SCIENCE RELATED TO LIFE

BOOK TWO

HEAT AND HEALTH

REH

AMERICAN BOOK COMPANY

Frontispiece *Underwood & Underwood*

Preparing for a sunbath. The light and heat of the sun are valuable for good health

SCIENCE RELATED TO LIFE

BOOK TWO

HEAT AND HEALTH

By

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AMERICAN BOOK COMPANY

NEW YORK CINCINNATI CHICAGO
BOSTON ATLANTA

REH SC. BK. TWO

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MADE IN U.S.A.

PREFACE

"Science Related to Life" is a series of four books written to supply the need of elementary science teachers for textbooks that can be used independently by pupils. Throughout the series the author has kept in mind the aims of elementary science, as recognized by modern courses of study, namely:

1. To develop in pupils an interest in the natural phenomena about them, and knowledge and appreciation of the practical applications of science.
2. To give pupils training in the scientific method.
3. To lead pupils to appreciate the order and beauty which pervade the realm of nature.
4. To show that science is a potent factor in human betterment, since it affords mankind leisure in which to enjoy greater comforts and cultural advantages, by giving him more comforts and greater leisure for their enjoyment, and for cultural development.

Following are outstanding features:

1. Each book is divided into *problems,* or "units."
2. In almost every case, the problem begins with an interesting approach, often in story form. This arouses the curiosity of the pupil and makes him eager to solve the problem.

3. Each scientific term is printed in italics, indicating that it is defined in the glossary. The glossary may also serve as a basis for a special list of spelling words in science.

4. Every scientific term is clearly explained in the text and is defined at least twice; first in the text or in the form of a footnote on the page where it appears, and then in the glossary.

5. The demonstrations are so simple that any pupil can perform them either at home or in the classroom with a minimum amount of apparatus.

6. Each problem ends with a simple summary, a set of questions, and suggestions for additional demonstrations and projects.

7. At the end of each book are simple, interesting biographical sketches of scientists mentioned in the text.

8. A list of reference books and suggestions for additional reading is appended.

TABLE OF CONTENTS

THE SCIENCE NOTEBOOK

People who live in great cities usually change their residences many times. Each time it is necessary to take inventory of belongings and to get rid of things that have piled up because of the collecting habit to which most people are slaves. Often, parting with these things is not easy, for the owners grow unreasonably fond of them.

One of the "treasure-boxes" that always comes in for an overhauling on such occasions is likely to contain notebooks written during school days, perhaps many years past. How lovingly one turns the musty pages! What work had been put into the science books! What pleasant recollections are aroused by those elaborate diagrams and the carefully shaded or colored sketches! They seem crude now, as does the faulty language in which the notes are written; yet one loves them because they represent sincere effort; an attempt to do the best of which one was capable. Although one may be cramped for space and determined to part with them, these notebooks still remain.

What practical suggestions can be given you in regard to *your* science notebook? In the first place, choose a book that appeals to you — one in which you will like to write. It need not be expensive, but let it be attractive. The loose-leaf form is superior to the bound form because one can add, subtract, or substitute pages without spoiling the appearance of the book in any way.

Write up your science notes at home. Every real student will think enough of science to wish to make his notes as complete and attractive as possible. In the classroom the time is extremely limited. A sheet of paper for rough notes, and a simple sketch that can be redrawn with more care at home, are all that the time generally permits. At home, one can not only improve the penmanship and draftsmanship, but there is an opportunity to add original notes and ideas and information gathered from magazines and library books. The true student of science will find this sort of homework a pleasure.

Throughout the textbook you will find demonstrations which you are required to do either alone or with the help of your teacher. After the demonstration has been performed you should write an account of it in your notebook.

The form in which the report of the demonstration is written is not of great importance. For the most part, it should be in composition form, telling in your own language what you saw in the classroom and what conclusions you reached as a result of such observation. It is a good idea, occasionally, to arrange the report in a more scientific form, carefully tabulating your observations in an orderly manner. This will help you to cultivate the scientific habits of orderliness that should be one of the purposes of studying this subject.

If you should decide to write your report in scientific form, the following arrangement is suggested:

Problem. Under this heading write the question that is to be answered by performing the demonstration.

Apparatus. Give a list of the materials needed in performing the demonstration.

Procedure. Under this heading tell in your own way, and as briefly as possible, how the demonstration is performed. Be sure to include every important step in the work. If you are performing the demonstration yourself, be sure to carry out all the steps with great care and to repeat the demonstration several times, if necessary, to get an average that is reliable. Make diagrams whenever you feel they will be helpful.

Observation. During the demonstration you should watch closely and you should note, under this heading, anything in connection with the demonstration that you consider important, especially if you think it will help to solve the problem.

Inference. The inference is what you learn from the demonstration. If the inference is correct, it is the solution of the problem which the demonstration is intended to settle. Usually it may be written in the form of a simple statement.

Do not be sparing in your efforts. Become a member of the S. S. N. C. ("the Superior Science Notebook Club"); not only will you get real pleasure out of your work, but you will, in time, have a treasure box of notes that will prove a delight to you in after years: a product of your own hands, that you will love and cherish.

Even animals can adapt themselves to their environment.

MAN'S USE OF SCIENCE

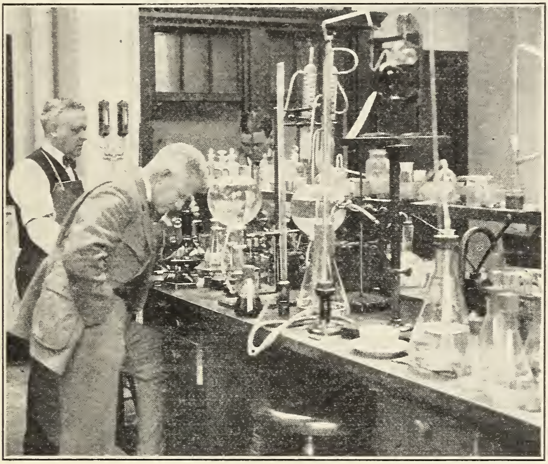
One of the chief reasons for man's superiority over other animals is that man is able to adapt himself to new surroundings and, if necessary, to make changes in his surroundings to suit his convenience. This enables him to move more freely than other animals over the surface of the earth. Animals remain, now, in the regions which they occupied ages ago. You never find a group of tigers or apes leaving their tropical homes to find new homes in temperate or frigid zones, or polar bears seeking new homes in tropical regions; it would mean sure death. Man, on the other hand, is able to make changes of this sort.

Man has learned to protect himself against floods, fires, disease, and extremes of heat and cold. When a savage performs the simple act of covering his body with an animal skin to keep warm he is performing an act of which no other animal is capable. Because of his ingenuity in protecting himself he can live quite as well in a frigid as in a torrid climate. An outstanding illustration of this fact is the recent expedition of Commander Byrd to the South Polar regions. Equipped with modern scientific devices, Byrd and his party withstood the rigors of months of Antarctic climate and returned without the loss of a single person

One of the most important discoveries of all times was man's discovery of fire. Why?

A good deal of man's success in overcoming the obstacles of his environment (surroundings) is due to his knowledge and control of the principles of heat. The story of man's use of heat from the time he learned to make a bonfire until this age of steam, hot water, and oil heating devices, is an interesting chapter in the history of man. At first his only thought in using heat was to protect himself against cold and to keep off dangerous animals. Later he made use of heat to provide comforts for the home and for manufacturing.

The account of man's fight against disease is another long and interesting story. In the days of early civilization it was believed that disease was caused by evil spirits which, in some way, entered the body of a person and made him ill. "Medicine men" wearing frightful masks and making dreadful noises on crude instruments danced around the sick person to frighten off the evil spirits. Often the patient was brutally



Ewing Galloway

Scientists try to find new ways to fight disease.

beaten in an attempt to drive out the evil one. Certain objects, such as teeth of animals and pieces of skin, were supposed to have the power to keep evil spirits away and so these objects were worn as good luck charms.

Over two thousand years ago the Greeks made a serious study of medicine and knew that cleanliness, fresh air, and exercise were necessary for health.

Unfortunately the splendid work of the Greeks in this field was unknown to European peoples of the Middle Ages and so progress in medicine, except among the Moslems (Mohammedans) of Spain and Arabia, was very slow.

Rapid progress, in fact, did not come until very recently, with the development of hygiene (the science of health) and surgery and with the study of germ diseases. How germs were discovered, how it was learned that they are often the cause of disease, and how germ diseases may be prevented or cured, is told in the chapter, "Disease Fighters," at the back of this book.

Sources of heat; can you name them?

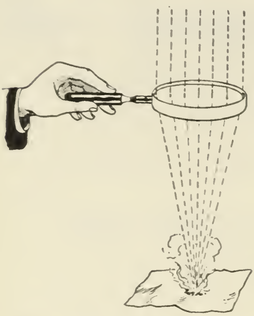
PROBLEM I

FROM WHAT SOURCES DOES MAN OBTAIN HEAT?

The ancients worshiped the sun because they realized how much its light and heat meant to them. Heat is just as necessary for life as are water and air. The chief source of heat on earth is the sun. Although it is about 93,000,000 miles away we feel its warm rays. Fortunate, indeed, are we to be so far from this great source of heat; to approach a few million miles nearer would mean sudden death to all living things by burning. Fortunate, also, are we to be no farther away from the sun; to retreat a few million miles would mean sure death by freezing. The sun's heat causes the winds to blow, the plants to grow, and the fruit to ripen. No wonder, then, that the ancients worshiped the sun.

Demonstration. To show that the sun is a source of heat. On a bright sunny day, hold a magnifying glass over the back of your hand in such a way that the rays of the sun pass through the glass and fall upon your hand. Can you feel the heat? Explain.

Hold a piece of dry tissue paper under the magnifying glass. Move the glass carefully until the image of the sun on the paper is a tiny, bright spot. Hold the glass in this position for a few moments. What happens? Where did the heat come from?



Friction produces heat. The sun is not the only source of heat. Man early learned to produce heat artificially. When the surfaces of two bodies rub against each other, they become heated. You can prove this easily enough by rubbing your hands together. The rubbing, or *friction,* causes the hands to become warm.

When a match is rubbed against a rough surface, such as sandpaper, heat is produced by friction. A carpenter's plane becomes warm, by friction between the metal of the plane and the surface of the wood. Wheels, constantly rubbing against the pavement, become warm.

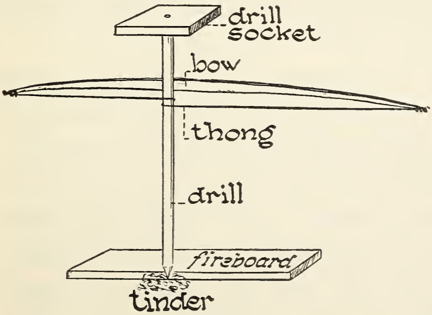
An interesting device for creating heat by friction is the Indian fire-drill. The device consists of a straight, dry stick, sharpened at one end, and a stone in which a small hole has been made. The Indian holds the stick upright so that the sharpened end of the stick rests in the hole of the stone. He then twirls the stick rapidly between his hands. This causes the pointed end of the stick to rub against the stone, producing heat enough to set fire to the stick.

Making a fire the primitive way.

The fire-drill such as Boy Scouts use is a form of Indian drill. Instead of stone, a piece of wood is used and the stick is twirled rapidly by means of a clever device that looks like a bow.

Another old-fashioned method of creating heat by friction was to strike a piece of steel against a piece of very hard stone known as flint. The heat caused sparks which were used to set fire to leaves and wood shavings.

Parts of machines that rub against each other, as, for example, a wheel and an axle, become heated by friction. These parts may be ruined in a short time by extreme heat. To prevent this the surfaces are oiled.



A Boy Scout fire-drill. Explain how it works.

