyelashes.

224. EYEBROWS, EYELIDS, AND EYELASHES. What is the use of the eyebrows? Of the eyelids? Whence does the light generally come into the eyes? Which lids are used more, the upper or the lower? What arrangement that may be compared with the upper eyelids is used to protect rooms from too much sunlight? Lift your upper eyelids between your thumb and fore-finger. What do you feel in the interior of the lid?

The eyebrows prevent the sweat from running into the eyes. The eyelids and eyelashes shade and close the eyes and protect them from dust.

225. THE EYEBROW-ARCH. Place three fingers on one eyebrow; move them up and down. What do you feel? This bone is somewhat like an over-hanging roof. Is it of benefit to us? In what way does it protect the eye?

We compared our eyelids to awnings or shades. Is there anything near the windows which might be compared to the eyebrow-arch ?

The eyebrow-arch (superciliary arch) forms a projection over the eyeball, and serves to guard it from blows and bruises.

The eyebrow-arches of monkeys, bears, lions, and other animals are larger and more prominent than those of men. Persons with large and prominent eyebrow-arches have a savage, ferocious look.

226. GLANDS OF THE EYE. How does the surface of the eyeball look, compared with that of the surrounding skin ? How does the surface feel ? What is spread over the surface of the eyeball ?

Is tear-water secreted in the eyes of all persons ? Is it secreted daily ? Is it secreted in the eyes of animals ? Whence does the tear-water come, or by what organs is it secreted ?

The tear-glands are situated below the outer ends of the eyebrows ; the oil-glands are situated inside of the lids. Their joint secretion keeps the surface of the eyeball smooth and shining.

If you handle the lid carefully, you can see the outlets of the oil-glands with a small magnifying glass in the following manner: Lift the lower lid of a person by gently pressing your finger upon it, and moving it downward ; then look at the **internal** edge. What is at the **external** edge of the eyelids ?

Sometimes the little oil-glands, whose outlets you have seen, become conspicuous in a disagreeable way. They swell, inflame, and form what is called a **sty.**

When you tried to see the little openings, or outlets, of the oil-glands, you should have seen one larger opening. Where? Find something similar in the upper eyelid. These two large openings are the mouths of two canals, through which the surplus tear-water is carried off toward the nose and throat.

In addition, the inner corner of the eye contains a cluster of little glands which secrete a slimy substance. This substance collects during the night; in the morning we find it dried and hardened.

227. THE SURFACE OF THE EYEBALL. Look at the dark center of the eyeball of your neighbor. What do you see there? Tell him to look toward a window and move a book up and down before his eyes. What do you notice? Of what else may you see an image in his eyes? Where have you seen similar images? What do you call objects in which you see images? Why is it that our eyeballs act like mirrors? Do all smooth or highly polished surfaces act as mirrors?

The surface of the eyeball acts like a mirror, because it is smooth and shining.

228. THE EYEBALL. Bring the eyeball of a calf. It is very similar to our own. What is its shape? We often hear persons speak of oval eyes, or of eyes shaped like almonds. Are they different from such as this?

What is the size of the eyeball? What do you see outside of the eyeball, attached to its enclosing membrane? These flat pieces are portions of muscles. The butcher has cut through them, and we see only those parts that are near the eyeball. Why must there be muscles?

At what place do you see a short white cylinder? Do you think it was longer when the calf was alive? What is its name? Examine it once more. How thick is it, and what is its consistence? Do you know a similar substance?

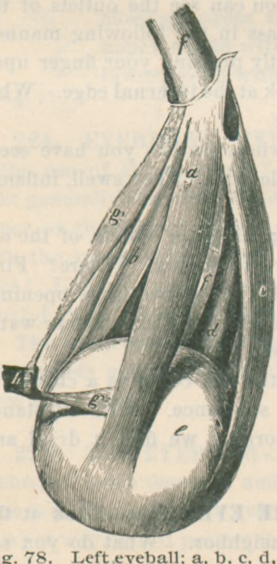

Fig. 78. Left eyeball; a, b, c, d, g muscles; f, optic nerve.

The eyeball has the shape of a sphere; its diameter is nearly an inch. Several muscles are attached to its surface. The optic nerve enters the eyeball at a place near the center of the back surface.

The muscles move the eyeball in many directions. The optic nerve reaches from the eye to the brain. If it were cut, or its connection were severed, we should be blind. By means of the optic nerve the brain obtains knowledge of what is going on in the eye.

229. MEMBRANES. Instead of the word eyeball, some persons use the term **bulb** of the eye. The structure of the eyeball is similar to that of a bulb; both consist of several thin pieces, or enclosing membranes, and a large central piece.

The eyeball is enclosed by three membranes called the white membrane, the blood-membrane, and the net-membrane. The white membrane protects the eye; the blood-membrane nourishes the eye; the net-membrane is affected by the light.

Where is the proper place for the protecting membrane? What qualities are expected from a protecting membrane? Press a knife against the eyeball. Try to cut it. What makes the knife glide off? In this way you will find that it serves its purpose well.

The white membrane (sclerotica)* is seen at the surface of the eyeball; it is tough, thick, and strong. The blood-membrane (choroid) is the membrane next below the white membrane; it is full of blood-vessels. The net-membrane (retina) is the internal membrane; it is very delicate.

230. THE HORN-MEMBRANE. Before we open an eyeball and look at the membranes, we will try to find out more by observing our own eyes or those of our neighbors. Does the white membrane surround the whole eyeball? Why must there be a transparent piece in front? This transparent piece is just as hard and strong as the white membrane.

Close one of your eyes. Place one or two of your fingers gently upon the eyelid, and move the eyeball in different directions. What do you feel?

The horn-membrane (cornea) is the transparent front part of the white membrane; its outline is circular.

The horn-membrane is fastened to the white membrane in nearly the same way that a glass is fastened on a watch.

The exterior surface of the horn-membrane is more prominent than the rest of the eye.

231. THE PUPIL is a circular opening in a colored ring below the horn-membrane. It looks like a black spot.

Pupil is the name for yourself. Why has this black spot been given your name? Suppose your father looks at the pupil of your

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* It should be understood that there is no particular knowledge conveyed by these scientific names, and that correct ideas about shape and nature are worth more than scientific names. Popular names are preferable, because their meaning is more generally understood.

eye, how does he appear there? Everybody looks small in the eye of another. Can you guess at the reason now? A similar word is puppet, a doll, or a small person.

232. THE RAINBOW-MEMBRANE is the colored ring surrounding the pupil. What color has it? Observe the eyes of someone whom you first ask to direct his looks toward a distant object, and then, to read from a book close by. What changes occur in his rainbow-membrane and pupil? Observe that the outline of the rainbow-membrane remains the same.

What is the size of the pupil in a glaring light? When is it very large? What causes the rainbow-membrane to expand? Is this arrangement useful? What animals change the size of their pupils more remarkedly than we do? What advantage does this give them? Can cats and owls see in a place which is entirely dark?

Look at the rainbow-membrane once more. Is it convex or flat? Draw a picture representing the shape of the rainbow-membrane. How many and what lines do you need?

There is a cavity between the horn-membrane and the rainbow-membrane. What form has this cavity? Do you observe any substance in this cavity?

The rainbow-membrane (iris) is a colored ring surrounding the pupil. In strong light the pupil becomes smaller by the extension of the rainbow-membrane.

The space between the horn-membrane and the rainbow-membrane is rounded in front and flat behind. It is filled with a transparent fluid called the eye-water (humor aqueus.)

You are now ready to open an eyeball and examine its parts. Any butcher will oblige you by cutting an eyeball from the head of a calf or sheep. Bring it to the next lesson, and, besides, provide yourselves with a sharp knife, a pair of scissors, a plate, and a towel.

233. THE INTERIOR OF THE EYEBALL. Before you open the eyeball, cut off the fat, the connective tissue, and the portions of muscles.

Try to cut through the white membrane in a direction parallel with the rainbow-membrane. Is it easily cut through?

After you have succeeded in making a small opening, cut all around with your scissors, thus dividing the white membrane into a front and a back half. What do you see of the interior?

Turn the white membrane back. What do you see now? This gelatinous substance is called the **jelly of the eye** (humor vitreus).

Separate the membranes from the jelly, and put the jelly on the plate. What special piece do you notice in the jelly? Find the **lens** of the eye. Loosen it with your scissors by cutting all around the margin. What quality is most prominent in the lens and the jelly?

Place the jelly in water. How does it look there? What forms have the two sides, or surfaces, of the lens? Which substance is harder, the lens or the jelly? Squeeze the lens between your fingers. What do you notice?

Try to find the blood-membrane, the rainbow-membrane, and the net-membrane. What do you find on both surfaces of the blood-membrane? Show the circular opening of the rainbow-membrane. What is it called? Is it still black?

What peculiarity of the net-membrane do you notice? Look at the outside. What is exactly opposite the place where the net-membrane is fastened? The net-membrane is the **continuation** of the optic nerve; it is the optic nerve spread in the form of a membrane.

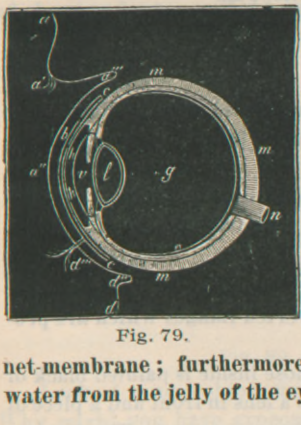

Fig. 79.

You may now draw a figure to represent the section of the eyeball obtained by dividing it into a right and left half. Compare your drawing with Fig. 79.

A longitudinal section of the eyeball (Fig. 79.) shows the white membrane in connection with the horn-membrane, the blood-membrane in connection with the rainbow-membrane, the optic nerve in connection with the net-membrane; furthermore, the lens that separates the eye-water from the jelly of the eye.

SECTION II.

LIGHT.

234. THE LENS. What part of the eye is similar to the object represented by Fig. 80? In what respect do the two differ from each other? Both are called lenses and are essentially the same in regard to light. They may differ in size and material, but all (optical) lenses are transparent and have a similar form.

Hold a (double-convex) lens in the rays of the sun, and find a very brilliant and hot spot, not far from the glass. How does this spot become brilliant and hot? What is the direction of the rays before they go through the glass? And afterwards?

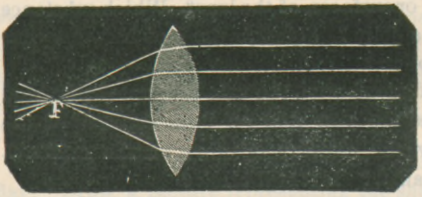

Fig. 80. Convex Lens.

Hold the lense near a piece of white paper, till an image of the window appears. Compare the image with the window itself.

Close the shutters, in order to exclude the bright day-light, and hold the lens near a lighted candle. Find a large inverted image of the flame on an opposite white wall.

Lastly, hold the lens near your hand while you look through it. How do your fingers appear? How does this image differ from the image on the wall?

A double-convex lens (a burning-glass) may produce three kinds of images; a small and inverted image, a large and inverted image, and a large and upright image.

A picture is something painted or drawn and consists of material substances. An image is not painted or drawn; it consists of light.

235. THE CAMERA OBSCURA is an apparatus made for the purpose of showing the small inverted images which are produced by means of a lens.

Usually it is a rectangular box whose inside is painted black or is covered with black paper. There is a lens in front and a piece of ground glass in the rear on which the image appears. The distance between the lens and the ground glass can be regulated.

Such a box is not complicated; you can easily construct one yourselves. A lens can be bought for 25 cents. The rest is card-board, paper, and thin board. A piece of looking-glass placed at an angle of 45 degrees (half of a right angle) against the back wall will

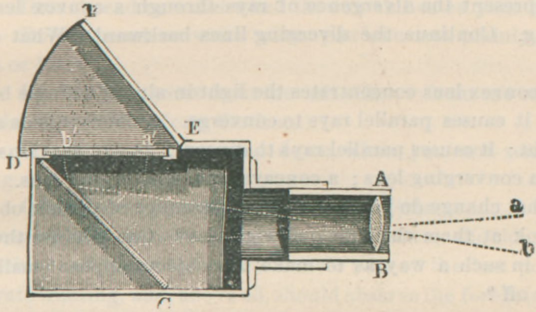

Fig. 81.

change the inverted image to an upright one, appearing on the upper wall which should then be made of ground glass. In this shape the camera obscura affords an excellent aid for drawing pic-ures of landscapes or other views.