Oil reduces the friction and thus prevents rapid heating.

You may be surprised to learn that shooting stars are visible because of friction. The space outside the earth's atmosphere contains many solid bodies that move at high rates of speed. When one of these bodies strikes the atmosphere the friction that results heats

Yerkes Observatory

The white line in this photograph is the trail of a shooting star. What causes it to burn up?

the body white hot. We see it as a shooting star as it burns up in the air. Shooting stars are really not stars at all, but fairly small bodies that move at a terrific speed through space. Most of them are so small that they burn up entirely before they reach the earth. Some, however, are so large that they do not entirely burn up in the atmosphere and they fall to the earth with great force. Such bodies are known as meteorites.

If you visit the Museum of Natural History, you will see some large meteorites that have been dug up by scientists. Some of these weigh many tons.

Combustion produces heat. When a substance combines with oxygen, the result is known as *combustion.* Combustion produces heat, and if the heat is great enough, many materials take fire and burn. When the temperature of a substance reaches a point so high

Am. Museum of Nat. History

A meteorite weighing several tons. What is the difference between a meteorite and a shooting star?

that the substance bursts into flames, it is said to reach a *kindling temperature.* The kindling temperature of paper is much lower than that of wood; while that of wood is much lower than that of coal.

How did early man discover fire? It is impossible to know the true answer to this question. Man may have learned of fire from volcanic lava which is often hot enough to set fire to forests and grassy plains through which it flows. It may be that the first fires he noticed were caused by lightning. Whatever may have been the starting point, however, scholars are agreed that man's discovery of fire was one of the first important steps in the onward march of civilization.

Primitive fuels. Many of the fuels we use today were unknown to primitive man. Coal, gas, and oil are products of civilization. Primitive man used as fuel the few things within his knowledge to which he could set fire with the faint spark of his fire-drill. Dried grasses and leaves were probably used to start the fire. Once the flame was kindled, twigs and branches could be added. Logs may have been used, but it is probable that their use as fuel came later.

Burning materials give off heat. Although the sun is the chief source of heat on earth, man cannot use it for heating the home, for cooking, or for the many purposes for which heat is needed in manufacturing. Man uses artificial heat much more than he uses the heat of the sun.

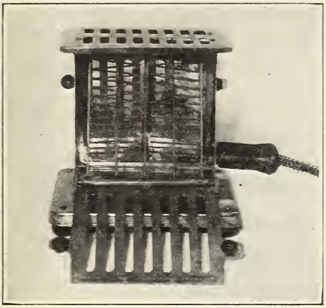
Demonstration. To show if combustion produces heat. Set fire to a piece of paper, a small pile of wood shavings, or a small quantity of excelsior. Hold the hands over the fire. Can you feel the heat? By what is the heat caused?

The common fuels used by man to produce artificial heat are wood, coal, oil, and gas. You will learn more about these fuels in a later lesson.

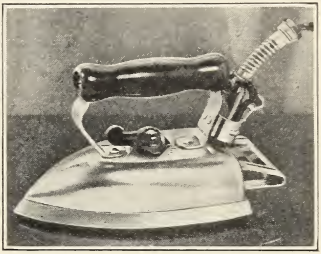
Demonstration. To show how the electric current causes heat. Turn on an electric light and hold the hand below the bulb. Does the lamp remain cold? What caused the heat?

Connect an electric flat-iron to an electric outlet and turn on the current. After a time touch the iron and note that it has become warm.

Connect an electric toaster in a similar manner and turn on the current. Observe the wire in the toaster. What change



Keystone View Co.



Keystone View Co.

Devices employing heat; what are they?

has taken place? Hold the hand near the toaster. To what is the heat due?

What may you conclude from this demonstration?

Other electric appliances used in the home are the electric stove, percolator, hot-pad, waffle iron, sun lamp, cigar lighter, and hot-plate. Can you name others?

Summary

The sun is the chief source of heat on earth.
Friction produces heat
Combustion produces heat.
Burning materials give off heat.
The electric current produces heat.

How Much Have You Learned?

Which of the following statements are true and which are false?

T. F. 1. The sun is the chief source of artificial heat.
T. F. 2. Heat and fire mean the same thing.
T. F. 3. When held in a certain way on a bright, sunny day, a magnifying glass and a piece of paper can be used to start a fire.
T. F. 4. If there were no friction, there could be no shooting stars.
T. F. 5. A fire-drill is a modern way of producing fire.
T. F. 6. When sawing wood, the saw becomes heated.
T. F. 7. Hammering produces heat.
T. F. 8. Another word for fire is combustion.
T. F. 9. Combustion is an artificial source of heat.
T. F. 10. Oxygen combining with a substance produces heat.
T. F. 11. Kindling point is the temperature at which a substance takes fire and burns.
T. F. 12. Volcanic eruptions may start fires.
T. F. 13. Lightning may set trees on fire.
T. F. 14. All heat is caused by burning substances.
T. F. 15. An electric current is a form of fire.

On a sheet of paper write the word or words needed to complete each of the following statements:

16. The —— is the earth's chief source of heat.

17. —— is the chief artificial source of heat.

18. Two electrical heating appliances are the —— and the ——.

19. Heat sufficient to light a match is produced by ——.

20. —— causes heating and final wearing out of certain parts of machines.

Supplementary Demonstrations and Projects

1. Hammer a piece of wood or a piece of metal to show how percussion produces heat.

2. Explain and demonstrate the principle of the friction cigarette lighter.

3. Make two lists, one of natural sources of heat and the other of artificial sources of heat.

4. Prepare an outline, for discussion in the classroom, on one of the following topics:

   a. Meteors and meteorites.
   b. Comets.
   c. The story of the friction match.

Man uses fuel to produce heat.

PROBLEM II

HOW ARE FIRES STARTED AND MAINTAINED?

It is 7 P.M. and the family has just finished dinner. The scene has changed from the dining room to the living room of a modest, comfortably-furnished apartment in the residential section of a great city. This is the children's hour, just before bedtime for the youngsters. The eight-year-old girl has chosen to read one of the gift books given her on the Christmas just past. She is snugly curled up in a large chair, and the floor lamp has been arranged so that plenty of light falls on the book. Under the window, the long, low radiator is murmuring gently, and filling the room with a pleasant warmth that makes the members of the family forget the chill sleet and snow that are falling outside. Suddenly the child looks up from her book, attracted, perhaps, by the singing radiator, and says, "Mother, what makes the radiator hot?"

Few children living in the city think about how heat in the home is produced. For them it is generally enough to know that during the winter the apartment is kept warm by radiators. The suburban and country children, however, learn early about the furnace that devours coal, the oil stove that must be kept full of kerosene, and the gas heater that takes the place of the furnace to heat the water in the summer time. Roaming about the big, clean cellar, they have often noticed the gas meters, and even understand the mysteries of the many hands and dials. They see the coal pile diminish. They see the ashes that result from combustion, and they know fairly well what is meant by dampers, drafts, and pressure. Perhaps somewhere in a remote room of the home there still stands an old-fashioned coal-stove something like the first stove invented by Benjamin Franklin.

It is important that the young scientist know how homes are heated, the uses of the various heating appliances, the source of supply of the important fuels, and the ways in which fuels may be conserved.

In general, the value of fuel depends on the amount of heat it gives off, on its kindling temperature, and on the abundance of the supply. For example, coal is an excellent fuel because its kindling temperature is neither too low nor too high for efficiency and economy, it is easily obtained, and its cost, considering the amount of heat it supplies, is reasonable.

Solid fuels. Wood. For a long time, in this country, wood was the only fuel used. This was due to

Am. Museum Nat. History

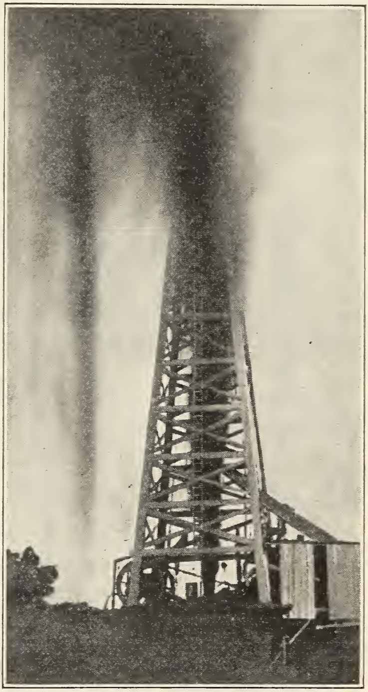
Such forests as these existed millions of years ago. The plants died, became part of swamps, and were subjected to great pressure. In time they became coal.

the fact that when the country was settled, wood was very plentiful and easily obtained. Today the supply of wood is getting so low that the cost has greatly increased. Wood, as a fuel, has the further disadvantages of being bulky, of burning up very rapidly, and of producing only about one fifth as much heat as an equal bulk of good coal.

Coal. The disadvantages of wood, as a fuel, and the fact that modern methods of coal mining have increased the supply of coal for home consumption, explain why coal has replaced wood as the common home fuel. The two varieties of coal commonly used are *anthracite,* hard coal, and *bituminous,* soft coal.

Anthracite is better than bituminous coal for use in the home because it is cleaner, burns more slowly, and is free from objectionable smoke. It is somewhat more costly than soft coal. Almost all the anthracite used in the United States comes from Pennsylvania.

Bituminous coal is used as a fuel much more than anthracite, especially in manufacturing. It contains a large percentage of *volatile*[1] material, which is responsible for the dense, black smoke that makes the use of soft coal so objectionable. Bituminous coal is found chiefly in the Alleghany Mountains and in Illinois, although smaller fields are scattered throughout the Middle West and the Rocky Mountain sections.



Ewing Galloway

An oil gusher. Why does the oil spout high into the air?

Liquid fuels. In very recent years, the fear that the natural supply of coal will soon dwindle has led to the introduction of other fuels in the home.

[1] Volatile (vŏl′á til): changing readily into a vapor.

Oil is rapidly coming into use as a fuel for heating the home. It is much cleaner than coal, and requires very little attention. Fuel oil is obtained from the crude oil drawn from the ground , very much as water is obtained from wells. Deep holes are drilled into the ground until the layer of porous rock and sand containing oil is reached. The oil is pumped out and transported to the refineries. Sometimes, in drilling, the oil spouts high into the air, forming a "gusher."

Other liquid fuels commonly used are alcohol and gasoline. The use of gasoline as a fuel will be explained more fully when you study the gasoline engine, in a later grade.

Demonstration. To show that alcohol can be used as a fuel. Pour a little alcohol into a small bottle. Make a wick of a piece of heavy string and soak the wick in the alcohol. Apply a lighted match to the upper end of the wick.

What may you conclude about the use of alcohol as a fuel?

Gaseous fuels. Gas is also used for heating and lighting. When the burner of the gas stove is turned on, the gas rushes in and mixes with the air that is drawn in from the room. When the proper mixture of air and gas is obtained, a noiseless and *non-luminous* [1] flame is the result. The most common kinds of fuel gas are illuminating gas, natural gases, acetylene gas, and hydrogen gas.

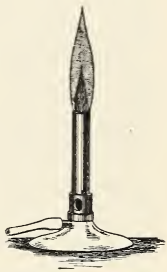
Demonstration. To show that gas can be used as a fuel. By means of a piece of rubber tubing, connect a Bunsen burner to a gas jet. A Bunsen burner is a device invented by

[1] Non-luminous (nŏn lū′mĭ nŭs): not shining, not giving light.

Professor Bunsen, of Heidelberg. It consists of a straight metal tube, several inches high, with small holes at the bottom to admit air.

Turn on the gas and apply a lighted match to the upper end of the Bunsen burner. Close the air holes in the burner. What is the color of the flame? Hold a saucer above the flame. What happens? Now open the air holes in the burner. What happens to the color of the flame? Why does the color change? What is necessary to make the gas flame burn well?