236. OPERA GLASSES consist of two tubes, each containing a convex and a concave lens. They are made for the purpose of showing large, upright images of distant objects.

Unscrew the lenses from one of the tubes and find out what images they give.

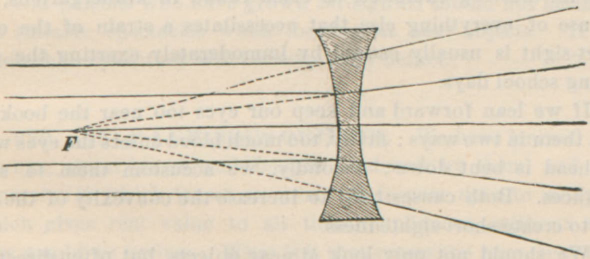

Fig. 82. Concave Lens.

Look at a near object first with one, then with the other lens. Why might you have expected that convex and concave lenses would produce opposite effects?

A convex lens collects parallel rays. What may you expect a concave lens to do with the same ? Try it. Let parallel rays of the sun fall on a concave lens and observe the light spot on the other side. Try it at different distances.

Represent the divergence of rays through a convex lens in a drawing. Continue the diverging lines backward. What do you find ?

A convex lens concentrates the light in almost a single brilliant point; it causes parallel rays to converge. A concave lens spreads the light ; it causes parallel rays to diverge. A convex lens is also called a converging lens ; a concave lens, a diverging lens.

What change do you see in the appearance of distant objects if you look at them through opera glasses ? Can you use the opera glasses in such a way as to make the objects appear smaller and farther off ?

237. SHORT-SIGHT. There are some who are obliged to wear spectacles because they are near-sighted. See what kind of glasses they have.

Where are there more near-sighted persons, in cities or in the country ? Why ? Does short-sight (near-sightedness) depend only on the length of time during which we read or write, or have the **kinds** of books we read anything to do with it ?

Not only should the use of small print be avoided, but also the use of tracing books in penmanship lessons, of paper with narrow lines for drawing exercises, as often found in kindergartens, and the use of everything else that necessitates a strain of the eyes. Short-sight is usually caused by immoderately exerting the eyes during school days.

If we lean forward and keep our eyes too near the book, we hurt them in two ways : firstly, too much blood enters the eyes when the head is bent down ; secondly, we accustom them to short distances. Both causes tend to increase the convexity of the lens and to create short-sightedness.

We should not only look at near objects, but often direct our looks toward distant ones, that we train our eyes in both directions, and improve their power of accommodation.

Short-sighted persons wear concave spectacles. Short-sight is caused by reading and writing too much, by using small print

or narrow lines, or by working in unsuitable light, or in improper positions.

Remember the following rules:

1. Do not read or write when the sun shines on your book.
2. Do not read or write when you can not plainly see the letters or lines.
3. Let the light enter from the left side or from the rear (not from the right side or from the front).
4. Do not bend your head down when you are reading or writing.
5. Often direct your looks to distant objects.

Near-sighted persons, particularly children, should not use spectacles at all times, but try to recover part of the lost power by moderate training, and, above all, should observe the foregoing rules.

238. LONG-SIGHT. In what persons have you observed far-sightedness? How did you find this out?

Many persons grow far-sighted in old age. This is caused by a flattening of the horn-membrane and lens, which do not receive as much nourishment as formerly. Others become far-sighted because they are not used to reading, writing, or looking sharply at near objects; they are persons who live mostly outdoors. Name them.

Long-sighted persons use convex glasses.

Old persons who have grown far-sighted should not hesitate to use suitable spectacles when looking at near objects. If they strain their eyes, they will increase their defect.

239. SELF-LUMINOUS OBJECTS. We have learned about the eye, about lenses and images produced by them, and about apparatus in which lenses are used. It is now time to study that which gives real value to all these appliances, without which they would be useless. What is it that enters the eyes, that passes through lenses and is changed by them in different ways?

All around you are objects. You close your eyes and the objects disappear; you open them and the objects stand out clearly. Whence does the eye receive the light which shows this table, this wall, and this chair? Do all visible objects throw out light? Is the table visible at all times? What two classes of visible objects can you distinguish?

Self-luminous objects are those which send out their own light. Objects that are not self-luminous can not be seen unless the sun or another self-luminous object throws light on them.

Give a list of self-luminous objects? Have you seen self-luminous objects darting through space high above your heads? Have you observed or heard of self-luminous animals? What is meant by the phosphorescence of the sea?

240. TRANSPARENT, TRANSLUCENT, AND OPAQUE OBJECTS. Transparent bodies transmit rays of light, so that objects can be distinctly seen through them; translucent bodies transmit rays of light without permitting objects to be distinctly seen through them; opaque bodies do not transmit rays of light.

Name objects belonging to each of the three classes. Is water transparent or translucent? Can you look through fifty feet of water? If it were very pure, you could, but as it is in our rivers and lakes, you can not.

May water be transparent or opaque? Is air absolutely transparent? Is the air in valleys as transparent as the air on mountains? How can you prove that glass is not absolutely transparent?

241. RAYS OF LIGHT. All visible objects radiate light. Can you prove that they do this in all directions? Can you also prove that light is radiated in straight lines? What are the straight lines in which the light moves, called?

Visible objects radiate light in straight lines and in all directions. These straight lines are called rays of light.

Construct two paper tubes, one to fit closely over the other. Cover the outer end of one with an opaque piece of paper that has a small opening in the middle, and the outer end of the other with a piece of tissue paper. Hold the tube opposite a window or a lighted candle, with the opaque paper directed toward the same, and move the other tube in and out till you see an image of the window or lighted candle on the tissue paper.

This apparatus is called an **optic chamber** or a **camera optica.** Compare the image with the object. Why is the image inverted? What quality of the rays is proved by the inversion of the image?

In summer time you may sometimes observe numerous bright circles in the shadow of a tree. Whence does the light come which forms the circle? Of what are the bright circles images? Under which trees do these circles appear large, under which, small? When may you expect the bright circles to change to the form of sickles or crescents?

Sometimes the bright images of the sun on the ground partly over-lap each other. What will be the final result, if we constantly increase the number of openings between the leaves?

242. SHADOWS. When does a shadow appear? Compare the two sides of an opaque object placed in the sunlight. Is the darkness only at the surface of the opaque object, or does it extend into the space behind the object? What is the name of this dark space? Define shadow.

What difference is there between your own shadow in the morning, at noon, and in the afternoon? What changes do you notice in your shadow when you pass a street lantern? When is the shadow darkest?

Let the shadow of the bars of a window through which the sun shines fall on a piece of white paper. Is it of equal intensity everywhere?

Represent the sun, the earth, and the shadow of the latter in a drawing. Compare the size of the shadow nearer the earth with the size of the shadow farther off. Imagine the whole shadow to be a body having height, width, and length. What is the form of this body?

In what position is the moon in relation to the sun and earth when struck by this shadow? What phenomenon will then be observed? Such an eclipse may last $1\frac{3}{4}$ hours.

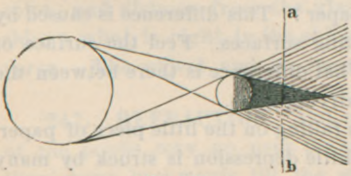

Fig. 83.

What are the conditions of a total eclipse of the sun? The diameter of the shadow which in such a case falls upon the earth, averages about 150 miles, and the longest time an eclipse of the sun can be total at any place on the surface of the earth is a little less than eight minutes.

A shadow is the dark space behind an opaque and lighted object. It has two parts — the full shadow and the half shadow (umbra and penumbra.)

The full shadow of the earth has the form of a cone. If the moon passes through this shadow, there is a total eclipse of the moon. The full shadow of the moon has likewise the form of a cone. If a part of the earth's surface passes through this shadow, it will be totally eclipsed; if it passes through the half shadow of the moon, it will be partially eclipsed.

243. REFLECTION. Put a piece of glass where it will reflect a ray of sunlight. Hold a string in the ray of reflected light. Where does the reflected ray commence? Where does it end? Hold a string in the original or direct ray of sun-light. Where does this ray commence and end? Represent the direct ray, the piece of glass, and the reflected ray in a drawing.

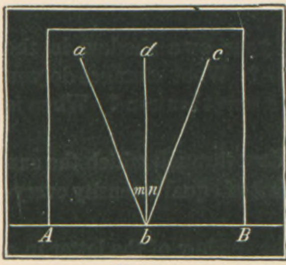

Fig. 84.

A ray of light falling on a piece of glass is thrown back or reflected. The reflected ray and the direct ray form equal angles with a perpendicular (b d) **erected at the lighted point.**

244. DIFFUSION. Put a piece of white paper in the place where the glass has reflected the sunlight. Does the paper reflect the light which the sun sends upon it? How do you know? Where does the paper send the light which it reflects? What difference is there between the direction of the light reflected by the glass and that reflected by the paper? This difference is caused by a difference between the reflecting surfaces. Feel the surface of the glass and of the paper. What difference is there between the two? Look at both with a magnifying glass.

There are thousands of rays falling on the little piece of paper. Each little elevation and each little depression is struck by many rays.

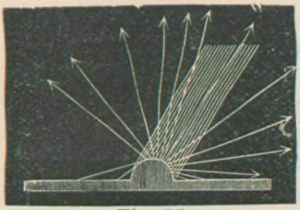

Fig. 85.

Sunlight falling on surfaces which are not perfectly smooth is scattered in all directions. Light scattered by reflection is called diffused light, the reflection itself, diffusion.

Name objects that diffuse light as paper does. Whence do we receive the diffused light shortly after sunset and before sunrise ?

245. NECESSITY OF DIRECT SUNLIGHT. In winter and spring we like to be in direct sunlight ; in summer we seek the shade. In this particular, children should imitate the good example of almost all animals, which like to bask in the sun.

You raise the objection that the direct sunlight burns the skin, causes freckles and sun-strokes, hurts the eyes, and lessens our energy ; we soon become tired when working in the sunshine.

You are right ; we should use it intelligently. We do not, when we exclude it altogether from our dwelling rooms, fearing, perhaps, the bright colors of carpets or curtains might fade. The sun is our friend, when we understand how to use it,

Direct sunlight, when intelligently used, gives us a healthy complexion, makes us cheerful, and heightens our energy. It should not be entirely excluded from our dwelling rooms.

246. THE LOOKING-GLASS. Compare the image in a looking-glass with the object itself. Do the image and the object look perfectly alike ? Open your reader, hold it in front of a looking-glass, and read from the image. How do the object and the image differ ? In what are they alike ? Should you look in a glass while raising your right arm, what arm is raised by your image ?

An object and its image in a looking-glass are alike in size, color, and distance from the glass, but are changed in regard to sides ; what is right in the object, is left in the image, and vice versa. The object and its image are said to be symmetrical.

247. REFRACTION. Put a stone into a washbasin. One of the pupils may go near the washbasin, look at the stone and then move backwards till the stone is out of sight and hidden by the side of the washbasin. Now pour water into the washbasin, but do not let the stone change its place. When there is a sufficient quantity of water in the basin, the pupil, without having changed his place, will again see the stone.

Whence does the light come which shows him the stone? Stretch a string between the stone and the eye of the pupil. This shows that the light does not move in a straight line. It does so in the water, but when it changes water for air, it changes its direction too.

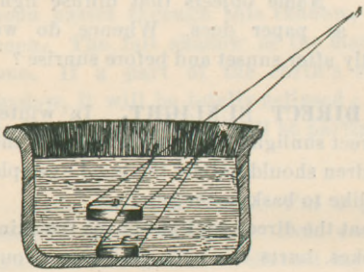

Fig. 86.

In the direction of what light does the pupil see the stone? It is a general law that we see everything in the direction of the light that **enters** the eye. We do not assume that we can look around a corner, though in fact we do it daily, The pupil has looked around the corner of the washbasin. We can look at things behind our back, if we use a looking-glass.

Does the stone appear in the same place in the basin filled with water as it does in the dry basin? Does the bottom of the washbasin seem to have changed its position? Does the depth of the washbasin seem to be the same as before? If you look at pebbles or other objects in the water of a brook or pond, where do they seem to be? Why does a cane or an oar appear to be broken when partly immersed in water?

Rays of light are refracted when changing their medium. *

To refract means to break or change the direction. The medium is the substance through which the light moves. An object lying in water appears to be in a higher place than that in which it really is. This is caused by the refraction of the light at the boundary of water and air, and by the fact that everything is seen in the direction of the light which enters the eye.

* There is but one exception; that is, when the rays of light pass the boundary at right angles.

SECTION II.

FUNCTIONS OF THE EYE.

248. THE EYE is similar to a camera obscura. Each has a lens, is dark inside, and excludes all the light not entering through the lens. Each is filled with a highly transparent substance; the back wall of each presents a suitable surface for the reception of the image; in each, the image is small and inverted.

The highly transparent substance in the eye is the jelly of the eye (vitreous humor), that of a camera obscura is air; the back wall of the eye is the net-membrane (retina), that of the camera obscura is the ground glass.

249. PROJECTIONS OF IMPRESSIONS. About eighty years ago a curious case was brought before an English Judge. A man had been assaulted and robbed on a dark night, and a certain person of bad repute was suspected of being the evil doer. He denied the charge, and as no third person had been present when the robbery took place, conviction seemed impossible. But the man robbed asserted that he recognized the culprit "because he had seen his features by the light rushing from his own eyes when they were struck by the robber". The Judge did not know whether to admit this evidence or to reject it. How would you have decided?

Do you believe the story of Baron Muenchhausen, who, finding that he had forgotten his matches, lighted his pipe with the sparks that flew from his eye when he struck it with his fist?

Close you eyes and thrust a finger between an eyebrow arch and the adjoining eye. What do you observe? Thrust a finger between the cheek-bone and the adjoining eye. What do you observe? What is proved by these experiences? Direct your attention to the places where you perceive the light.

Every impression that the net-membrane receives is projected outside. We do not perceive the image on the net-membrane, but the objects that produce the image.

If a spot in the upper half of the net-membrane is irritated, we perceive light below the eye ; if a spot in the lower half of the net-membrane is irritated, we perceive light above the eye. The inverted image on the net-membrane causes the perception of upright objects outside.

250. DURATION OF IMPRESSIONS. A live coal moved in a circle appears as a bright line. How can this be explained ? Name similar phenomena. Draw the picture of a bird on a piece of cardboard, and that of a cage on the opposite side. Fasten two strings at opposite places, and whirl the cardboard around this string. What do you see ?

Impressions made on the net-membrane last longer than the time during which the corresponding objects are in their places.

251. USE OF TWO EYES. Put a thick book upright before you with its back opposite your nose, close one eye, and notice how much of the book you can see. Close the other, and notice the same. What do you find ?

Look at the objects in your room with but one eye, then with both eyes. In which case do you see the objects more correctly ?

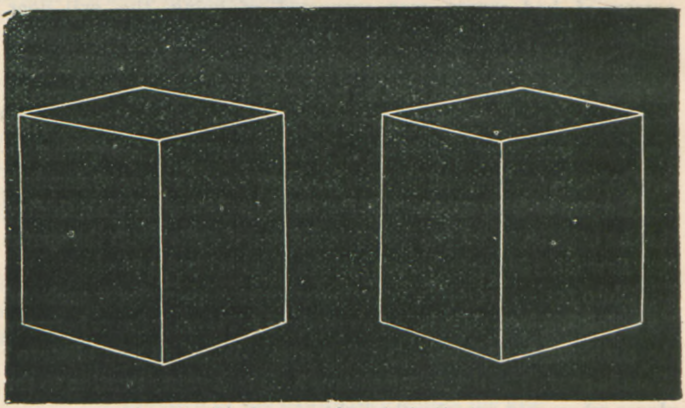

Fig. 87. The images of a cube in the two eyes.

A near object produces two unequal images in our two eyes—one representing more of the left side, the other more of the right side. The inequality of the two images is the reason why we see the object as a body, not as a picture.

The two eyes enable us to see more of an object than could be represented in a drawing.

252. THE STEREOSCOPE is an instrument with two prismatic glasses at one end and a place for two well lighted photographs at the other. A partition extends from between the two glasses towards the middle of the photographs.

Hold a printed sheet in the place for one of the photographs, letting it extend over the upper margin of this place; then look with one eye through the glass on this side, and notice how the print is changed in **place and appearance.**

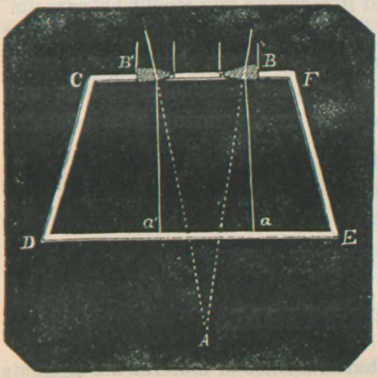

Fig. 88.

Close the eye with which you have just looked and find out whether you can see the printed sheet (whose place must remain unchanged) with the other eye. Try the same with the other side. Now look with both eyes at the printed sheet, this time placed under both glasses.

If you take two photographs instead, they will also overlap each other, and as they are nearly alike, you will not notice that you look at two photographs; they will appear as **one object.** In the same way you do not usually notice that you get two impressions of one object before you, one from each eye.

The two photographs resemble the two views of an object which we get with two eyes. The photographer took them from two different places. He photographed an object or landscape twice at the same time, with a double camera obscura, just as if the two eyes had fixed the images of their net-membranes.

Sometimes the objectivity produced by photographs in stereo scopes appears greater than in nature, and the distances between things nearer and farther off, magnified and unnatural. In this case the two cameræ obscuræ were not arranged correctly; they gave views that would be seen with eyes half a foot apart from each other. This inequality may be increased so far as to make it impossible for us to unite the two views into the appearance of one object.

It is interesting to notice that in certain cases our eyes, similarly, show us two pictures instead of one object. Hold one finger at a distance of about eight inches in front of your face, a finger of the other hand eight inches further off, and then look steadily at one of the fingers. How does the other appear ?

This concludes our studies in optics. I hope you have gained some knowledge of this beautiful and highly interesting branch of science, but the object aimed at in teaching you would be very imperfectly attained indeed, if you should now cease to think and study. You have seen on previous occasions that there is much that you may find out, either by your own observations and thoughts, by consulting books, or by conversing with educated persons.

CHAPTER XIV.

MAGNETISM.

250. MAGNETS. Of what substance or material are magnets made ? Show what they can do. Find out whether all parts of the surface attract iron and steel. Fasten a small iron ball to a string, hold a bar magnet upright, and move the iron ball along the magnet, without touching it. What do you observe ?

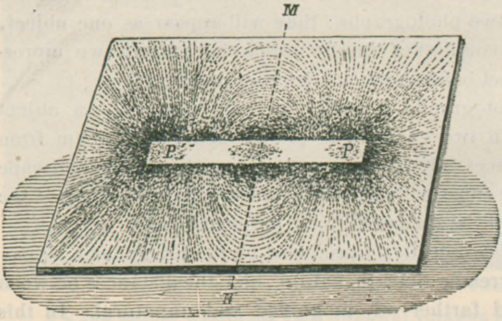

Fig. 89.

Cover the magnet with a sheet of paper, and find out whether it attracts through the paper. Strew iron filings on a sheet of paper covering a magnet. What do you see ?

Magnets are pieces of steel which have the power of attracting iron and steel. The places having the greatest attractive power are called the poles.

How many poles has a magnet, and where are they?

254. INDUCTION. Get a knitting needle and find out whether it is magnetic. If it is not, place the two poles of a horseshoe magnet upon the middle of the knitting needle, move them to one end of the needle, then to the other, then again to the first, repeat this motion twenty times each way, without lifting the magnet off the needle, and at last lift it from the middle. See whether the needle has grown magnetic. What use have we made of the horseshoe magnet?

A magnet may be used to develop (induce) magnetism in a piece of unmagnetic steel.

255. MAGNETIC NEEDLE. Try to balance the magnetic knitting needle on the nail of your thumb. Notice in what position it rests. Take it off the nail and try again. Suspend a double wire loop (Fig. 90.) from a string and balance the needle in it. Watch the position and direction of the needle each time. Do you notice anything remarkable?

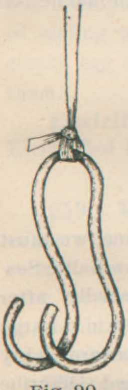
Fig. 90.
Wire loop.

A magnetic needle, capable of freely turning on its center, points with one end to the north and with the other to the south.

The end of the magnet pointing to the north is called the north pole; the end pointing to the south is called the south pole.

In what other way can we find north and south? What persons must know at all times where north and south are? What do they use for this purpose?

A compass consists of a box with a magnetic needle. The magnetic needle is capable of freely turning on its center. The bottom of the box contains the names of directions, or the points of the compass.

256. NORTH-MAGNETISM AND SOUTH-MAGNETISM. Hold the north pole of a bar magnet near the north pole of the magnetic needle. What do you observe? Suspend the bar magnet in the wire loop and hold the north pole of the needle near the north pole of the bar. What do you observe? Learn how the south poles of two magnets act towards each other. Learn how the south pole of one magnet acts toward the north pole of another and vice versa.

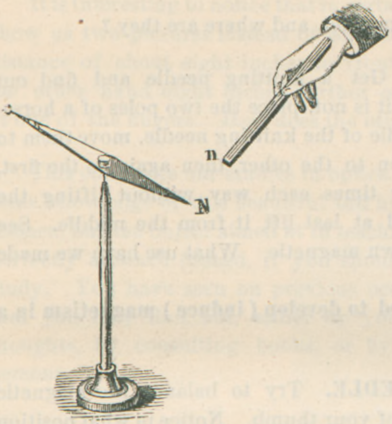

Fig. 91.

The magnetism of the north pole is called north-magnetism; the magnetism of the south pole is called south-magnetism.

Like poles of magnets repel, unlike poles attract each other.

The north pole of a magnet attracts what the south pole repels; the north-magnetism and the south-magnetism are of opposite qualities.

CHAPTER XV.

ELECTRICITY.

257. AMBER OR ELECTRON. The substance we must use is called amber. It is found on the shores of the Baltic Sea especially after a storm. Large pieces are highly prized. Describe its appearance.

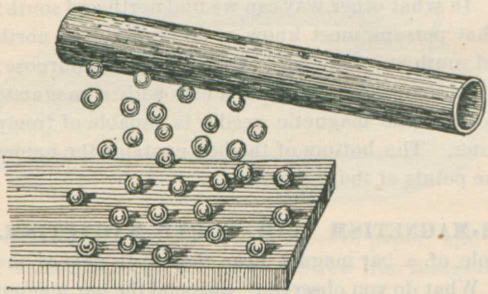
Fig. 92.

Rub a piece of amber with a woolen cloth and hold it over small pieces of paper, (shreds of cotton or silk, feathers, gold-foil, bran, saw-dust, or any other light object). What do you observe ?

A piece of amber, after having been rubbed with a woolen cloth, attracts light objects. The Greek name for amber is electron. Electricity is the attractive power of amber.

258. ATTRACTION. Heat a piece of writing paper over a lamp, place the paper on a table, rub it a few times with India rubber, lift it carefully, and place it near a wall.

Suspend a wire loop from a narrow ribbon, and balance a walking stick in the loop. Rub a rubber comb with a piece of flannel and try to pull the stick around with the comb. Place the comb in the loop and try to pull it around with the stick.

Instead of the comb and flannel use a **glass tube** about 18 inches long and $\frac{3}{4}$ of an inch thick, (not thinner, lest it should break in your hands and injure you), and a silken pad composed of three or four layers of silk, and repeat the former experiments.

Place an egg in an egg cup and balance a lath of about four feet in length upon the egg. Let it follow the glass, comb, or a piece of sealing wax. Attract soap bubbles with electrified bodies, let empty egg shells, paper hoops, and other light objects roll after them.

Electrified and unelectrified bodies attract each other. Electrified bodies are those having the power of rubbed amber.