Illuminating gas. Most of the *illuminating gas* used in the home is made from soft coal. The coal is heated to a very high temperature in specially constructed containers known as retorts, and the gas is collected in huge tanks, from which it is sent through pipes to the buildings where it is used.



A Bunsen burner. How did the device get its name?

Acetylene gas is frequently used in sections of the country that are not supplied with coal gas. It is made by the action of water on a substance known as calcium carbide. When mixed with air in a special type of burner, acetylene burns with a brilliant white light. It is used for illuminating purposes. Sometimes acetylene gas is mixed with oxygen and burned as in the oxy-acetylene torch. The great heat produced is sufficient to cut steel and other metals.

Natural gas is found in the earth and is brought to the surface through pipes that are let down into the gas pockets. Ohio, Indiana, Pennsylvania, and West Virginia are the chief sources of supply. Natural gas may be used for illumination but it does not produce a very bright light.

Hydrogen gas has been mentioned before, in connection with inflating dirigibles and balloons. It burns very readily and is used in combination with other gases for producing heat and illumination.

Demonstration. To show that kindling temperatures differ. Gather some small quantities of paper, dry wood, tiny bits of hard and of soft coal, tar, oil, glass, celluloid, sand, and various other substances. Arrange them in tiny heaps, putting the oil in the bottom of an old tin pan. Try to set fire to each substance and notice the results.

Which objects burn? Which do not? Which ignite (take fire) quickly? Which burn longest? Are all substances equally easy to burn?

On a pile of paper, heap plenty of wood and then place some small pieces of coal on top of the heap. Set fire [1] to the paper with a match. Does the coal take fire at once, just as the paper does? Why not? What does this show about the kindling temperature of coal? Of paper? Of wood?

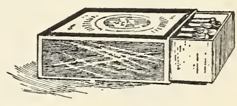
Demonstration. To show what becomes of fuels after they are burned. Weigh a small piece of dry wood carefully on the scales. Burn it in an open glass vessel and wait until the fire goes out. Has the fire changed the appearance of the wood? What substance is left? Has moisture collected on the inside of the glass vessel? Where did this water come from?

[1] All such experiments should, of course, be made where there is no danger of injuring property.

Weigh the ashes that remain. Is the weight of the ashes equal to the weight of the wood before it was ignited? What has caused this?

What most fuels contain. Most of the common fuels contain carbon, hydrogen, and mineral matter. Because mineral substances do not burn, they are considered as impurities in the fuel. Therefore the smaller the percentage of mineral matter present, the better the fuel. When the fuel burns, some of the oxygen in the air combines with the hydrogen in the fuel to form water (hydrogen oxide). Some of the oxygen combines with the carbon to form carbon dioxide. Tiny particles of carbon float off into the air, and if collected in a chimney or in some other way, make the fine, black carbon soot with which we are all familiar. If the flame is hot enough, the only part of the original fuel left after burning will be the mineral part, commonly known as ash.

Kindling temperatures. Some substances, such as paper and the substance of which the tip of a match is made (phosphorus and sulphur), require very little heat to ignite them. They are therefore said to have low kindling temperatures. Substances such as wood and coal have higher kindling temperatures, that is, they require more heat before they burn.



Of what substances are the tips of matches made?

Any substance that burns may be used as fuel. Some substances are, of course, better fuels than others. Furthermore, a fuel that serves well for one purpose may not be so useful for other purposes. Thus, in the manufacture of steel a very high temperature is needed, and coke (coal from which the volatile matter has been driven out by heating) can be used to good advantage. On the other hand, coke and coal are so bulky that they would take up too much room if used to run automobiles.

Fuels may be heated to kindling temperatures by placing them in fires or by applying fire to them. The heat made by friction when flint and steel are rubbed together or in rubbing sticks together is sometimes sufficient to raise paper or leaves to the kindling temperature, so that they will burn.

If certain chemical substances, as phosphorus and sulphur, which are found on the tip of some matches, are rubbed on a rough surface, the friction causes sufficient heat to raise the substances to their kindling temperature. They burst into flame and the resulting heat sets the wooden match on fire.

A spark plug. How is the spark produced? What does it ignite?

If a piece of paper is brought into contact with the heated wire of an electric toaster, the paper will burn. The wire heated by an electric current is hotter than the kindling temperature of paper, and will therefore set fire to the paper.

A spark plug is a device used in automobile engines to ignite gasoline vapor. In this device, the path of the electric current is interrupted by a tiny gap in the wire and the current is made to leap across the gap. As it does so it creates an electric spark. This spark is hot enough to ignite the gasoline vapor, which has a very low kindling point.

You have learned that combustion is the result of the action of oxygen on a substance. This process is also known as *oxidation.*

Sometimes a substance, such as a rag soaked in oil, may be lying in a place where the ventilation is poor. Heat is produced in the oil rag by the slow process of oxidation and because the heat is not rapidly carried off, it accumulates until the kindling point of the oil is reached. The oil rag will then take fire without any outside help. Combustion that is caused in this way is known as *spontaneous combustion.* Spontaneous combustion sometimes occurs in saw mills where a pile of sawdust is gradually becoming heated because of poor ventilation. It may occur in a barn where hay is stacked in a poorly ventilated place. Many serious fires are the result of spontaneous combustion. Not long ago the contents of a modern steel and brick building were destroyed by fire caused by the spontaneous combustion of an oil rag.

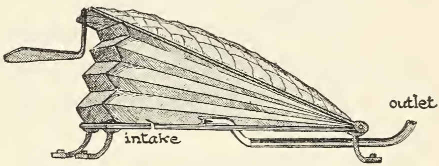
Burning fuels require air. "Come on, boys, let's build a fire!" suddenly exclaimed a youth to a group of companions who had been huddling together for warmth. It was a raw afternoon in November and with shouts of approval each member of the group started off for material to build the fire. The spot chosen was ideal — a vacant sand lot devoid of trees or vegetation of any kind; it was a safe place in which to make a bonfire. In less time than it takes to tell, the boys came scampering back, some with paper, some with small, dry sticks of wood, one with a discarded bushel-basket, and still another with the prize contribution — a good-sized wooden box that had once held canned goods, perhaps tomatoes. A sympathetic passerby supplied a match.

What is necessary in order to have fire?

With the speed and precision worthy of trained scouts, the boys went to work. First, the paper was rolled into large, loose balls with plenty of air spaces in them. On top of these the small sticks were placed, and around the pile the longer sticks were arranged, leaning inward toward the top like the framework of an Indian *tepee.* The lone match was then carefully struck, shielded from the wind until it flared up, and applied to the paper in two or three places near the bottom of the heap. The paper burst into jets of flame that ignited some of the small sticks and made a pleasant, crackling sound. Soon, however, the paper burned into ashes, the fire dwindled, and for a time it looked as though the bonfire would be a failure. To make things worse, the wind suddenly died down.

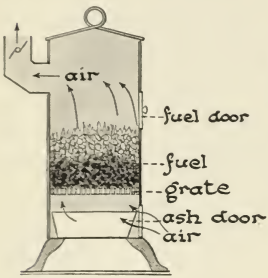
However, the little sticks on top of the paper pile were glowing feebly, and with a sudden inspiration, one of the boys removed his cap and began fanning the sparks, gently, but steadily. The embers glowed more brightly and then little tongues of flame shot up and licked the upright sticks that surrounded the pile. Then the other boys used their caps to fan the flames. In a short time there was a roaring flame that sent great sparks high up into the air. When the sticks began to settle, the burning heap was crowned with the big box. Flushed with success, the boys formed a circle around the fire and made merry as they forgot the chill afternoon air. A kindling spark, fresh air, and a supply of fuel had done the work.

Instead of fanning the flame with a hat, as the boys did, it might have been fanned by blowing air through an old-fashioned bellows. Study the illustration to see how the bellows works. Blacksmiths use bellows to blow air into their charcoal fires. The air is blown in through the bottom of the blacksmith's forge.



The bellows. For what is it used?

In the old-fashioned coal stove, air enters through the draft into the ash pit under the coal and passes through the layers of coal to aid the burning. The hot gases pass up the chimney through a pipe which leads from the stove. The fire may be checked by a *damper*. This is a piece of metal, circular in shape, which just fits inside the stove pipe. When the damper is closed, the air current is stopped and burning almost stops. The damper is controlled by a handle outside the pipe. By turning the handle the damper may be closed, opened, or partly opened. If there is a free passage of air through the fire bed, the fuel burns very rapidly.



What is the purpose of the grate and the damper?

In coal furnaces, air may be admitted to the fuel through the *grate* which consists of a series of cast iron bars separated by spaces. The fuel rests on the grate. Fresh, cold air is allowed to enter through the bottom of the grate by means of cast iron doors or shutters in the furnace, below the grate. When these doors or shutters are closed, the supply of air from this source is shut off, and the fire is checked or all burning stops.

Furnaces on ships, locomotives, and in factories often require a great deal of air so that the fuel may burn rapidly and produce high temperatures. This air is supplied by blowers creating what are known as forced drafts.

Smouldering fire. When the supply of air is not sufficient to keep a fire burning, the fire will begin to smoulder and will finally die out. Smouldering fires left by campers are very dangerous, for a fresh supply of air brought by a rising wind may rekindle the dying fire and cause it to burst once more into flames. A smouldering fire may be extinguished by excluding air. This can be done by throwing a heavy blanket over the fire or by covering the smouldering embers with sand, ashes, or soil.

Summary

Fuels are needed to produce fires.

Fuels may be solid, liquid, or gaseous.

Fuels must be heated to kindling temperatures to produce fires.

Fuels require air in order to burn.

Questions

1. Name three solid, three liquid, and three gaseous fuels.
2. What is the difference in fuel value between hard coal and soft coal?
3. Give other names for hard coal and soft coal.
4. Compare wood and coal as fuels for heating the home, giving advantages and disadvantages of each.
5. What is an oil gusher?
6. What is meant by the kindling temperature of a fuel?
7. Name two fuels that have low kindling temperatures and one that has a high kindling temperature.
8. Of what is the tip of a friction match made?
9. How did the early American Indian make a fire?
10. On what principle does the spark plug work?
11. What three conditions are necessary in order to have fire?
12. What effect has the wind on a good-sized fire?
13. What is the purpose of a damper?

14. How is the amount of air that enters the grate of a coal furnace regulated?

15. For what is the bellows used?

16. Why should campers be careful to put out their fires before they leave camp? What is a good way to extinguish such fires?

Can You Also Answer These?

17. Is coal found on the surface? How is it reached? How do miners dress? What tools do they use? What means are used for getting the coal to the surface? How is it shipped to various parts of the country? In what units is it sold? About how much does hard coal cost today?

18. What are the chief sources of oil in the United States?

19. Name two great oil-producing countries outside the United States.

20. What is coke? How is it made? For what is it used?

21. Compare the fuel qualities of hard coal, soft coal, and coke.

22. How is alcohol used as a fuel? What is the color of the alcohol flame? How does the temperature of the alcohol flame compare with that of the wood or the coal flame? (Test this by trying to heat water with each.)

23. What is meant by spontaneous combustion? What precautions can be taken against it?

24. In what respect are fuels that have high kindling temperatures, such as anthracite coal, more valuable than those that have low kindling temperatures?

Supplementary Projects

1. Make gas by heating wood shavings in the bowl of a clay pipe.

2. Make charcoal.

3. Learn how to read the gas meter and to figure gas bills.

4. Locate, on a map, the important coal and oil fields of the United States.

5. Read, in your geography, an account of various methods of coal mining. Prepare a report for use in the classroom.

How man makes use of fire.

PROBLEM III

HOW DOES MAN MAKE USE OF FIRE?

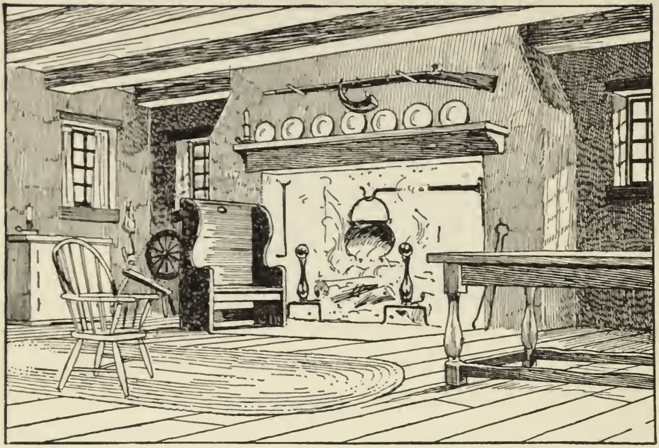
Fire, the friend of man. The Greeks have an interesting legend about Prometheus, the founder of civilization and the friend of man, who, in order to make man comfortable, stole fire from the sun and brought it down to earth. For this offense against the gods, he was chained to a great rock and tortured horribly, for vultures ate daily at his liver. Each night the wound healed and each day the torture was renewed, and so the terrible punishment continued for years until he was set free.

Fire is, indeed, one of the greatest friends of man and the history of its use is extremely interesting. The Greek legend is, of course, an impossible myth. Man may have got his first idea of fire from the burning volcanoes. It is even possible that glowing volcanic lava was used in some cases for heating. One of the earliest methods of making fire was rubbing two sticks together until a spark was produced. As civilization developed, this crude method was replaced by the fire-drill such as the Indians used. Every Boy Scout knows how the drill works, and many, no doubt, have actually made and used such drills in the course of their scout training.

The next step in advance was the use of flint which, at a later age, was used with steel. By striking together the flint and steel, a spark was made. It was not until 1829 that the modern friction match was improved by Walker, an Englishman; and now firemaking is so simple that no skill is required in the process.

Fire is used to supply heat. Campfires. Nowadays we think of campfires in connection with vacations and picnics. It is great fun to build a campfire and to gather around it to make merry and to keep warm. Until a very recent time campfires were a real necessity. As the name indicates, campfires were made by soldiers in camp during wartime. Before modern methods of communication were developed, fires were used to signal people in time of war or other danger.

Open fireplaces. In Colonial days before coal stoves and modern heating devices were invented, homes were heated by log fires built in open fireplaces. This was not a very good method of heating rooms, for much of the heat went up the chimney, and unless the fire was very large one could keep warm only by sitting near the fireplace. But so pleasant is the fire in the open



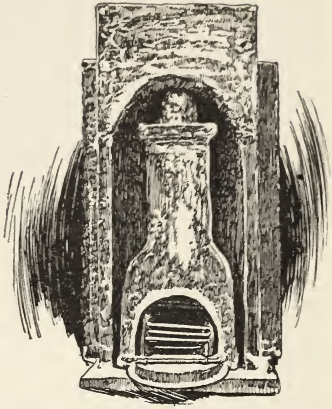
An old-fashioned open fireplace. What fuel is used?

fireplace that many homes have such fireplaces today although they are no longer a necessity.

Grate fires. A slight improvement over the open fireplace is the grate fire. An iron grate consisting of a basket to hold the fire is placed on a hearth or in a brick fireplace. Wood or coal is used for fuel. This is an inefficient form of heating, since much of the heat passes up the chimney and is lost.

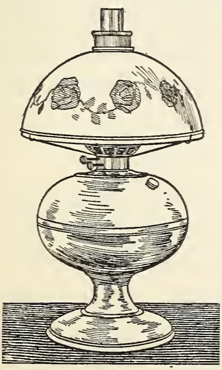
Stoves. Benjamin Franklin invented one of the earliest stoves. It resembled an iron box and contained a grate on which fire was built. At first the stove was put inside the fireplace but later, when the stove pipe was added, the fireplace became unnecessary. Stoves that burn wood or coal are still very common today and many of you may have stoves in your homes.

Other heating appliances. There are many other heating appliances. Chief among these are oil stoves, in which some form of oil is used as fuel; gas heaters; and furnaces which use either oil or coal as fuel. Furnaces supply the home, by means of a system of pipes, with heat by hot air, hot water, or steam.



An early type of stove. Locate the grate.

Fire is used to supply light. In ancient times fire was the only means of supplying light at night and so the bonfire served the double purpose of heating and lighting. Later, torches of pitch knots were used for lighting, and we still use torches for exploring caves and, in some uncivilized parts of the world, for lighting the way of the night traveler. Torches made of some substance soaked in oil were used by the Romans during the Middle Ages. Later light was obtained by burning wicks in animal and vegetable oils.



What fuel is used in this lamp?

Candles, for supplying light, are known to us all. When the electric light current goes wrong, many of us resort to candles as a ready means of lighting the home.

Kerosene lamps are still used in the country and in some small communities where gas and electricity are not available. Their use in the home is somewhat dangerous because of the risk of fire and because they usually give off fumes that are injurious to the health.

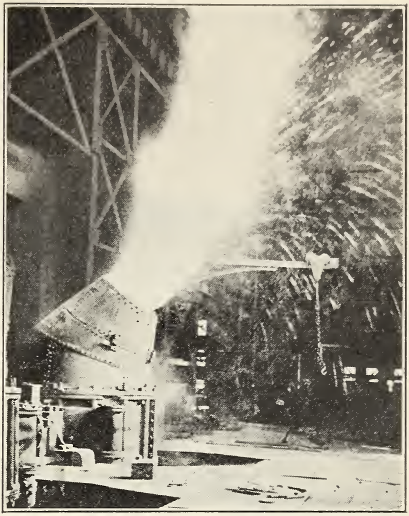
The use of the gas flame for lighting is a big improvement over the kerosene lamp. It is much safer and gives a bright flame. Only recently has the gas light given way to the electric light for lighting the home and streets.

Fire is used to cook foods. Without the use of fire, man would still be eating raw food as do the beasts in the jungle. Cooking softens food, making it more digestible and more appetizing. It also permits a much greater variety of food than would otherwise be possible. Cooking makes foods safe by destroying germs or any living microörganisms which might harm the body. Foods are preserved by boiling them to kill all harmful bacteria, and then placing them in *sterilized* jars tightly sealed.

Fire is used to obtain metal from ores. When man learned how to obtain the pure metals from the *ores*[1] in which they are found, he made a great step forward in civilization. Iron and copper tools, and weapons are the result of this discovery. The process of ex-

[1] Ore: a substance found in the ground from which we can extract a metal.

tracting pure metal from the metal ore is known as *smelting.* Other metals separated from the natural ore by smelting are lead, tin, gold, and mercury. Smelting is an expensive process and often the per cent of pure metal contained in a quantity of ore is so small that it does not pay to do the smelting. This is often the case even with gold ore, although pure gold is so precious.



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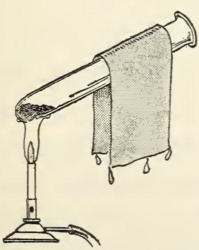
High temperature is needed in making steel.

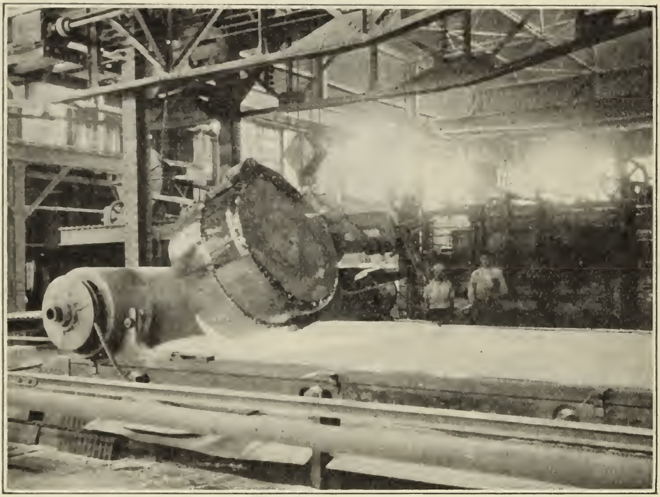
Demonstration. To show that fire can be used to extract a metal from its ore. Put several grains of oxide of mercury into a glass test tube and heat the tube over a Bunsen burner flame. Cool the upper part of the tube with a wet cloth. Note the silvery substance that collects. What is this substance?



What manufacturing process is based on this principle?

Fire is used in manufacturing. The manufacture of steel, brick, tile, glass, and pottery, all depend upon heat. In fact heat is used for so many purposes that it would be an enormous task to list them.

Numerous chemical products and processes depend upon heat. One of these processes is distillation. In distillation, a solid or liquid substance is heated until



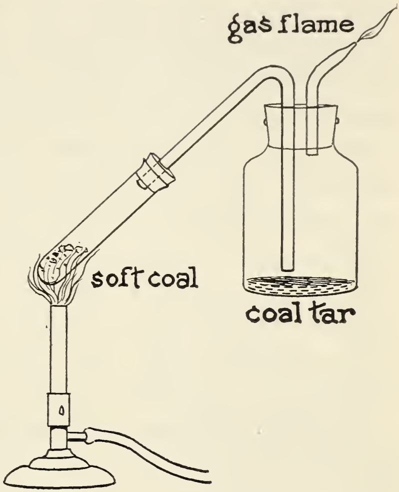
Keystone View Co.

A ladle of molten glass is being poured on the table. It is then rolled into thin sheets of glass.

it is changed to a vapor form, and then the vapor is condensed into a liquid. You may recall how we distilled water to separate it from its impurities.

Demonstration. To show how coal tar is obtained. Put a quantity of soft coal into a test tube connected with a jar as shown in the diagram. Heat the tube in the flame of a Bunsen burner. Note the smoke that rises from the test tube, enters the jar, and settles on the bottom of the jar.

After a time a liquid forms at the bottom of the jar. This liquid is distilled coal tar. Apply a lighted match to the open end of the tube that leads out of the top of the jar. What happens? This gas is illuminating gas. Where did it come from?



Coal tar is a very valuable substance. Many dyes and drugs are manufactured from it.

Gasoline, kerosene, benzine, and other liquid fuels are obtained from *petroleum,* a natural oil found in the earth and taken out by drilling wells down to the source of supply. Petroleum is heated in air-tight vessels. The gas that comes off within a certain narrow range of temperature is gasoline. Heating the oil at a higher temperature gives kerosene, while heating at a still higher temperature gives lubricating oils, vaseline, and other products.

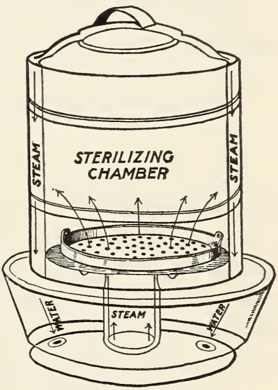
Fire is used to remove and destroy waste materials. Large cities now have places containing special furnaces for destroying garbage and other waste matter collected by the street-cleaning department. These furnaces are known as incinerators. As soon as enough incinerators are built it will become unnecessary to dump garbage into the ocean or rivers, as is now the case in many cities. The result will be safety for bathers who are now risking their health by bathing on beaches where refuse is often washed in. Fire is also used for clearing land by burning trees and brush.

Fire may cause explosion which is put to useful purposes. An explosion is a rapid burning, caused by the sudden combination of oxygen with certain substances. Explosion of a small amount of gunpowder is used for propelling bullets and shells in guns and cannons. Dynamite and other explosives are used in excavating, tunneling, and blasting in the construction of canals, railroads, mines, and roads.