259. REPULSION. Suspend a wire loop from a narrow silken ribbon, place an electrified comb in the loop, and approach it with another electrified comb. Bring an electrified glass tube near the electrified comb. Suspend an electrified glass tube and approach it with another electrified glass tube. What conclusions do you draw from your observations ?

There are two kinds of electricity (as there are two kinds of magnetism); the one electricity is called the positive (glass) electricity, designated by the sign +. The other is the negative (rubber) electricity, designated by the sign—.

Objects having the same electricity repel each other ; objects having opposite electricities attract each other.

Determine what kinds of electricity are developed in sealing wax, rock crystal, paper, shellac, and other substances.

260. CONDUCTORS AND INSULATORS. Attach a piece of hard rubber (a comb) to one end, and a cork to the other end of a stiff wire. Hold the rubber with two or three fingers of your left hand, electrify it with the other, and find out whether the cork is electrified. Substitute a silken thread for the wire and repeat the same experiment. What do you observe?

Substances that conduct electricity from one object to another are called conductors of electricity; those which do not conduct the electricity are called insulators of electricity.

Metals, moist objects, and the human body are conductors of electricity; silk, rubber, glass, wax are insulators of electricity.

261. THE ELECTROPHORUS consists of a plate of hard rubber (about one foot square,) a disk of zinc* to which are attached three silken strings, and a fox-tail.

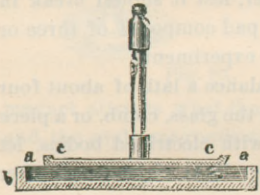

Fig. 93.

Brush or beat the rubber with the fox-tail, place the disk, which is held by the strings, upon the rubber plate, lift it by the strings, and bring it near some light objects. The light objects are not attracted — the disk is not electrified. Repeat the experiment with thefollowing modification: After having placed the disk upon the plate, touch it for a moment with a finger, then lift it by the strings, and bring it near the light objects. They are attracted — the disk is electrified.

An explanation of the last experiment, or rather, the theory, by means of which we try to understand this and other electric phenomena, is at follows:

262. THE TWO ELECTRICITIES. The two kinds of electricity are present in every object, be it electrified or unelectrified. In an unelectrified object the quantities of the two electricities are equal; in an electrified object the quantity of one electricity exceeds that of the other.

At first it seems strange that an unelectrified object should have electricity, but after consideration you will become familiar with the idea. We will illustrate it in the following simple way.

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* The disk is made of two circular pieces of sheet zinc connected by means of a rounded edge of zinc about half an inch in height.

Suppose two boys of equal strength take hold of each other. In this state neither of the two boys is able to do anything except to hold the other; neither is able to write, to throw a ball, or to pick up a pen. Though each of them has a certain power, he is unable to exercise this power otherwise than in balancing that of the other.

The two electricities in an unelectrified object hold similar relations to each other—they hold or bind each other, and are unable to exercise their power on anything outside.

263. INDUCTION. Now suppose that a third person uses his power to tear one of the boys away. How does that affect the other?

Something similar occurs when an electrified object comes near an unelectrified **conductor;** for instance, when the metallic disk is placed upon the electrified plate of hard rubber. The plate has an abundance of free negative electricity and the disk has the two electricities united with each other, bound up in each other. How does the free negative electricity of the plate act upon the two united electricities of the disk? Which electricity is at the upper, which at the lower side of the disk? Which of the two is held captive, which is free?

What happens when a person touches the disk while it rests on the plate? What happens if the disk, after having been touched, is separated from the plate by means of the silken strings?

The separation of the two electricities in a conductor (as, for instance, the metallic disk) by the free electricity of an object near by is called **induction.**

If an electrified object (A) comes near an unelectrified con-

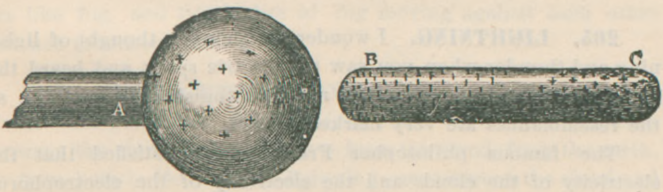

Fig. 94

ductor (B C), the two electricities of the latter are separated—the opposite electricity is attracted toward the electrified object,

and the like electricity is repulsed. The opposite electricity is held captive; the like electricity is repulsed and free.

If we place the unelectrified disk of the electrophorus on the electrified plate, the two electricities of the disk are separated; the opposite electricity is attracted and held captive, the like electricity is repulsed and free. If we touch the disk with a finger, we allow the repulsed electricity to escape through our bodies. If we then lift the disk by means of the silken threads, the disk is filled with free electricity.

It is essential that you have a clear idea of this process; otherwise you will be unable to understand any of the electrical phenomena. Induction is the key to the understanding of the whole subject.

264. ELECTRIC PHENOMENA. Repeat the experiment with the electrophorus. Touch the disk, lift it by means of the strings, and bring a knuckle of your hand near the round edge. What happens? With what electricity is the disk charged when it is suspended by the silken strings? What takes place in the knuckle or hand held near the electric disk? Hold the electric disk over the head of a child. What happens? Hold it close to your face. What sensation does it produce?

If we place a finger near the electric disk, a spark flies out and a crackling noise is heard. If we hold it close to the head of a person, his hair rises on end. If we hold it near the face, we have a sensation as if we were touched by spiderwebs.

The electric spark appears when the two opposite electricities break through the separating air and join each other. The singular sensation in the face is caused by the rising of the numerous little hairs on its surface.

265. LIGHTNING. I wonder whether you thought of lightning and thunder when you saw the electric spark and heard the accompanying noise. It would not be astonishing if you did, as the resemblances are very marked indeed.

The famous philosopher Franklin was satisfied that the electricity of the clouds and the electricity of the electrophorus were identical. He, therefore, boldly set out to experiment with the electricity of the clouds. For this purpose he constructed a kite with a pointed metal rod attached to it, and, when an opportunity offered, flew his kite directly toward a thunder cloud. The electricity descended by means of the hempen string which held the kite, so that if Franklin had held the end of the string in his hand, he would most assuredly have been killed by lightning. But he was careful. He fastened a **key** to the end of the **hempen** string, and held in his hand a **silken** string, which had been tied to the other. In this way he insulated himself from the kite and drew the sparks from the key.

Lightning is a discharge of atmospheric electricity, accompanied by a vivid flash of light. The electric spark and lightning are essentially the same, only different in their intensity.

266. THUNDER. What happens if lightning strikes a frame house or a tree ? This proves that lightning communicates heat to substances which it strikes or through which it passes. So it does with the air. The air occupying the path which lightning takes is immediately and intensely heated. What effect has heat upon air and upon other substances ? See ¶ 43.

Consequently the air occupying the path of lightning suddenly expands. We may take it for granted that this air suddenly expands to more than ten times its former volume. How will that affect the surrounding air ?

The motion caused by the expanding air will be communicated to the air all around. In a short time the motion will reach the air surrounding ourselves. What part of the body is most sensitive to the motion of air ? What shall we hear ?

Thunder is the noise caused by the vibration of air following lightning. The air vibrates, because the electric spark suddenly heats and expands the air through which it passes.

Thunder is not caused by the concussion of clouds. Clouds are like fog, and two bodies of fog moving against each other can not produce a loud noise.

267. THE LIGHTNING CONDUCTOR.* Explain Fig. 95. From what place does the electricity come when lightning passes between the cloud and the earth — from the cloud, from the earth, or from both ? Does all the lightning pass between the cloud and the earth ?

In which class of objects may the two electricities be separated

* Invented by Benjamin Franklin in 1749.

more easily — in conductors or in insulators? What parts on the outside of houses, particularly on the roofs, are conductors of electricity? Suppose a cloud charged with electricity is near a house.

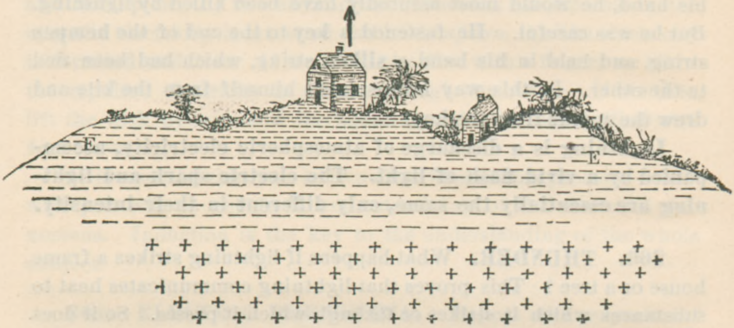

Fig. 95.

What parts of the house may be struck more easily — the conductors or the insulators, and why? It was a consideration like the above that suggested to Franklin the advisability of preparing a **path** for lightning, a pathway by which lightning can be conducted harmlessly into the ground.

The lightning conductor is composed of three parts: one above the roof, one in the ground, and a conductor between the two. The part above the roof consists of an iron or copper rod with a gilded point; the part in the ground is another metal rod ending in water or moist earth; the conductor consists of any metal forming an unbroken connection between the two.

A rainpipe may be used as such a conductor, excepting that care must be taken that there is no interruption. Why?

CHAPTER XVI.

GALVANISM.*

268. TELEGRAPH WIRES. In many streets and country roads, and everywhere along the railroads, you see high poles with numerous wires. What is the name of these poles? Why? Of

* Galvani was a professor in Bologna, Italy, who, in the year 1789, discovered the peculiar kind of electricity that is made use of in telegraphs and telephones. To distinguish it from the electricity caused by friction it is called Galvanism.

what do the wires consist? Other wires, which are placed in the ground or laid at the bottom of lakes and oceans, consist mainly of copper. Ask your teacher to show you samples of these wires. Describe them.

Telegraph wires are suspended in the air and conducted through the ground or the water. The first consist of iron, the second and third of copper.

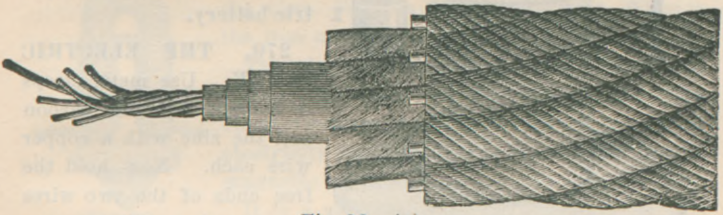

Fig. 96. (a)

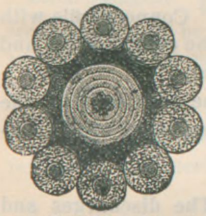

Fig. 96. (b)

Copper wire used underground is usually covered with gutta-percha. Submarine wires are protected by various substances; they are called cables.

Fig. 96 represents a portion of the Atlantic cable laid in 1866. Its copper center is protected first by a stout layer of gutta-percha, then by a woven coating of jute, and, outside of all, by a sheath made of ten iron wires, each of them covered with hemp. Give two reasons why the copper wires are covered.

269. AN ELECTRIC CELL. The electric or galvanic cell consists of a glass tumbler, a cylindrical piece of zinc, a porous cup of earthenware, and a piece of carbon. The carbon is placed in the porous cup and surrounded with nitric acid*; the zinc is placed outside of the cup and inside the tumbler, and surrounded with dilute sulphuric acid. The contact of carbon and zinc with the acid produces electricity.**

The fluids do not quite cover the carbon and zinc, a short piece of both is outside and dry. The outside or free part of the carbon

* Nitric acid, or a liquid composed of a saturated solution of potassium bichromate, or (better) sodium bichromate, mixed with one sixth of its volume of sulphuric acid.

** The mixture, or rather the combination, of sulphuric acid and water, must by prepared by pouring the former into the latter. If done the opposite way, the acid may be thrown out and may injure the surrounding objects.

shows positive electricity, the free part of the zinc, negative electricity.

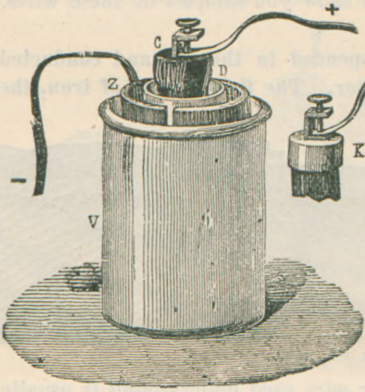

Fig. 97.

Besides this kind of electric cell there are many others in use.

The combination of several electric cells is called an **electric battery.**

270. THE ELECTRIC SPARK. Use metal clasps to connect both the carbon and the zinc with a copper wire each. Now hold the free ends of the two wires close together. What do you notice? Connect a file with one of the copper wires and scrape over its surface with the end of the other.

An electric spark appears whenever the free ends of the carbon and zinc of the electric cell are connected or disconnected.

271. THE ELECTRIC CURRENT. The discharges and the new charges follow each other so rapidly that a wire connecting the pieces of carbon and zinc is said to contain a constant double current of electricity: the positive electricity of the carbon flows continually towards the zinc, and the negative electricity of the zinc flows continually towards the carbon.

The **continuity** of the electric current is the most marked and most valuable quality of galvanic electricity.

The **power** of the galvanic or electric current depends on the power and number of the galvanic cells. To produce a strong current, several galvanic cells are properly connected with each other. The combined electricity of three or four cells is sufficient to melt a thin iron wire, and the heat may be used to explode gunpowder in a mine or to discharge a cannon at a distance. The power of sixty of these cells is sufficient to produce a bright electric light, which consists of carbon made incandescent by a strong galvanic current. But the most important effect of the current is the one described in the following paragraph.

272. ELECTRO-MAGNETISM. Fig. 98 represents a bar of soft iron having the form of a horseshoe and an **insulated** wire coiled around it. Prepare such an instrument and find out whether it is a magnet. What substance is used for magnets? Now send a current of electricity through the coil of wire, not through the iron horseshoe. What remarkable change takes place? Interrupt the current of electricity by separating the wires. What is the consequence? When is the iron magnetic and when unmagnetic?

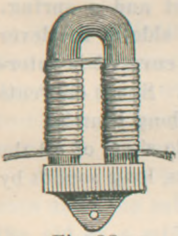
Fig. 98.
Electro-magnet.

The electro-magnet is a piece of soft iron placed within a coil of insulated wire. The electro-magnet is magnetic when a current of electricity passes through the coil; it is unmagnetic when there is no current.

It is a very valuable circumstance in this phenomenon that, though the cell and the electro-magnet may be at a very great distance from each other—may be thousands of miles apart—the one may still be affected by the other.

273. THE ELECTRO-MAGNETIC TELEGRAPH. Fig. 99 represents the receiver of telegraphic despatches. Show the elec-

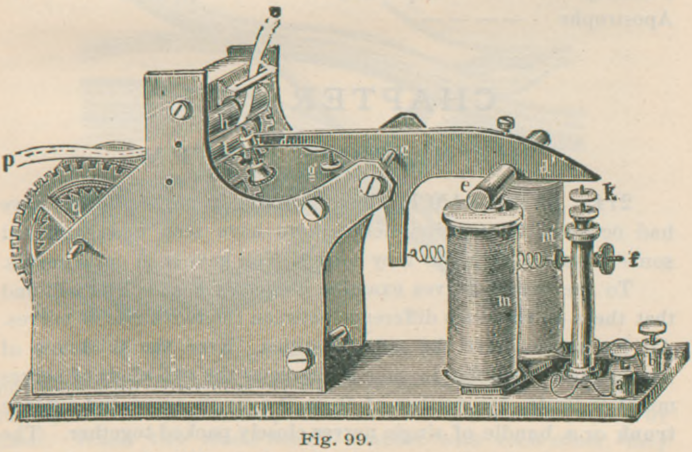

Fig. 99.

tro-magnet in it. What takes place when an electric current is sent through its coil of wire? Is there anything near the electro-magnet which may be attracted? Do you see the part that moves this piece of iron away from the electro-magnet, if the electro-magnet loses its power? Both the pieces of iron and the spring are attached to a bar capable of being moved about a fixed point or line. What is this bar called? See ¶ 179.

The receiver of the telegraph* consists of a lever of the first kind, moved to and fro by an electro-magnet and a spring. When a current is sent to the receiver, one side of the lever moves towards the electro-magnet; when the current is interrupted, the spring draws it the opposite way. Short currents produce short sounds; long currents produce long sounds.

The following table contains the telegraphic signs of all the letters, short sounds being represented by points, long sounds by lines:

A	· —	H	· · · ·	O	· · ·	V	· · · —
B	— · · ·	I	· ·	P	· — — ·	W	· — —
C	— · — ·	J	· — — —	Q	— — · —	X	— · · —
D	— · ·	K	— · —	R	· — ·	Y	— · — —
E	·	L	· — · ·	S	— — —	Z	— — ·
F	· · — ·	M	— —	T	—		
G	— — ·	N	— ·	U	· · —		

Full stop · · · · · · Repetition · · — · · Hyphen — · · · · —

Apostrophe · — — — — ·

CHAPTER XVII.

THE NERVOUS SYSTEM.

274. APPEARANCE. Several times in our studies we have had occasion to mention nerves; we have seen and examined some of them. How do they look? You have seen optic nerves.

To see dental nerves examine a sheep's head. You will find that there is not much difference between the two kinds of nerves. All the nerves have the same qualities. Even the thickness of nerves does not differ in such a degree as the two kinds of nerves might indicate, for neither of them is a single nerve, but a **nerve trunk** or a bundle of single nerves closely packed together. The optic nerve, for instance, consists of more than one thousand single

*Invented by Samuel Morse 1832.

nerves or **nerve fibers** lying closely side by side, any one of them not thicker than about 1-2000 (.0005) of an inch.

Nerves are white, solid cylinders, smooth and shining at the surface, harder than meat, but somewhat compressible between the fingers. Each nerve that is visible without the aid of a microscope consists of numerous nerve fibers, and is more properly called a nerve trunk.

275. DISTRIBUTION. Fig. 48 (p. 75) shows the distribution of the nerves in the human face. Look at the white lines. Are they nerve trunks or nerve fibers? Follow some of the nerve trunks to the surface. What do you notice? Follow the nerve trunks in the opposite direction. What becomes of them?

The nerve trunks break up into finer and still finer branches until the subdivisions become too small to be seen without the aid of a microscope. Traced the other way the nerve trunks unite with others, finally forming large masses called nerve-centers.

276. NERVES COMPARED WITH BLOOD-VESSELS. All the blood-vessels are intimately connected with each other, and form one coherent system of tubes in such a way that a drop of blood may pass from one place to any other; while the nerves are

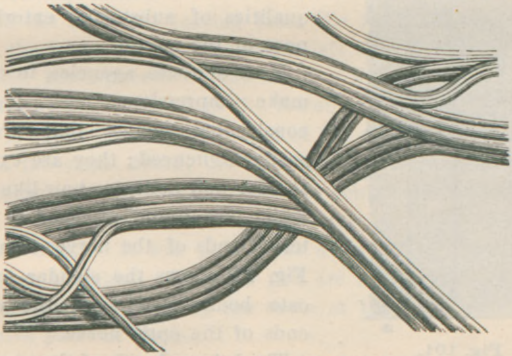

Fig. 100. Nerve fibers.

not intimately connected with each other, each of them commencing by itself, independently of other nerves, and terminating by itself. When two blood-vessels connect with each other, they form one single tube, while the nerve fibers remain independent of each other, even when they lie close together.

Nerves and blood-vessels resemble each other in their distribution through the human body; both are found in nearly all the organs. But all the blood-vessels form one coherent system, while the nerve fibers usually remain independent of each other.

Considering the functions of nerves and blood-vessels this point of contrast should be noticed; for blood-vessels carry the same fluid throughout the body, while nerves conduct a variety of impressions to the brain and to other organs.

277. THE NERVOUS ELEMENTS. Where are the external ends of the fibers of the optic nerve? Where, those of the nerves of touch? The external ends of the nerves of smell are in the lining membrane of the nose; those of the nerves of taste in the lining membrane of the tongue and the soft palate.

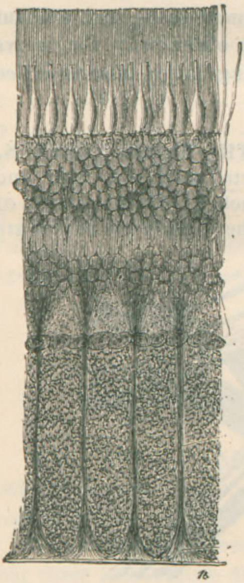

Fig. 101.
Elements of retina.

By what are the external ends of the optic nerves affected or stimulated? By what, those of the auditory nerves? Those of the skin are affected by pressure and temperature, those of the nose and tongue, by the qualities of substances entering the nose or the mouth.

Most of these agencies, in order to make impressions, need peculiarly constructed bodies that are very easily influenced; they are extremely slender and delicate, hair-like organs which are found attached to the external ends of the nerves mentioned. Fig. 101 shows the slender and delicate bodies that form the external ends of the optic nerve.

The **internal** ends of the nerve fibers are occupied by rounded, soft bodies called nerve cells. Their diameter is about eight times as large as that of the nerve fibers. Many thousands of them are found in the brain and spinal cord.

The nervous system is built up of three elements: the hair-like organs, the nerve fibers and the nerve cells. The

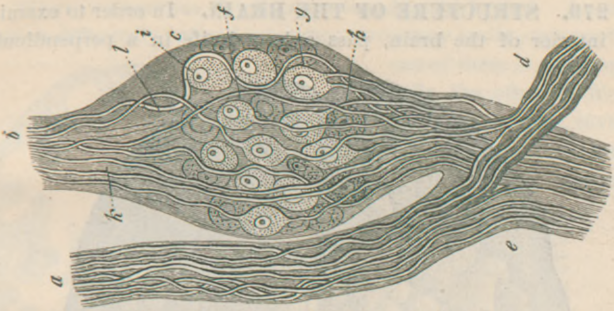

Fig. 102. Nerve cells and nerve fibers.

hair-like organs are external or peripheral, the nerve cells are internal, or central, the nerve fibers are intermediate.

278. THE BRAIN. We will examine a calf's or sheep's brain. What shape has it? Describe the upper surface.

The folds, or **convolutions,** which you see at the upper surface are more or less numerous in different persons and animals; they are deeper and more numerous in the brain of man than in that of any animal.

Find the deep cut passing from the front to the back, separating the brain into a right and a left half. The two halves are called **hemispheres** of the brain. Find also a small piece with parallel folds located in the lower part. This piece, whose weight is about one eighth of that of the main part of the brain, is called the **small brain,** the two hemispheres, the **large brain.**

A third part is distinguished as the **continuation of the spinal cord.** It is located below the large brain, in front of and near the small brain. It was partly cut away when the brain was taken from the skull. Perhaps you are also able to distinguish some nerve trunks entering the brain at its lower side. There are twelve pairs of them.

The brain is the nerve-center located in the skull. It has three parts: the large brain (cerebrum), the small brain (cerebellum), and the continuation of the spinal cord (medulla oblongata). (Fig. 103. See next page.)

What are the characteristics of the large brain? What are the characteristics of the small brain?