Fire supplies heat to kill harmful bacteria. You have already learned that harmful microörganisms, or bacteria, in water are destroyed by boiling. Milk, like water, may contain harmful bacteria. These bacteria may come from the cow that gives the milk or may in some way enter the milk before it gets to the consumer. Pasteur, a French scientist, discovered that bacteria will die if the substance in which they are found is heated hot enough. It has been found by careful testing that milk heated to a temperature between 130° and 158° Fahrenheit, and kept at that temperature for about twenty minutes, will be made safe for drinking. This treatment of milk is known as *pasteurization* and the milk, thus made comparatively free from microörganisms, is said to be pasteurized.

Bottles, cans, and other food containers are likely to contain harmful bacteria. These containers may be sterilized[1] by means of steam forced into the container under pressure.

Food utensils and surgical instruments must be sterilized before using. Pots and dishes should be rinsed in boiling hot water. The practice of eating from dishes that are dried by soiled dish towels is not safe, for dish towels often contain harmful bacteria that are transferred to the dishes and finally get into the mouth. Often, surgical instruments are sterilized in a hot flame. You may have seen your dentist sterilize one of his instruments in this way.



Steam sterilizer.

For what can this device be used?

Fire supplies energy to drive engines. Many engines are driven by steam which is the result of heat applied to water. In a type of engine known as the internal combustion engine fuel oil is forced into a chamber where it changes to a gas and burns. This burning oil furnishes the power to drive the engine.

In the gasoline engine, burning gasoline supplies the power that drives the engine.

[1] Sterilize: heat to free from disease germs.

Summary

Fire is used to supply heat to keep man warm.

Fire is used to supply light.

Fire is used to cook foods.

Fire is used to obtain metals from ores.

Fire is used in manufacturing.

Fire is used to remove and destroy waste materials.

Fire is used to cause explosions which can be made to serve useful purposes.

Fire is used to supply heat to kill harmful bacteria.

Fire is used to supply energy to drive engines.

How Much Have You Learned?

In each of the following statements, three words or phrases appear in parentheses. One of these completes the statement correctly; the other two do not. On a sheet of paper write the word which makes the statement correct.

1. Fire furnishes (clouds, heat, oxygen) to man.
2. Open fireplaces are found in the (home, street, camp).
3. One device for heating the home is the (Bunsen burner, electric light, hot-air furnace).
4. Heat in an electric toaster is generated by (electric current, copper wire, electric spark).
5. The purpose of a torch is to supply (heat, carbon, light).
6. Acetylene is a (solid, liquid, gaseous) fuel.
7. Metal is obtained from ore by (hammering, smelting, burning).
8. Coal tar is obtained by (mining, smelting, distillation).
9. Fire destroys waste in (incinerators, insulators, retorts).

10. Bacteria may be destroyed by (excluding light, cleaning, boiling).

11. Ridding surgical instruments of bacteria is called (pasteurization, sterilization, germination).

12. Explosives are used to (sterilize, heat, destroy).

13. The friction match was invented by (Edison, Franklin, Walker).

14. The friction match is tipped with (carbon, sulphur, oxygen).

15. The Bunsen burner uses (gas, oil, electricity) as fuel.

Supplementary Projects

Make a piece of pottery.

Visit a glass-making factory and make a report of your visit to your classmates.

Read, in an encyclopedia, an account of the smelting of metal ores and prepare an outline for report to your class.

Find out, by consulting an encyclopedia, how volcanic eruptions are caused. Make a cross-section drawing of a typical volcano to show the cause of eruptions.

On an outline map of the world, locate the regions of active volcanoes.

Make a scrap book containing pictures of open fireplaces.

Make an oil torch.

Sterilize a glass bottle.

Publishers Photo Service

Fire extinguishers.

PROBLEM IV

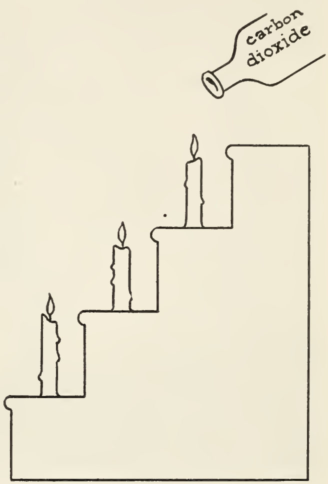
HOW MAY FIRES BE EXTINGUISHED?

One of the most interesting experiments Harold ever witnessed was performed by his science teacher. On each step of a miniature flight of stairs the teacher placed a lighted candle. Then, taking a bottle which appeared empty, he held it over the top candle and tipped it as though pouring out an imaginary fluid. To the surprise of all, first the top candle was snuffed out, and then the one below it, and then the next and the next; and so, slowly, the mysterious, invisible power crept down the stairs, *extinguishing*[1] candles as it went!

Harold learned later that this strange, invisible substance that issued from the bottle and stalked down the stairs, putting out candles like an elf before going to

[1] Extinguish: to put out.

bed, was carbon dioxide, a heavy, invisible gas, which, unlike air, does not support combustion. Small fires may be extinguished by means of this gas. Because it is one and a half times as heavy as air, it settles down over the flame like a blanket, and smothers the fire.



What makes it possible for the gas to flow downward?

Extinguishing fires by removing fuel. Making a bonfire is great fun, but many serious fires have been started in this way. Sparks from a bonfire are likely to set fire to near by buildings or trees. Making bonfires in the city streets is forbidden because of the damage which may result. A good way to extinguish a bonfire is to scatter the burning materials. Each small part of the fire may then be put out with ease. If the bonfire is too large to handle in this way, the next best thing is to remove from the path of the fire all combustible material. The fire will thus have no new material to burn and will die out when the burning materials have become ashes.

Demonstration. To show that fire will go out when the fuel is removed. Strike a match and place it carefully on a stove or some other non-burning substance. Watch it until it is completely burned up, leaving only the ash. The three conditions necessary for fire are fuel, air, and a kindling temperature. Which of these three conditions was removed?

U. S. Forest Service

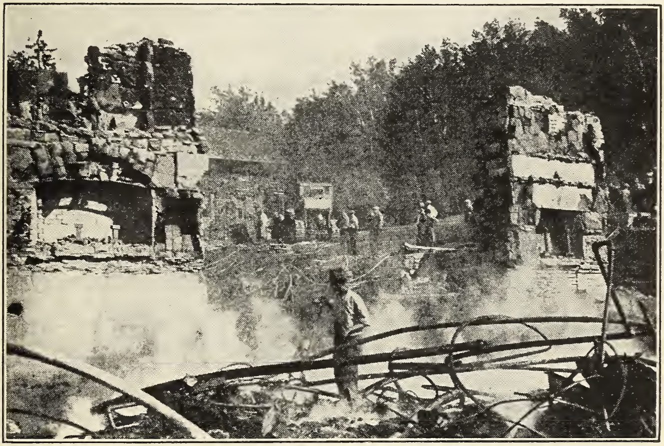
Removing fuel from the path of a forest fire.

Forest fires are fought by removing fuel from the path of the fire. Trees, bushes, and other combustible materials are cut down by the forest fire fighters and often trenches are cut across the path of the fire. When the fire reaches the cleared space it has no more fuel to feed it and dies out or becomes weak enough for the fire fighters to extinguish.

When firemen arrive at a burning house, one of the first things they do is to shut off the gas supply. This is important because gas, when exposed to great heat, is likely to explode and to cause great damage.

Fires may be avoided by the proper construction of buildings. Modern buildings, particularly in large cities, are built of materials that resist fire. The term *fireproof* is often applied to such buildings, but there is really no such thing as a fireproof building. Fire-resisting or slow-burning would be a better name.

Brick, concrete, tile, terra cotta, and some kinds of cement are good fire-resisting materials. Steel, so necessary for the skeleton of tall buildings, expands and becomes twisted out of shape when exposed to great heat and so must be protected by some covering of fire-resisting material. Hollow tile, concrete, or



Destruction caused by fire. Is steel fireproof?

cement are used for this purpose. Wood may be made fire-resisting by chemical treatment and chemically treated wood is often used in modern buildings.

Fires may be extinguished by reducing the temperature. You have learned that before a fuel can burn it must be raised to the kindling temperature. If burning fuel, therefore, is cooled to a temperature below the kindling point, it ceases to burn. This is usually done by throwing water on a fire. The water reduces the temperature of the burning fuels below the kindling point and causes the fire to go out. Further reduction in temperature results when some of the heat of the fire is used for converting the water into steam.

Demonstration. To show that water extinguishes fire. Immerse all but one end of a stick in water. Ignite the dry end and watch the progress of the fire. What happens when it reaches the water? What must happen to the water before the fire can continue? If the temperature is reduced to less than the kindling point, what will happen to the fire?

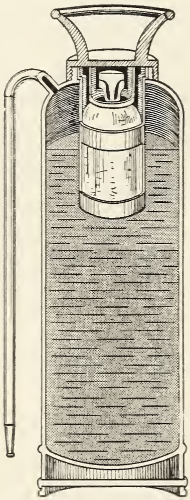
Question. Which of the three conditions necessary for fire was removed when the stick stopped burning?

Fire may be put out by smothering. As you know, one of the conditions necessary for fire is a supply of oxygen, or air which contains oxygen. If, in some way, the supply of air is cut off, the fire will go out. Most fire-extinguishing devices are based on this principle. In most cases, fires are extinguished with water. The burning material is flooded with water so that, not only is the temperature of the fuel reduced, but the air is prevented from reaching the fuel by a blanket of water. If the burning substance is oil, water should not be used. The oil, which is lighter than water, will float on the surface of the water and will continue to burn.

For small fires, fire extinguishers other than water have been discovered. We shall now learn about some of these extinguishers.

Demonstration. To show that fire needs air to keep burning. Set fire to a stick. After a time cover the burning wood with a quantity of sand. What happens? Why?

Make a little carbon dioxide gas by pouring some *sulphuric acid* over a small quantity of *bicarbonate of soda* in a glass jar. Set fire to a piece of wood and pour the carbon dioxide gas over the flame. This is possible because carbon dioxide is heavier than air. What happens? Why?



The small bottle contains sulphuric acid and the larger vessel contains sodium bicarbonate and water. Explain how this fire extinguisher works.

Carbon tetrachloride is another chemical much used in fire extinguishers. Carbon tetrachloride vapor is about five times as heavy as air and does not support combustion.

Emergency fire extinguishers. Because air, or oxygen, is needed to keep a fire burning, almost any material is a good emergency fire extinguisher if it cuts off the supply of air. Sand is an excellent substance for this purpose and has been used in many fires to good effect. Many a life, too, has been saved simply by wrapping the person whose clothes have caught fire, in a heavy blanket that excludes air and prevents further progress of the flames.

Guard against carelessness.

How does wool extinguish flames?

Summary

Fires may be extinguished by the removal of burning materials.

Fires may be checked or put out by cooling the burning materials below the kindling temperature.

Fires may be put out by keeping air away from the burning materials.

How Much Did You Learn?

Which of the following statements are true and which are false?

T. F. 1. A fireproof material is something that is guaranteed to burn.

T. F. 2. In order to have fire, oxygen is necessary.

T. F. 3. Water absorbs heat when applied to a fire.

T. F. 4. Water may prevent air from reaching burning fuel.

T. F. 5. Blankets may be used for putting out small fires.

T. F. 6. Sand thrown on an oil fire helps the oil to burn.

T. F. 7. Carbon dioxide does not support combustion.

T. F. 8. No gas is as heavy as air.

T. F. 9. Water is the best extinguisher to use for a kerosene fire.

T. F. 10. Hot water is of no use in putting out fires because it raises the kindling point of the fuel.

T. F. 11. Forest fires are fought by removing the fuel in the path of the fires.

T. F. 12. Steel is not a fireproof material.

T. F. 13. Steel resists fire better than brick.

T. F. 14. Air supports combustion because air contains oxygen.

T. F. 15. Carbon tetrachloride is a good fire extinguisher because it is five times as heavy as air and does not support combustion.