279. STRUCTURE OF THE BRAIN. In order to examine the interior of the brain, pass a long knife in a perpendicular

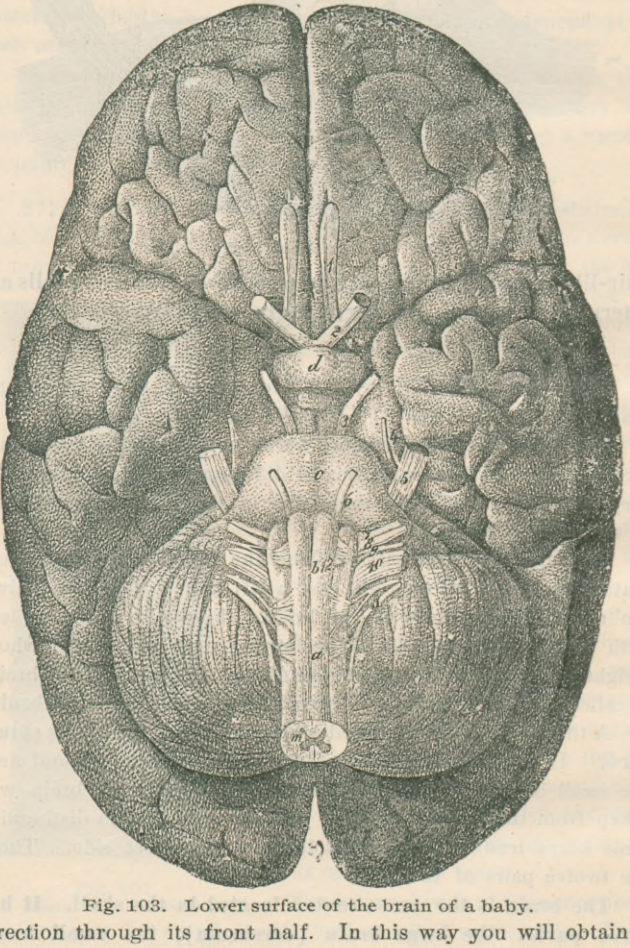

Fig. 103. Lower surface of the brain of a baby.

direction through its front half. In this way you will obtain a transverse section. What do you see? Is there any regularity in the distribution of the gray and the white matter? Now cut through the cerebellum. How are the gray and the white matter distributed here? The figure which you see in the section is called the tree of life (arbor vitae).

What two nervous elements are found in the brain? As there are two differently colored substances, you may easily suppose that one of them is made up of cells, the other of fibers. By microscopic investigations it has been found that the gray matter is almost entirely made up of cells, while the white matter contains the fibers.

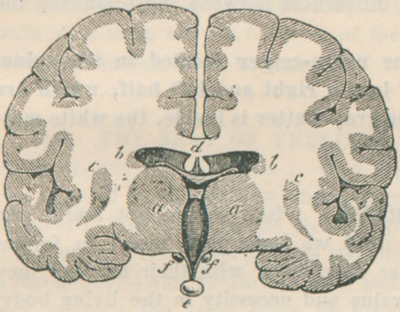

Fig. 104.
Transverse section of the brain.

The brain contains two substances called the gray matter and the white matter. The gray matter forms the outer part of the brain, and contains the nerve cells, the white matter forms the inner part and contains the fibers.

Fig. 105.

280. THE SPINAL CORD. Fig. 105 gives you an idea of the shape of the spinal cord when taken from the interior of the spinal column. Fig. 106 shows cross sections through the cord. Describe the figures. The cross section of the interior gray matter shows a resemblance in form to one of the capital letters. To which?

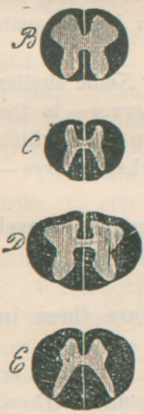

Fig. 106.

At what place do the nerve trunks commence? There are thirty-one pairs of nerves commencing in the spinal cord. Name the resemblances and the differences between the brain and the spinal cord.

The spinal cord is the nerve-center located in the spinal column. It is separated into a right and left half, which are united in the middle. The gray matter is inside, the white matter, outside.

281. SENSORY NERVES. Often we do not realize the value of our possessions until we have lost them. In former times people had a similar experience with their nerves; they did not understand their value and necessity in the living body, until, by accident, they had injured or destroyed them.

Injuries to nerves are not very frequent, because, as a rule, they are well protected. Perhaps the most common instance of this kind is the loss of vitality in certain dental nerves. If this has taken place, the dentist may scratch, file, or drill into the tooth whose nerve has been destroyed, without causing pain.

Let us consider another case. A nerve connecting the skin of a finger with the brain is cut somewhere in its course, as, for instance, in the elbow. What takes place? Just what takes place in the case of a tooth—the skin loses its sensibility. Now, we might put a red hot iron on the skin of this finger, or cut into the skin until blood flows, or pour boiling water on it; no pain would be felt.

What will follow if the optic nerve be cut? Name similar cases. Where is the proper beginning of these nerves—in the various organs we have mentioned, or in the brain? In which direction does the impression or stimulus travel in these nerves—in the direction **to** the brain or **from** the brain?

Sensory nerves are nerves in which impressions travel toward a nerve-center.

282. MOTORY NERVES. Motory nerves are those in which an impulse travels from a nerve-center.

The word motory has a meaning similar to that of motion or movement. Why did the motory nerves receive this name? Where do they begin? Where do they end?

Our will emanating from the brain, sends the message through the motory nerves. What happens if a motory nerve be cut? What ability have the muscles lost, if the nerves connecting the brain with them are cut? Most of the motory nerves carry impulses to muscles, some, to glands.

283. THE SEAT OF FEELING. If your finger be burnt where do you feel the pain? Why does a person, whose sensory nerve of the finger is cut through, not feel pain, if his finger be burnt? His finger is not changed if the nerve is cut through at the elbow. His finger has all the substances our fingers have, is just as sound and healthy as ours, and the burning must, therefore, produce the same effect on his finger as on ours. Either pain is felt in the fingers of both or of neither of us.

One of the two statements must be wrong and one must be right. Is it possible that a person may feel pain, when he does not know anything about it? Then it must be wrong to say that a person feels the pain in his **finger.** It certainly can not be denied that a person feels pain, but it is not true that he feels it in his finger—he feels the pain in his **brain.**

Strange as it may seem at first thought it is nevertheless perfectly true that all our feelings are perceived in the brain, and that the sensations are **erroneously** ascribed to different parts of the body.

Remember that we imagine we feel with the end of a long stick, or with the end of a long line, when we are angling or trolling. When we have a bite, it seems as if we felt with the end of the line. This error is caused in the same way as the error of locating pain or feeling in various parts of the body.

There are other facts that point to the same error. If we strike the elbow at a certain spot (called the funny bone), we feel a tingling pain in our fingers. The fingers themselves were not touched, only the nerve that passes from the fingers to the brain.

When a limb is amputated and pressure is exerted upon the end of the stump, it seems as if there were a sensation in the missing part. Pain or pressure is felt in a foot or arm that no longer exists!

The seat of feeling is the brain. It is a common error to locate feelings or sensations in any other part of the body.

284. SENSATIONS. When we plunge our hands into cold water, the sensation of cold is produced in the following way: first, the cold water stimulates the sensory nerves of the hand; second, the stimulation is carried along the sensory nerves from the hand to the brain; third, the mind becomes conscious of the feeling of coldness.

Objects within our field of vision produce a sensation in the following way: the objects send light into our eyes; an image of the object is produced on the net-membrane; the net-membrane is stimulated by the light; the stimulation is carried to the brain; the mind becomes conscious of a sensation.

The sensation of sound is produced in the following way: external objects vibrate; the vibration is carried through the air to the drum-membrane and conducted through a series of little bones to the fluid filling the labyrinth; nerves in contact with the watery fluid are stimulated by the vibration; the stimulation of the nerves is carried to the brain; the mind becomes conscious of a sensation.

How may a hollow tooth produce the sensation of pain? How may a heavy book produce the sensation of pressure?

To produce a sensation it is necessary, first, that an external object should stimulate a nerve; second, that a nerve should carry the stimulation to the brain; third, that the mind should become conscious of the stimulation.

285. THE SYMPATHETIC SYSTEM. Are the stomach, the heart, intestines, blood-vessels, etc. supplied with nerves? Under ordinary circumstances we do not feel these organs; we neither receive sensations from them, nor do we move them. Nevertheless, their functions can not be performed without the regulating influence of nerves.

Nerves stimulate the glands of the stomach to secrete gastric juice; nerves stimulate the muscles of the stomach to move the walls in and out. In fact all the organs of the body, except those in which blood-vessels are also missing, are supplied with nerves. Nerves, like blood-vessels, are present in every active organ of the body, some for nutrition, others for order and regularity.

The nerves regulating the processes of digestion, circulation, secretion, and nutrition are not primarily or immediately connected with the brain or spinal cord. There is a third nerve-center, which administers to the needs of the heart, the liver, the stomach, and the glands. This nerve-center is the sympathetic system.

The sympathetic system consists principally of a double chain of ganglions (small groups of nerve cells) which lie in front of the spinal column, one on each side. The ganglions are connected by strings composed of nerve fibers.

The sympathetic system regulates the processes of digestion, circulation, secretion, nutrition, and others that are performed without the activity of the mind.

The sympathetic system is a kind of assistant, to whom are entrusted those functions of the body, whose regulation would be onerous and annoying to the headmaster residing in the brain. It would be extremely troublesome, nay, impossible, for the mind to regulate the secretion of every gland, the motion of every morsel of food, and the nutrition of every organ.

Only in extreme cases, as when one of the processes of nutrition or secretion is disturbed, does the mind become conscious of it. This is accomplished by a special nervous connection between the sympathetic system and the brain. Such cases are the following: we feel pain at the stomach; our hearts beat too fast; our perspiration is excessive, etc.

Certain states of the mind may also affect the work of organs usually under the control of the sympathetic system. Fright, terror, or expectation cause a quicker beating of the heart; shame or embarrassment dilate certain blood-vessels, thus producing a rush of blood into the face; fear contracts the same blood-vessels, thus producing paleness of the face, etc.

286. REFLEX ACTIONS AND INSTINCTS. That we may better understand the functions of nerves, we will consider the part they take in some of the common occurrences of daily life:—

1. Someone asks me to cut a rose from one of my bushes; I perform the action. Here the sensation of sound is carried by sensory (receiving) nerves to my mind, and by means of motory (sending) nerves I direct certain muscles of the arm to do the work.

2. I rest my head upon my arm. The pressure of the hard support becoming unpleasant, after some time I change my position. In this case the sensation of pressure is carried to the mind

by means of receiving nerves, the sensation gradually becomes disagreeable and painful, an impulse is sent through sending nerves, and muscles affected by them effect a change of position.

3. My hand accidentally touches a hot object. I instantly remove it. In this case the sensation of heat is carried to the brain by means of receiving nerves and the contraction of muscles is caused by an impulse sent through sending nerves.

4. When I smell the juice of oranges, saliva collects in my mouth. The sensation of smell is caused by receiving nerves, the secretion of saliva, by sending nerves.

If we compare the four instances, we find that the mind is not equally active in all of them. It is active in the first case, because I become conscious of the request, and the will directs the action of cutting. In the second instance, I gradually become conscious of the pressure. I deliberately change my position, or I do it without a conscious direction of my will. In the third and fourth cases, the removal of the hand, and the secretion of saliva, are done without the direction of the mind.

Involuntary actions of the body, such as sneezing, winking, the removing of the hand from a hot spot, etc., are called **reflex actions.** It is as if the irritation or impulse of a receiving nerve were reflected through a sending nerve.

Some actions require the direction of the mind when first performed, but become unconscious and change to reflex actions after a sufficient number of repetitions, as for instance, walking—it takes a child a long time to learn it. Reading, performing on instruments, knitting, embroidering, in fact every kind of mechanical work becomes unconscious after a certain number of repetitions.

All the actions of the body are the consequences of previous impressions. The nervous centers are thrown into activity only by effects of changes that have taken place in receiving nerves; the activity of the sending nerves **follows.** The more highly organized a being is, the more it will influence the activity of sending nerves, will place its mind or will between the actions of receiving and sending nerves, invent new combinations, and acquire abilities that other beings do not possess.

Most of the actions of the lower animals are reflex actions. Some have been repeated a great number of times, in exactly the same way, so that no activity of the mind is required to perform them in the best possible manner; the offspring inherit the bodily organizations allowing the repetition of the same actions with the least possible mental activity, and thus **instincts** are developed.

REFLEX ACTIONS are actions of our organs which are performed *without the consciousness of the mind.*

287. BRAIN AND MIND. The brain is the seat of the mind. Disturbances or injuries of the brain are accompanied by disturbances of the mind. Permanent abnormities of the brain are accompanied by permanent insanity, imbecility, madness, or other diseases of the mind.

The principal mental actions are thinking, willing, and feeling. A temporary injury to the brain, such as is caused by a blow on the head, deprives us of consciousness—makes us unable to think, to will, or to feel. If the heart is prevented from sending a sufficient supply of blood to the brain, the person faints—becomes unconscious. If the brain is flooded with a great quantity of blood, as happens when a blood-vessel of the head bursts, the person is seized by an apoplectic fit.*

288. MENTAL HEALTH. The health of the mind and of the brain depend on each other. Sorrow, anger, an excitable temper, worry, and similar mental conditions have a depressing effect upon the mind and, through the mind, upon the brain. A brave heart and a cheerful disposition are conducive to a healthy brain.

Nothing wears upon the nervous system more than constant worry. If the heart is depressed, if a person has lost his courage, if he constantly dreads failure, he can not do half the work of which he otherwise would be capable.

289. SLEEP. How long does your baby-brother sleep during the day? How long do your parents sleep? What do your parents tell you about going to bed and rising? Is it healthful for a girl of fifteen or sixteen to study till midnight and rise at six or seven in the morning?

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* To restore to consciousness a person who has fainted, he should at once be laid flat on the back, that the blood may more easily be pumped into the head. His face should be briskly sprinkled with cold water, and some strong smelling substance, as hartshorn, be held to his nostrils.

A person seized with an apoplectic fit should be moved as little as possible, and a physician be called at once. Meanwhile apply cold bandages or bags of ice to the head.

During sleep the brain has a complete rest, which is as necessary for its health as periods of rest are for the muscles or the stomach. Children should have plenty of sleep; they should go to bed in season and not rise too early.

Children who habitually go to bed late and have only a small amount of sleep are incapable of vigorous work—they grow feeble in mind and body. Girls who study till midnight suffer from anaemia (bloodlessness) and muscular debility; they endanger their present and future health greatly.

290. REST AND EXERCISE. To keep the brain in a healthy condition, it must be treated similarly to our muscles. What promotes the strength and capability of our muscles? The same is true of the brain and mind.

Regular, moderate, and varied mental exercise and sufficient rest are necessary to the health and strength of the mind.

In early youth children are soon overworked and tired, their attention is easily diverted, and concentration of mind upon one subject is hardly possible. After a few years the mind is better able to concentrate itself and the reasoning powers begin to develop. Still they easily tire and must not be kept too long upon one subject. The desire for knowledge must still be encouraged and strengthened by interesting, stimulating methods of teaching.

Adults (business men or scientists) who have to contend with others for renumerative and pleasant positions in life, usually keep their thoughts busy in only a few directions and easily become one-sided and narrow-minded in their mental aspirations. Variety of mental work and exercise is as necessary for their mental health as varied muscular exercise is necessary for their bodily health.

CHAPTER XVIII.

ALCOHOL.

291. ITS EFFECTS. Alcohol is contained in wine, beer, cider, whisky, and all kinds of intoxicating drinks. It is alcohol that causes intoxication.

The enormous extent to which these beverages are used throughout the civilized and uncivilized world, and the destructive effects consequent upon their use, have awakened the interest of physicians, lawmakers, and people in general. Many persons consider this question as one of the utmost importance to the welfare of individuals and of the entire commonwealth.

There is hardly an organ or system in the body whose composition is not changed or whose function is not disturbed by the continued use of alcohol.

It will be proper to take up, in regular order, one system after the other, and hear what experienced persons have found out.

292. THE BONES. A lady having received as a present a young and very tiny King Charles' dog which she wished to keep small, was advised to feed him a certain amount of alcohol daily, in order to check his growth. She did it with the result that the poor little dog stopped growing entirely. At the same time he lost his former liveliness and activity, became fretful and lazy, and died before he was a year older.

It is seldom that the same experiment is made with children, because the state would punish anyone who assisted in such a crime. Yet, in rare cases, it has been made, the result having been the same with the poor children as with the dog — their growth was stunted, they lost their natural liveliness and cheerfulness, became peevish and irritable, behaved and moved like old men, and died before they reached maturity.

What parts determine the height of the body and the length of the limbs? What, therefore, is the influence of alcohol upon the bones?

Alcohol checks the growth of bones.

293. THE MUSCLES. To learn whether or not the strength of the muscles is impaired by the use of alcohol, it will be best to consider the experience of persons who, like soldiers, travelers, or athletes, have to do very hard work, or perform especial feats of strength.

The experience repeatedly gained by them is that alcoholic drinks lessen the strength. A number of soldiers bear the fatigue of a long march better when they have received no alcohol. Many arctic travelers have stated that alcohol weakens the power to endure both bodily labor and cold. It is now generally conceded to be a serious blunder for anyone to depend upon alcohol as a means of increasing his strength or endurance. Just the contrary effect of alcohol has been proved.

The above is not the only proof of the injurious influence of alcohol on muscles. When persons have been used to alcoholic drinks, the number of fibers in their muscles is found to be fewer and the connective tissue to have increased.

Persons used to alcoholic drinks have lost part of their muscular power — the number of muscular fibers has decreased and that of the connective tissue has increased.

294. ARTERIES. The arteries are injured in several ways. How does the face, particularly the nose, of a hard drinker look?

Red cheeks are considered an indicator of health. Is that the impression made by the face of a drunkard?

The **healthy** red is spread evenly over the face or it makes a handsome spot on the cheeks, but the red of the drinker looks loathsome, his face is blotched. These red blotches are caused by dilated blood-vessels. The walls of the arteries contain a number of circular or ring-shaped muscles that help, to a certain degree, to keep the arteries in proper width. By the use of alcohol the nervous control over these ring-muscles is weakened, and the consequence is an extreme dilatation of the arteries and a flushing of certain parts of the skin.

A second injury is to the walls of the arteries, which lose some of the strong elastic tissue that, in a healthy person, is of the greatest importance to a well regulated circulation. The place of the tough elastic tissue is taken up by oil-drops. Then the blood gradually distends the weakest places and a so-called **aneurism** is caused, which usually ends in the bursting of arteries.

In drunkards the ring-muscles of the arteries are expanded and certain parts of their faces are flushed. Part of the elastic tissue is replaced by oil-drops, and the walls of the arteries are weakened so that they easily burst.

295. THE HEART. Through the use of alcohol, the muscular elements of the heart decrease and the fat cells increase; in other words, the fat cells take the place of the muscular tissue. Which is stronger — a heart containing very few fat cells or one in which they abound?

Through the use of alcohol, the muscular elements of the heart decrease in quantity and the fat increases. A fatty heart can not pump a sufficient quantity of blood through the body.

A post-mortem examination discloses the fatty heart as the cause of death. Fatty degeneration of the heart is so often due to indulgence in alcoholic drinks that physicians call a fatty heart a "whisky heart."

296. THE BLOOD. The influence of alcohol upon the blood shows itself plainly in a gradual disappearance of fibrin.

Why must a defective composition of blood affect the composition and function of other organs? What is the use of fibrin when we are wounded? What must happen if the blood of a wounded person does not contain enough fibrin?

Hence all wounds and all surgical operations on persons indulging in alcoholic drinks are attended with danger.

297. DIGESTION. The digestive organs being the first to come in contact with alcohol, it is easily understood that they are the first to suffer from it.

In what part of the digestive system does alcohol remain for a long time? What may we, therefore, expect? Upon the entrance of alcohol, the internal membrane of the stomach becomes overcharged with blood, and presents the same appearance that a part of the skin does when it is inflamed.

This unnatural condition of the stomach causes a loss of appetite. If a person drinks beer or wine just before dinner, he is unable to eat the usual quantity of food. If he continues to drink, the function of the stomach is disturbed for a longer time.

Persons dying from the use of alcohol show a frightfully distorted stomach, with ugly ulcers and deformities that caused great pain before resulting in death.

The "gin drinker's liver", as the physicians call a liver degenerated through the effects of alcohol, presents a shrunken, hard, rough mass, unable to do efficient work.

298. RESPIRATION. Alcohol sometimes causes slight inflammations of the air-passages, thus increasing the tendency to colds. Furthermore, it weakens the muscles of respiration, thus lessening the amount of air breathed in.

The injurious effect of alcohol upon the lungs themselves has also been demonstrated to be the cause of consumption. This consumption is known as "alcoholic phthisis."

299. THE KIDNEYS. Excessive drinking often produces a kidney disease known as "Bright's disease".* The working substance of the kidneys gradually disappears, and is replaced by an excess of connective tissue. At last the organ is unable to do its work, and death ensues.

Alcoholic drinks being fluid, it is to be expected that they will affect the organs most active in excreting fluids. The injury is done in several ways: first, they throw too much work on the kidneys; secondly, they interfere with the proper preparation of the nitrogenous waste which it is the function of the kidneys to excrete; thirdly, part of these substances passes through the kidneys unchanged.

300. THE NERVOUS SYSTEM. The most direct effect of alcohol is upon the brain and the nervous system generally.

A small quantity of wine or spirits causes an increased flow of blood to the head. The blood brings more nourishment than usual, more than is wanted—the brain is overfed, and the person becomes irritable and excited, talkative, dizzy, and unable to think clearly.

If the quantity is increased, the person behaves in a manner that is painful to behold, losing control over himself and committing deeds that are hurtful to himself and others. If let alone, he is soon overcome by sleep, and on awakening is troubled with a sick headache and nausea.

A repetition and further increase of the dose is followed by more serious and troublesome consequences. The talkativeness is accompanied by indistinct speech, and the dizziness, by trembling limbs and reeling steps. This shows that the nervous system has lost control of the muscles. At the same time, the sensations become indistinct, hearing and touch are dulled, the vision is obscured, the eyeballs do not move together, and objects appear double. A person in this state is like one insane—his mind is wandering and his memory, uncertain. At last he loses consciousness entirely, can

* Sometimes Bright's disease follows scarlet fever, typhoid fever, or cholera.

not hold himself upright, and falls into a heavy sleep, from which he can not be awakened. In this condition he may suffer a sudden death from paralysis of the heart or apoplexy of the brain.

When at last the person has slept off his "drunken fit", he awakens in a state of health that is almost unbearable — his digestive organs are quite out of order; his head is heavy and painful, and his moral sense, weakened.

Drunkards are subject to numerous and serious diseases of the nervous system. Congestion (accumulation of blood) of the brain and its membranes, apoplexy caused by the bursting of blood-vessels, inflammation of the brain followed by its gradual consumption, and analagous diseases of the spinal column and the organs of sense are not infrequent.

These bodily disorders are accompanied by a variety of mental derangements, such as hallucinations, delirium tremens (trembling madness), dipsomania (a mad passion for alcohol), loss of memory, and imbecility.

Intemperate persons not only destroy their own health and happiness, but also that of their families. Their children inherit certain physical, mental, and moral imperfections; they grow weak in body, mind, and will. The children of drunkards show a tendency toward epilepsy, St. Vitus dance, rickets, insanity, or imbecility.

CHAPTER XIX.

TOBACCO.

301. Tobacco contains a highly poisonous substance called nicotine.

Do you know a boy who smokes? How does he look? Is he an attractive boy? Is he clean and neat in person and dress? Is he well-behaved and a kind playmate?

The answers to these questions will show that in the majority of cases a boy who smokes is rude, associates with a low class of society, and is dirty in his person and dress. He has coarse manners; he is not fair in his dealings with other children, but abuses them or imposes upon them.

On the other hand think of a boy who is well cared for, and is kind and obliging to others, neat in person and attire, who is refined in his manners, and liked by his parents, teachers, and schoolmates. Is he found smoking cigars or cigarettes ?

The desire of boys or young men to smoke or chew originates from the example given by older persons. It is the natural desire of young persons to imitate their elders in behavior and looks. When the first shadow of a coming mustache begins to show, the young man enjoys a touch of his upper lip or a look in the glass — he is proud of the appearance of this token of manliness and imagines himself to be at the threshold of a new life. This is an innocent pleasure, which may be enjoyed without harm to anyone.

But the use of tobacco, in any form, is not harmless. There is no difference of opinion about its injurious character. The experience of every country shows that boys and young men invariably injure their health by smoking or chewing tobacco.

Look at a youngster who believes that he is doing a courageous act in puffing the smoke of his first cigar, or in chewing the nasty stuff for which he has spent his money. You can plainly see that it produces very disagreeable sensations — a copious flow of saliva, giddiness, headache, great paleness of the face, cold sweat, trembling limbs, nausea, diarrhoea, and, sometimes, a general breakdown, showing itself in nervous exhaustion and fainting fits.