On a sheet of paper, write the word that will complete correctly each of the following statements.

16. A gas which can extinguish fire is ——.

17. Fuel, a kindling temperature, and —— are necessary conditions for burning.

18. The acid used in the carbon dioxide fire extinguisher is ——.

19. —— is the commonest fire extinguisher.

20. Wrap a —— around a person whose clothes are on fire.

Supplementary Demonstrations and Projects

1. Make a fire in a large baking pan and cover it with a small asbestos mat. Explain the result.

2. Place a jar, mouth down, over a lighted candle. What happens? Why?

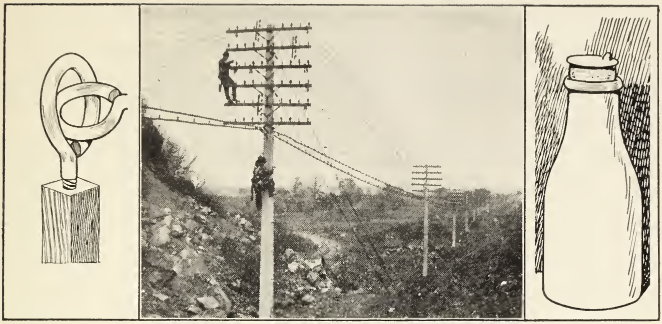
3. Explain the construction of the school fire extinguisher.

4. Explain the use of automatic sprinklers in a modern fireproof building.

5. Explain how buildings are protected by lightning rods against fires.

6. Go to the library and read the chief regulations concerning fire prevention. Make a report to be read in the classroom, giving the scientific reasons for each rule.

7. Write a composition on fire prevention in the home.



Ewing Galloway

Change in temperature may cause expansion or contraction.

PROBLEM V

HOW ARE EXPANSION AND CONTRACTION CAUSED BY HEAT?

Because he had been brought up in the city, everything that he saw in the quaint little mountain village of Bellecrag aroused the curiosity and captured the interest of the high school lad who was spending his summer vacation there. The musical clang-clang of the blacksmith's hammer on the anvil drew him irresistibly to the door of the ramshackle shop. Close beside the bronzed figure of the blacksmith, a wagon wheel lay, resting on its hub. The blacksmith's helper, a young country boy in his early teens, held the red-hot steel rim of the wheel by means of a long pair of tongs, and turned it slowly on the anvil while the swarthy giant rained blows on it with his heavy hammer. Finally the hammering ceased, and with sure, deft movements, the blacksmith fitted the rim over the waiting wheel. A few well-directed taps fitted it into place, and several buckets of water poured on it served to cool it.

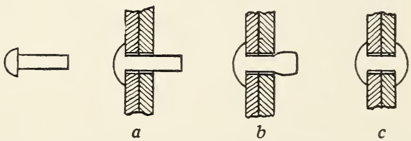
The blacksmith was making use of his knowledge that solids absorbing heat expand, that is, grow larger; and solids losing heat contract, that is, grow smaller. Heating the rim caused it to expand enough to permit the blacksmith to slip it over the wheel, and then the sudden cooling caused it to contract so that it fitted tightly into place over the wheel.

Demonstration. To show the effect of heat and cold on solids. Obtain a bolt and nut that fit. Remove the nut and heat it red hot in the flame of a Bunsen burner, holding the nut in a pair of tongs. When hot, try to fit the nut to the bolt. Can you do it? What has happened? Is the nut too tight or too loose? Allow the nut to cool, or plunge it into cold water. Now try once again to fit the nut to the bolt. Does it fit? What did heating do to the nut? What effect did cooling the nut have?

Can you explain why a blacksmith heats the rim of a wheel before it is put into place?

You may see the effects of expansion of solids on the streets. On hot days the asphalt with which most of our city streets are paved expands and, therefore, needs more room. The only direction in which it is free to expand is upward. This causes it to become wavy. This upward bending of the pavement is known as buckling. All expanding solids buckle if they are held too tightly in place at the sides and ends.

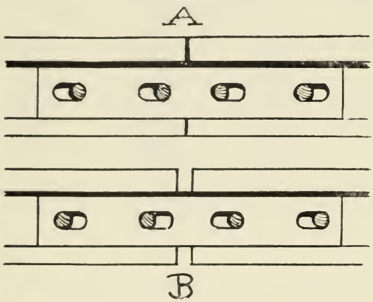
Riveting is possible because metals expand when heated and contract when cooled. Rivets are cylindrical pieces of steel, resembling bolts, and are used for holding together two plates of steel. The shape of a rivet before it is heated is shown in the figure. Holes, just a little larger than the diameter of the rivet, are bored in the steel plates that are to be held together. When the plates are in position, the rivet is heated white hot and pushed into the holes, as shown in figure *a*, below. A pneumatic hammer, such as you read about last term, hammers the small end of the rivet until it spreads out, forming a head, as shown in figures *b* and *c*. When the rivet cools, it contracts and holds the plates tightly together. You may have seen riveters at work on the steel framework of tall buildings. The rivet is heated in a blacksmith's forge. It is then taken out of the fire by means of long tongs and hurled through the air to the riveter, who catches it in a small bucket of sand. With another pair of tongs, the riveter takes the rivet from the sand bucket and places it in position for hammering. This is all done so quickly that the rivet is still red hot when it is hammered into place.



Why are rivets heated white hot before they are inserted into steel plates?

Steel is used a great deal in the construction of bridges and the bridges therefore expand in hot weather and contract in cold weather. If the bridge were rigidly fastened at both ends, the constant strain of expansion and contraction would cause damage to the structure. To avoid this, one end of the bridge is not rigidly fastened and cylindrical rollers are placed under this end to allow it to change in length.

Steel rails expand in warm weather. If the lengths of steel rail were laid so that they touch, there would be no room for expansion and, like the asphalt pavement, they would buckle (see figure A). To avoid this, rails are laid with spaces between them, as shown in figure B. Needless to say, the slightest buckling of the rails might cause trains to jump the tracks.



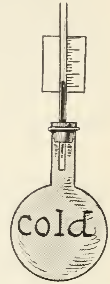
An expansion joint. Explain how this device allows for expansion of steel.

Whenever steel is used, in bridges, railroads, or buildings, allowance must be made for expansion in hot weather and contraction in cool weather. This is done by making some of the connections[1] with bolts instead of with rivets. The bolts fit rather loosely into holes a trifle too large for them, thus allowing a little "play." Certain beam-ends are left free instead of being fastened rigidly in place. Sometimes, during a fire, the steel expands so much in spite of these precautions

[1] Such a connection is known as an expansion joint.

that the walls of a building are pushed out of place and fall.

Demonstration to show effect of heat and cold on liquids. Fit a piece of glass tubing into a one-hole rubber stopper as shown in the illustration. Fill a bottle or a flask[1] with water and fit the stopper tightly into place. Heat the bottom of the bottle gently over a Bunsen flame.



What happens to the water[2] in the tube? What causes this change?

Now cool the flask suddenly by immersing it in a basin of cold water. What happens? Why?

When water is heated, as you have demonstrated, it expands. It is therefore lighter than an equal volume of cold water. When mixed with cooler water, therefore, warm water will be buoyed up by the surrounding cooler and heavier water. This causes it to rise to the surface. This fact is made use of in hot-water heating systems, as you will later learn. For the same reason surface water in rivers, reservoirs, lakes, and oceans is warmer than water near the bottom.

How can you demonstrate expansion of liquids with this device?

[1] In these demonstrations it is necessary to use a flask that will not crack when exposed to extremes of heat and cold. Flasks for such purposes are obtainable for work in science. The Florence flask is very useful for such demonstrations.

[2] Water differs from other liquids in that it expands when its temperature falls below 39° F.

The *thermometer*, an instrument for measuring temperature, is based on the fact that most liquids expand when heated, and contract when cooled.

Demonstration. To show effect of heat and cold on air. Stretch a piece of thin rubber over the mouth of a slender-necked bottle. Hold the rubber in place by means of a rubber band. Heat the bottle gently over a gas flame. How does the rubber membrane behave? What causes this?

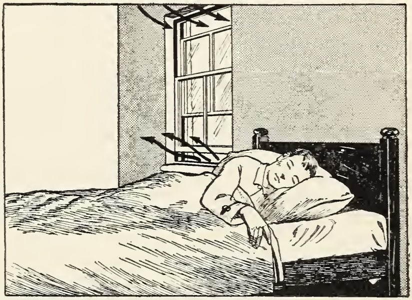
Just as warm water is buoyed up by heavier, cold water, so warm air rises because it is buoyed up by heavier, cool air. Air, heated in a chimney, rises as it expands and carries with it smoke and tiny sparks.

Why is the ice placed near the top of the icebox?

In a heated room the warmer air rises to the ceiling. You can prove this by standing on top of a ladder in the room, or by using a thermometer to compare the temperatures of the air near the floor and near the ceiling.

Cooled air falls because cool air is heavier, volume for volume, than warm air. If, in a heated room, a draft of cold air were suddenly let in at the ceiling, this cold air would fall toward the floor. Ice is placed near the top of the icebox for this reason. The ice cools the air, which then falls, filling the lower spaces of the icebox with cold air. The illustration shows how the air in an icebox circulates.

The rise of heated air and the fall of cooled air in a room produces circulation of air and, when fresh air is supplied, the circulation serves to ventilate the room. A simple way to ventilate a room, as you learned last term, is to open the windows at the top and bottom. Cool, fresh air then falls to the bottom, circulates through the room, and forces the warmer and less fresh air to go out through the top of the window. In winter, radiators placed near the floor help the circulation by heating the cool air near the floor, causing it to rise.



Why is this a good way to ventilate a room?

If you live in a small house, you have probably noticed that the attic, or top floor, is always warmer than the rest of the house while the cellar is cooler. How do you explain this?

Summary

Solids, liquids, and air expand when heated, and contract when cooled.

Questions

1. Why are rivets placed in position while they are red hot?

2. Why do railroad builders leave small gaps between the lengths of rail?

3. The metal cap of a glass jar is sometimes difficult to unscrew because it is on too tight. How can you remedy such a condition?

4. What causes the mercury in a thermometer to fall?

5. Why should a sealed bottle of root beer be just a little less than full?

6. Why is ice placed near the top of an icebox?

7. Why are attics usually warmer than cellars?

8. Explain how circulation of air aids ventilation.

9. Why are radiators placed near the floor?

10. Name one liquid that expands when cooled below a certain temperature.

Can You Also Answer These?

11. Name a machine that makes use of the expansion of a gas by heating.

12. How do clockmakers overcome the tendency of pendulums to expand in warm weather?

Which of the following statements are true and which are false?

T. F. 1. Only metals expand when heated.

T. F. 2. Metals expand only when heated red hot.

T. F. 3. A pound of cold water is heavier than a pound of hot water.

T. F. 4. A cubic foot of cold water is heavier than a cubic foot of hot water.

T. F. 5. Spaces are left between lengths of steel rails to save money.

T. F. 6. In an icebox, the coldest air is near the top where the ice is.

T. F. 7. Asphalt becomes wavy as the result of expansion by heat.

T. F. 8. The steel framework of a skyscraper never changes in size.

T. F. 9. A balloon filled with cold air would not rise.

T. F. 10. Thermometers illustrate expansion of liquids by heat.

Supplementary Demonstrations and Projects

1. Examine and explain the compensating pendulum of a clock.
2. Explain, using diagrams, how to ventilate a room properly.
3. Make the mercury in a thermometer expand by heating it with your hand.
4. Explain how the thermostat works.
5. Fill a toy balloon with warm air. What happens? Why?

How is temperature recorded?

PROBLEM VI

HOW IS HEAT MEASURED?