These symptoms are produced by a poisonous substance called **nicotine,** contained in tobacco. A few drops of pure nicotine will bring about a rapid death through paralysis of the heart. It belongs to the class of poisonous substances called narcotics, some of which are used as medicines. Nicotine, however, is so powerful in its effects that it is regarded as too dangerous to be used as medicine.

302. RESPIRATION. The inhalation of smoke containing poisonous substances is injurious. Persons suffering from lung diseases should avoid places filled with tobacco smoke. A disease peculiar to habitual smokers is "smokers' sore throat."

Everywhere we hear the demand for fresh air. We try to thoroughly ventilate our dwelling and sleeping rooms, our schools, and our assembly halls; yet we suffer our friends and visitors to fill the room with the injurious smoke of tobacco, or to enjoy themselves in places filled with a smoking multitude.

If fresh air is necessary to health, foul air or air filled with a poisonous smoke must be injurious. What do you think of a person suffering from a lung complaint, and either smoking himself, or sitting in a place filled with smoke? What good advice should be given him?

It is worthy of special remark that the smoking of cigarettes is more injurious to the throat or lungs than the smoking of cigars or pipes.

303. THE STOMACH. The smoke and the juice of chewed tobacco interfere with the secretion of saliva and disturb the work of the stomach.

The first advice a person suffering from dyspepsia receives from his physician is to give up smoking or chewing.

304. THE BLOOD. Tobacco interferes with the proper development of the blood cells. The skin of an habitual smoker looks yellowish-white. His muscles are feeble.

Indulgence in tobacco causes a feeling of lassitude and indisposition to exertion of any kind. If a person is not yet sufficiently warned by these symptoms, attacks of palpitation of the heart, trembling limbs, sleeplessness, melancholy, even a gradually increasing paralysis of the body, and the loss of eyesight may be experienced.

QUESTIONS FOR REVIEW.

WATER.

What does the thermometer show? What is vapor? What is the boiling point of water? How may you prove that our breath contains vapor? What qualities are common to steam and vapor? What difference is there between steam and fog? When does fog appear? What air can hold much vapor?

What difference is there between dissolving and melting? When does water evaporate quickly? What are crystals? What is distillation? What are springs? What well-water is poisonous? Describe the circulation of water.

What countries have but little rain? How do forests improve the climate of countries?

HEAT.

What are rays or heat? What difference is there between hot, warm, and cold objects? Why are cloudy nights warmer than cold nights? Describe the formation of dew. What difference is there between a continental and an insular climate?

Describe the effect of heat upon solid, liquid, and æriform substances. Describe a thermometer. What is convection? Describe how a stove heats a room. What is wind? How is wind caused?

How are mammals protected from the cold? How, birds? How, other animals? What are poor conductors of heat?

DIGESTION.

When does the weight of a person decrease? How is the loss of substance caused? Describe the course of food through the body.

Describe the three kinds of teeth. Name the parts of a tooth. Name the substances of which a tooth is composed. What causes hollow teeth?

What is the use of saliva? Describe starch. Where is it found? Locate and describe the salivary glands; the food-pipe; the stomach; the three coats of the stomach. Name the kinds of proteids and state where they are found. Describe the intestines; the bile; the liver. What fluids are mixed with food in the intestines? What are chyme and chyle? Describe the milk-tubes.

What is the usual cause of disorders of the digestive organs? Why must food be well chewed? What is nourishing food?

State the amount of nourishing substances contained in wheat. What is the value of sugar as an article of food?

On what does the value of beef as an article of food depend? Describe two parasites found in raw meat. Compare the value of flesh of mammals, birds, and fish. What valuable substances are contained in eggs? In milk? Describe a lactometer and state how it is used. State three uses of fat in the body.

RESPIRATION AND COMBUSTION.

What qualities has air? Prove that air presses in all directions. Describe a pair of bellows.

Compare the chest with a pair of bellows. Describe the two ways of breathing. Describe the motions of the air cells. What is the color of the lungs? Describe the structure of the lungs.

What two substances escape from a burning candle and how are they detected? What is the composition of fresh air? What changes occur during the burning of a candle?

Compare the inhaled air with the exhaled air. Compare the changes of air in respiration with those in combustion.

What changes are observed in the air of a room occupied by persons? How does carbonic acid affect our health? From what sources do organic substances enter the air of dwelling rooms? How do we counteract the evil effects of foul air in a room? How much fresh air in needed for this purpose? Describe a ventilating flue. Describe a means of admitting fresh air into a room without causing draught.

CIRCULATION.

Describe a Hero's Fountain; a syringe. What is a piston? What does the word volume mean? What are the parts of a suction-pump? Of a force-pump? What is a valve? Describe a rubber syringe.

Of what does the heart consist? How is the heart widened? What is the work of the left heart? Of the right heart? Name the three kinds of blood-vessels. Describe each. Prove that blood contains the elements of every substance in our bodies. Of what benefit is rapidly flowing blood? What is the function of the capillaries? Describe the two kinds of blood. Of what substances does blood consist? Name the parts of the heart. How should wounds be treated?

THE SKIN.

What qualities has the skin? What organs and appendages are found in the skin? Describe the two layers. Name the parts of a hair. Describe the sweat-gland. Describe two kinds of papillæ. Of what use is a daily sponge-bath?

EXCRETION.

What is excreted by the lungs and the skin? Describe the kidneys. Name the renal organs. What does urine contain? What effect has an increased amount of blood in the skin? How are serious kidney diseases often caused?

MUSCLES.

What can muscles do? Of what do the two ends of many muscles consist? How are the parts of our body kept in their places? What are fibers? How is the expansion of muscles caused? How are substances moved through tubes and hollow organs of the body? Describe the two kinds of muscles. How do muscles grow large and hard? Of what benefit are large and hard muscles? How is our sleep modified by the work previously done? When may exercise become injurious?

LEVERS AND BONES.

What is a lever? Describe the three kinds of levers. When is a lever in equilibrium? What is the use of levers?

Name three bones each representing a lever. What are joints? Describe three kinds of joints. How is the union of bones in joints accomplished? Describe the ends of the bones in a joint. What is the function of ligaments? Describe a fresh bone. Of what two main substances do bones consist? What effect has each of these substances upon the condition of bones? Why are long bones hollow? Describe one of the bones in the vertebral column. Name the curves in the backbone. What is the use of the backbone? Name the bones of the arm and of the leg. What bones form the largest bony structure of the body? Describe the bones of the chest. Describe the structure of the skull. What is a suture? Name four uses of bones.

What should be done in case of broken bones? How are crooked legs caused? How may round shoulders be avoided? What organs are injured by tight lacing? What injuries are done by tight shoes?

THE LOWER SENSES.

What does the sense of feeling enable us to perceive? Describe the nose. What is smell? Where do the nerves of taste commence? What two senses are closely connected?

SOUND AND THE EAR.

How are sounds produced? Describe the sound waves. What is pitch? On what does pitch depend? Describe the structure of the ear. Of what use is the outer ear?

Name the parts of the middle ear. Of what does the inner ear consist?

THE ORGANS OF VOICE.

Describe the voice-box. Describe the voice-cords. Describe the part the mouth takes in the production of the voice. How are good voices spoiled?

THE EYE AND LIGHT.

Of what use are the eyebrows, the eyelids, the eyelashes, and the eyebrow-arches? Locate the glands of the eye. Describe the outside of the eyeball. Locate its three membranes. Describe the horn-membrane, the pupil, and the rainbow-membrane. What does a longitudinal section of the eyeball show?

Name the three kinds of images which a convex lens may produce. What is a camera obscura? How does a concave lens change the direction of parallel rays falling upon it? How is short-sight caused? How, long sight? What are self-luminous objects? What are transparent, translucent, and opaque objects? What are rays of light? What is a shadow? When does a total eclipse of the sun occur? What is the law of reflection? What is diffused light? What benefit do we derive from direct sunlight? Compare an object and its image in a looking-glass. State why objects immersed in water appear in a higher position than they really are.

Compare the eye with a camera obscura. What is done with every impression that the net-membrane receives? What is stated about the duration of impressions on the net-membrane? What difference is there between the views we obtain with one eye and those we obtain with two eyes? Describe the stereoscope.

MAGNETISM.

What are magnets? Describe the induction of magnetism in a piece of unmagnetic steel. What peculiar power has a magnetic needle? State the law of magnetic attraction and repulsion.

ELECTRICITY.

What are electrified bodies? State the law of electric attraction and repulsion. What are conductors of electricity? What, insulators? Describe an electrophorus. Where are the two kinds of electricity found? What is the difference between electrified and unelectrified objects? What is induction? What is lightning? What is thunder? Describe a lightning conductor.

GALVANISM.

Describe an electric cell. When does an electric spark appear? What is an electro-magnet? Describe the receiver of the telegraph.

THE NERVOUS SYSTEM.

Describe a nerve. Describe the distribution of nerves. Compare nerves with blood-vessels. Name the three elements of the nervous system. Describe the brain. Describe the two essential substances found in the brain. Describe the spinal column. What are sensory nerves? What are motory nerves? What is the seat of feeling? How is a sensation produced? Of what does the sympathetic system consist? What does it regulate? Describe a reflex action. How are instincts developed? What connection is there between the brain and the mind? When does the brain rest? What kind of exercise does the mind need?

ALCOHOL.

What organs or systems of the body are changed or disturbed by the continued use of alcohol? Prove that alcohol checks the growth of bones. How are the muscles affected? What effect has alcohol upon the arteries? Upon the heart? Upon the blood? What appearance has the stomach of persons dying from the use of alcohol? How does the "gin drinker's liver" look? What kidney disease is often caused by excessive drinking? Describe the effect of alcohol upon the nervous system.

TOBACCO.

What poison is contained in tobacco? What effect has the smoke of tobacco upon respiration? How does smoking or chewing affect the stomach? What effect has the use of tobacco upon the blood? In what other ways may the use of tobacco be hurtful?

OPINIONS OF TEACHERS.

From Hon. Henry Raab, *State Superintendent of Illinois.*

I have examined your "Elementary Science and Physiology" and do not hesitate in saying that I consider it a valuable contribution to popular science teaching. The arrangement of the subject matter is excellent, the language is simple, and all experiments are so easy that it cannot but interest and instruct both old and young. I like the plan of the work, and am confident that even inexperienced, conscientious teachers will find it a desirable means of instruction.

From F. Louis Soldan, *Principal Normal and High School, St. Louis, Mo.*

I have examined with some care the plan, arrangement, and method of your work "Elementary Science and Physiology" and I am most favorably impressed. The method of presentation, as outlined by you, proceeds inductively, and will tend to stimulate the self-activity of the pupil, and rouse his interest in scientific work. I am confident that your book will be appreciated by every teacher.

From H. O. R. Siefert, *Ass't Superintendent Public Schools, Milwaukee, Wis.*

Your "Elementary Science and Physiology" has impressed me very favorably. If used correctly it will make the study of physiology a *delightful occupation* to pupil and teacher. Your plan of basing the teaching of the functions of the several organs on scientific principles is well conceived, and will help to make the learner an active student. I do not hesitate to say that I consider your book *far above the average text-book on physiology.*

From Emil Dapprich, *Director of German-American Teacher's Seminary, Milwaukee, Wis.*

I have carefully read the manuscript of your "Elementary Science and Physiology" and its perusal has given me a great deal of pleasure. If physiology is taught as you propose it in this book, it will be taught well. The arrangement of the topics, the methods of presenting them, the experiments proposed, and illustrations used will make the work a valuable help to teachers.

From M. F. Weymann, M. D., *Professor High School, Council Bluffs, Ia.*

While we are well aware of the vast importance of physiological teaching in the Public Schools, we know equally well that many parts of that science—and often the most important—are memorized by the pupils without a full appreciation of the facts. This is due to a lack of knowledge in such auxiliary branches as physics and chemistry. Dr. Dorner has tried to avoid this difficulty by giving, along with the regular work, instruction in those branches, and, although this may seem a difficult task, has succeeded remarkably well.

The whole work is based on object lessons so that the pupil deduces and formulates in his own language the scientific truths, in my opinion the only correct way. A feature of particular merit is the ingenious application of scientific principles to facts and occurrences within our daily observation. The number of such examples is so great as to make the little book to a certain extent *unique*, even without the other points of excellence.