Baby is about to get his daily bath. He lies stretched out and contented, kicking his pink toes aimlessly about. Quietly and swiftly the experienced mother moves about getting things ready, for baby's bath requires as much careful preparation as any scientific demonstration. At last all is ready, all but the water. This must be just right, for no guess-work will do here. First the hot water is allowed to run into the tub, and then a little cold. When it seems about right, the large thermometer, encased in wood, is plunged into the bath. The mercury leaps up, 80° — 90° — 100° — 103°. A little more cold water is added. Baby's body is very sensitive. The water must be about the same temperature as his body. Now it is just right, and the kicking, cooing, gurgling baby is carefully lowered into the tub.

What a remarkable little instrument the thermometer is! How many useful purposes it serves! About 1592, Galileo (see picture in heading), an Italian scientist, invented the first instrument for recording temperature. His invention resembled the thermometer shown in the drawing on the right side of the heading. This device consisted of a hollow glass bulb fitted into a glass tube. The bulb was heated to force out some of the air. When the tube was put in water and cooled, the water rose part way in the tube. When the temperature became warmer, the liquid would fall. The changes in temperature could be noted on the scale back of the tube. But it was not until the eighteenth century that Gabriel Daniel Fahrenheit, a German scientist, improved this clever device by working out a scale based upon the freezing point and boiling point of water. Without the thermometer today, we would be very much handicapped. The chemist would

Armstrong Roberts

The temperature of baby's bath must be just right. How is the temperature tested?

be lost without it. The Weather Bureau would miss it seriously. Many valuable articles of manufacture which now depend on mixtures of elements at exact temperatures would be crudely made. The process might even be impossible. The nurse in the hospital or sick-room, who now watches the condition of her patient with the aid of a thermometer, might, without it, be at a loss to recognize important changes in the patient's condition. Mariners use it; aviators use it; mountain-climbers use it; cooks use it. In fact, science could never have advanced so far and in so many ways without Galileo's invention.

Parts of a thermometer. The important parts of a thermometer are: a glass tube the inside, or bore, of which is very narrow, a bulb at the lower end which contains mercury, and a metal or a wooden frame to which the tube is fastened. The air is exhausted from the part of the tube above the mercury and the upper end of the tube is sealed.[1]

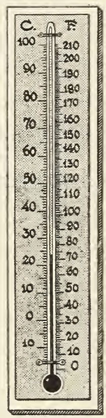
Mercury or colored alcohol is used in most thermometers. Water is not suitable because it expands, instead of contracting, at temperatures below 39 degrees Fahrenheit, freezes solid at 32 degrees, and boils at 212 degrees. Alcohol freezes at a very low temperature (200 degrees below zero, F.) and can therefore be used to indicate temperatures far below the freezing point of water.

[1] A closed space, such as a sealed tube, from which all the air is exhausted, is known as a *vacuum*.

Demonstration. To learn how a thermometer is constructed. Carefully examine a Fahrenheit thermometer. Notice that the tube of the thermometer is sealed both at the top and at the bottom. With what liquid is the tube filled? On what principle does the thermometer work? Why may the tube not be open at the top? Does the liquid fill the tube? What is in the space above the liquid?

Study the marks, the numbers, and the notes or words printed on the scale. Where is the freezing point of water?

Suppose you had simply a sealed tube containing mercury, and a plain board, ready for mounting, but without markings of any kind. How would you determine where to mark the boiling point of water, 212 degrees, Fahrenheit? Where would you mark the freezing point, 32 degrees? What would you do to complete the markings? How would you test your thermometer?



How does the Centigrade thermometer differ from the Fahrenheit?

Kinds of thermometers. The thermometer we have just discussed is called a *Fahrenheit* thermometer, named for its inventor. This type is used chiefly in England and in the United States. The *Centigrade* thermometer is the one generally used in other countries and for all scientific work. On the Centigrade scale the freezing point of water is 0 degrees, and the boiling point is 100 degrees.

Question. What advantage has this over the Fahrenheit scale? Which is greater, one degree Centigrade or one degree Fahrenheit?

Between the freezing point and the boiling point in the Centigrade thermometer there are 100 degrees. Between the same points on the Fahrenheit scale there are 180 degrees. One degree Centigrade is thus equal to 1.8 degrees Fahrenheit. When the Centigrade thermometer reads 1 degree, that is, one degree above freezing, the Fahrenheit thermometer will read 1.8 degrees above freezing, that is, 1.8 degrees above 32, or 33.8 degrees. To change from Centigrade to Fahrenheit scale, therefore, multiply the degrees Centigrade by 1.8 (or $\frac{9}{5}$) and add 32 degrees. Thus, 70 degrees C.[1] equals $70 \times \frac{9}{5}$ plus 32, equals 158 degrees F.[2] To change from Fahrenheit to Centigrade, subtract 32 degrees from the Fahrenheit reading and take $\frac{5}{9}$ of the result. Thus, 158 degrees F. equals $(158-32) \times \frac{5}{9}$, equals 70 degrees C.

Questions. How does the thermometer make use of the principle: liquids absorbing heat expand; liquids losing heat contract?

Where is the freezing point of water on the Fahrenheit scale?

Where is the freezing point of water on the Centigrade scale?

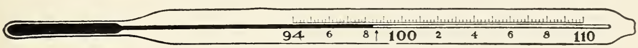
Where is the boiling point of water on each of these scales?

Prove that 110° C. equals 230° F.
Prove that 60° C. equals 140° F.
Prove that 10° C. equals 50° F.

[1] The letter, C., is used as an abbreviation to indicate Centigrade.
[2] The letter, F., is used as an abbreviation to indicate Fahrenheit.

Uses of thermometers. The commonest use of the thermometer is to indicate the temperature of air. For this purpose the mercury or alcohol thermometer is used. Health authorities tell us that the temperature of a properly heated room should be 68° F. which is equivalent to 20° C. ($68 - 32 = 36$; $\frac{5}{9} \times 36 = 20$).

Thermometers are used by physicians and nurses to indicate the temperature of the body. The type of thermometer used for this purpose is known as the *clinical* thermometer. It is a small, delicate instrument with a short column of mercury and a very narrow bore. The scale reads from 90 degrees F. to 110 degrees F.



For what is th's thermometer used?

Each degree is divided into fifths and, sometimes, into tenths. The normal temperature of the body, that is, the temperature of a healthy person, is 98.6 degrees F. Temperatures much above or below this indicate that something is wrong with the individual; 100 degrees or more indicate that the person has fever. When the temperature reaches 101, 102, or 103 degrees, a physician should be called at once. The mercury in a clinical thermometer remains at the highest temperature last recorded. Before using it, therefore, the mercury must be shaken down to a point below normal body temperature. Always wash the thermometer in a cold *antiseptic*[1] solution immediately after using

[1] Antiseptic (ăn′tĭ sĕp′tĭk): substance that will destroy harmful bacteria.

it. Hot water will cause the mercury to expand to such an extent that it will burst the tube.

Thermometers are used to indicate the temperature of common liquids used in manufacturing such as water, oils of various kinds, milk, and some acids. For this purpose a thermometer similar to the bath thermometer is used. It resembles the room thermometer but is usually encased in a plain wooden frame that will not be damaged by the liquid in which it is immersed.

In some manufacturing processes, temperatures much higher than the boiling point of water are often used. To measure such extreme temperatures, mercury and alcohol are not suitable, and air thermometers or metal thermometers are used.

In an air thermometer, a column of air, instead of mercury, is made to expand when heated. Because air is invisible, a very small quantity of colored liquid is used above the air column, and as the air expands or contracts, the liquid rises or falls. Instead of air, other gases such as hydrogen may be used.

A metal thermometer depends upon the expansion and contraction of solid metal rods or strips. Metals that melt at very high temperatures are used for this purpose. The housewife's oven thermometer is a thermometer of this type.

Summary

Thermometers are used to measure temperature and temperature changes.

The chief parts of an ordinary room thermometer are a sealed tube with narrow bore ending in a bulb at the bottom, mercury or alcohol in the tube, and a scale.

Thermometers are based on the principle that solids, liquids, and gases expand when heated, and contract when cooled.

Some types of thermometer are:

1. The room thermometer for indicating air temperatures.
2. The clinical thermometer for indicating bodily temperatures.
3. Gas thermometers, employing air, hydrogen, or some other gas and used where extremely high temperatures are to be measured.
4. Metal thermometers, used for the same purpose as gas thermometers.

How Much Have You Learned?

Each word, or number, in column A fits correctly into a statement in Column B, but not into the statement directly opposite it. Rearrange the words, or numbers, in Column A so that they do fit the statements directly opposite them.

Use a sheet of paper so as not to mar the book.

Column A	Column B
temperature	A bodily temperature of 103 degrees F. indicates ——.
mercury	The freezing point of water is —— degrees C.
32	The name of the man who improved the thermometer is ——.
212	The space in the bore above the mercury is a ——.
0	The —— thermometer measures the heat of the body.

100	The substance most commonly used in a thermometer is ——.
Fahrenheit	A thermometer is used for measuring ——.
vacuum	The freezing point of water is —— degrees F.
clinical	The boiling point of water is —— degrees C.
fever	The boiling point of water is —— degrees F.

Which of the following statements are true and which are false?

T. F. 1. Thermometers are used to measure temperatures.
T. F. 2. Colored water is used in high-priced thermometers.
T. F. 3. For measuring extremely low temperatures, alcohol is useful.
T. F. 4. A gas thermometer is used for measuring the temperature of gas.
T. F. 5. Zero degrees C. is the same temperature as 32 degrees F.
T. F. 6. Torricelli invented the thermometer.
T. F. 7. The space above the mercury in a thermometer is filled with air.
T. F. 8. Mercury, rather than water, is used in thermometers to save space.
T. F. 9. To change degrees Centigrade into degrees Fahrenheit, multiply by $\frac{9}{5}$ and add 32.
T. F. 10. The thermometer tube is sealed at the top to prevent the escape of mercury.

Supplementary Projects

1. Keep a daily record of outside temperatures for a month and make a graph to show the changes from day to day.

2. Keep an hourly record of temperatures in the classroom for one day.

3. Take the body temperature by inserting a clinical thermometer in the mouth. (Keep the lips closed over the thermometer for two minutes.)

4. Write a composition on the important uses of the thermometer.

Do all substances conduct heat equally well?

PROBLEM VII

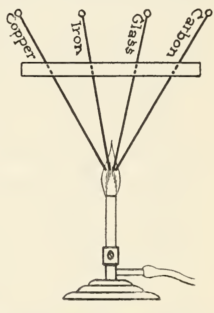
HOW DOES HEAT TRAVEL IN SOLIDS?

James will never forget an experience which he had when, as a boy of eight or nine, he was poking the fire in the great coal range that almost filled one end of the huge kitchen. He became interested in the glowing coals and soon noticed that the end of the poker was a brilliant red. The glowing poker seemed to fascinate him and he watched it change from a bright red to a dazzling white. Suddenly he dropped it with a shriek of pain. He had held on just a little too long, and the heat had passed upward, until it had reached his hand. You may be sure that, from that day on, he was very careful about handling pokers.

The poker that James used was made of iron. Heat travels through iron, and through most metals, as we shall learn, very rapidly. Had James used a glass rod instead of an iron poker, the heat would have taken much longer to travel from the hot end in the fire to his hand.

The way in which heat travels through solids is known as *conduction*, from the Latin, *ducere*, to lead. Any substance through which heat travels is known as a *conductor*. Substances which conduct heat rapidly are good conductors of heat; those which conduct heat slowly are poor conductors.

Demonstration. To show that all solids are not conductors of heat. Prepare a number of specimens of different materials all the same length and thickness, if possible, such as a stick of wood, a glass rod, a stick of wax, a hard-rubber rod, and a porcelain rod. Insert one end of each of these into a basin of boiling-hot water. After a few moments feel the other end with the finger tips. Which become hot quickly? Which become hot only after a time? Which do not seem to become hot at all? How do you account for these differences?

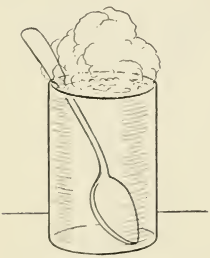


Demonstration. To show that some solids are better conductors of heat than others. Prepare rods of copper, iron, glass, and carbon so that they stick through a board as shown in the figure. The rods should all be equal in length and in thickness. Place a piece of sealing wax on the upper end of each rod. Heat the lower ends of the rods, where they come together, in a Bunsen flame. Watch the sealing wax.

Which piece of sealing wax is the first to melt? Which is the last? What may you conclude from this demonstration?

A similar test using only metal rods of various kinds will show that almost all metals are good conductors of heat. You probably have noticed this fact yourself. The handle of a metal spoon immersed in a hot drink often becomes so hot that it is difficult to hold. Wooden spoons or glass spoons do not behave in this way. Because metals are good conductors of heat, pots and kettles are made of metal. The metal permits the heat from the fire to pass through it and into the contents of the pots and kettles. Heat is transmitted through the metal of water boilers to the water within. Radiators and stoves become heated rapidly because they are made of iron, a good conductor of heat.

Perhaps you understand better, now, why the steel framework of modern buildings must be protected against fire, although steel itself does not burn.



Demonstration. To show air as a conductor of heat. Put a metal spoon in a glass of boiling-hot water. After a minute or so, touch the upper end of the spoon. Result? Is the spoon a good conductor of heat? The air immediately surrounding the spoon seems to be just barely warm. Is the air a good conductor of heat?

Substances that are very poor conductors of heat are known as nonconductors or heat *insulators*. The word *insulate* means to separate, as an island is separated from the mainland. Insulators are substances which prevent heat from going through them. A nonconductor placed between two good conductors prevents heat from passing from one conductor to the other; thus one conductor is *insulated* from the other.

Because air is a nonconductor of heat, any substance that contains many air spaces is also a poor conductor of heat. Such substances are said to be *porous*. There are many substances of this kind, such as wood, wool, felt, cork, sand, fur, sawdust, and asbestos. Can you add others?

Demonstration. To show that asbestos is a poor conductor of heat. Hold a piece of asbestos in a Bunsen flame for several minutes. Does the heat reach your hand? Substitute a piece of iron. Iron is a good conductor of heat. Is the result different?

What do you conclude about asbestos as a conductor of heat?

Nonconductors of heat serve a number of useful purposes. Asbestos is used for covering steampipes and other hot objects. This serves a double purpose; the heat is kept inside the pipe, where it is needed, and combustible objects near the hot pipes are protected from the heat, thus preventing fires. Asbestos is used in theaters for fireproof curtains. In case of fire on the stage the curtain is dropped, preventing the heat from reaching the body of the theater. Asbestos shingles for roofs of suburban and country homes are quite common. The asbestos keeps the heat of the sun from getting into the house.

Keystone View Co.

Why is this a good roof for tropical climates?

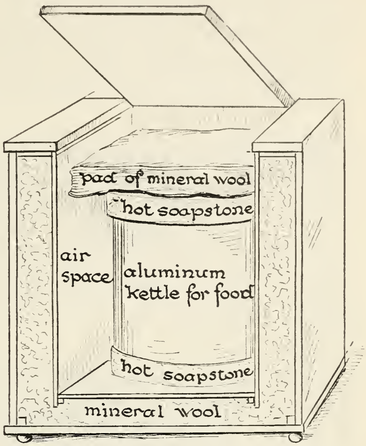
Questions. What are some uses of asbestos in the kitchen? Sawdust and cork are used in the construction of iceboxes and fireless cookers. Can you tell why?

Often, ice that is cut during winter is stored for later use and covered with sawdust and cork. This keeps the outside heat from reaching the ice and thus prevents rapid melting.

Woolen clothes are sensible in winter because wool is porous and so is a nonconductor of heat. Thus it prevents the cold winter air from reaching the body. It also keeps the heat of the body from getting out. Cotton, which is more closely woven, is not quite so good an insulator as wool and therefore not so desirable for extremely cold weather. You have all appreciated the comfort that comes from the use of woolen blankets in winter. A woolen blanket is much warmer than a cotton blanket of equal size and weight.

Question. Why are winter gloves often lined with fur or wool?

Demonstration. To show that some nonconductors are better insulators than others. Obtain four small pieces of ice, all equal in size. Wrap one in wool, one in asbestos, one in felt, and one in paper. In order to make a fair test, the wrappers should all be about equal in thickness. Place all of these wrapped pieces of ice in the bottom of a pan and heat it for two minutes over a Bunsen flame. Compare the results.



Explain why food may be kept hot in this device.

Which wrapper proved to be the best insulator? Which the poorest?

A similar test can be made by wrapping equal thicknesses of various nonconducting substances around a hot pipe and noting which is the best insulator. Many interesting experiments of this kind can be made. Try some of them at home.

It is safe to take hold of a hot pan with a dry kitchen towel. Would not a wet towel do just as well? No, a dry towel is a poor conductor of heat because it contains many spaces filled with air. The wet towel contains a large quantity of water, and water is a better conductor of heat than air.

Builders make use of heat-insulating devices in constructing houses. Walls built of hollow tiles have air spaces in them which keep the house cool in summer and warm in winter.

Keystone View Co.

Why do hollow tile walls protect a building against extremes of heat and cold?

Question. Can you explain why the hollow tiles are good insulators?

In sections of the country where the winters are very severe, windows are sometimes built double, that is, two windows with an air space between them. This air space prevents the cold outside air from entering the house.

Some building materials are themselves good heat insulators and are thus desirable for wall construction. For example, a four-inch thick concrete wall is a better insulator than a four-inch brick wall.

Summary

Solids transmit heat by conduction.

Most metals are good conductors of heat.

Air is a very poor conductor of heat.

Porous substances are nonconductors of heat and make good heat insulators.

Questions

1. Name five good and five poor conductors of heat.

2. Why should every pot cover be provided with a wooden or a hard-rubber knob?

3. Why is the bottom of a tea kettle usually made of copper?

4. Explain why hot soup remains hot for a long time in a fireless cooker.

5. Explain why cold milk remains cold for many hours in a thermos bottle.

6. Why are the walls of an icebox sometimes filled with cork or sawdust?

7. Why is the handle of a coffee percolator made of wood?

8. Hollow walls keep a house cool in summer and warm in winter. Explain how.

9. The housewife puts hot plates on an asbestos pad; what is the reason for this?

10. Why should woolen clothes be worn in winter?

11. To take a roasting pan out of the oven, would you use a wet or a dry towel? Explain your answer.

Can You Also Answer These?

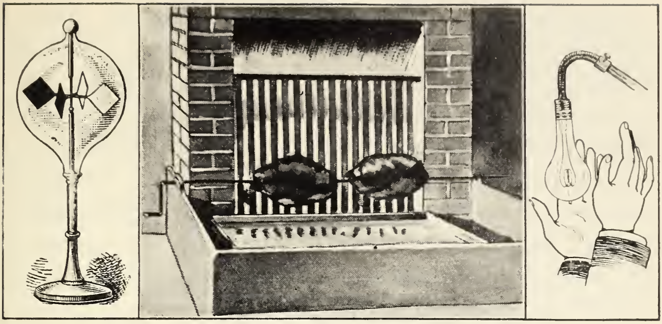
12. Which roofing material will keep the house cooler, tin or tile? Why?

13. Why is a thermos bottle made in two sections with a vacuum between the inner and the outer bottles?

14. In sections of northern Europe and North America, windows are often made double with an air space between the inner and the outer windows. Why? Would this same device be useful in torrid countries? Give reasons for your answer.

Supplementary Projects

1. Show by an experiment of your own that paper is a good heat insulator.
2. Study the construction of a vacuum bottle.
3. Study the construction of a fireless cooker.
4. Study the construction of a refrigerator.



How is heat conducted in each of these illustrations?

PROBLEM VIII

HOW IS HEAT CARRIED THROUGH WATER AND AIR?

Heat applied to a liquid sets up convection currents. Heat does not travel through liquids and gases in the same way that it travels through solids. When heat is applied to a liquid or a gas, the heated portions expand and become lighter, volume for volume, than the portions that are not heated. The result is that the heavier, cool portions force the lighter, warm portions to rise. The heavier, cooler liquid or gas then flows in, taking the place of the warmer substance. Thus a current or circulation is created. Because the heat is thus conveyed[1] from one place to another, these currents are known as *convection currents* (from the Latin word *vehere*, carry).

[1] Convey: to carry.

Demonstration. To show convection in liquids. Place a small quantity of fine powdered charcoal (or a small quantity of fine sand) in the bottom of a tall narrow glass vessel. Carefully fill the vessel with water. If necessary, wait a few moments for the charcoal to settle. Without disturbing the contents, apply heat to the bottom of the vessel. Note the behavior of the charcoal particles. Which way do they travel? What causes them to move in this direction? After a few moments, feel the water in the vessel near the top. Is it warm? How did the heat travel upward?

Unlike solid substances, the minute particles (*molecules*) of liquids actually move from place to place when heated, carrying the heat with them. The movement is always, at first, in an upward direction if the liquid is at rest.

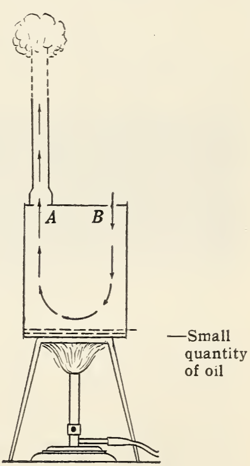
What causes the warm colored water from the small bottle to rise to the surface of the cold water in the larger vessel?

Heating water in a kettle is an illustration of the transmission of heat by convection. The gas flame touches only the bottom of the kettle, yet, in a short time, the entire contents are heated. The heated water at the bottom of the kettle rises when it expands and the heavier, cool water takes its place. This cool water in turn becomes heated and the circulation continues until all the water in the kettle is hot.

Hot-water heating systems are based on the principle of convection currents. Water heated in the boiler, usually located in the cellar, expands, becomes lighter, and rises. It enters the radiators while the cool water in the radiators falls through return pipes and reënters the boiler to be heated in turn.

Hot-water heating systems will be discussed more fully later.

Heat applied to air sets up convection currents. When air is heated, it behaves very much like liquid that is heated. Air in a room that is heated by fire in a fireplace is a good illustration of how convection currents are formed. The air near the fire becomes heated and rises. The warm air reaches the ceiling, travels across the room to the opposite wall, and gradually cools, returning by way of the floor to the open fireplace where the process begins over again. Thus a constant circulation of air is maintained.



Demonstration. To show convection currents in air. Hold the hand several inches above a gas flame. How does the heat from the flame get to the hand?

In a heated room, climb a chair or a high stool. Why is the air near the ceiling warmer than the air near the floor?

Obtain an empty, five-gallon oil can. Pour a very small quantity of oil into the can. Remove the stopper and cut a hole, *B*, about the same size as the opening, *A*, in the top of the can. Heat the can over a gas flame. After a time smoke will rise from both openings. Now place a glass lamp chimney over the opening, *A*. The smoke immediately stops coming through the hole, *B*, and rises only through the opening, *A*. Light a candle and hold it over the hole, *B*. The smoke from the candle will be drawn into the can. This shows that a convection current has been set up in the can. Place a second chimney on top of the first. The smoke now rises faster.

You now know why houses are provided with chimneys. Not only do they carry off the smoke, but they

The taller the chimney, the better the draft.

help the circulation of air in the rooms. The chimney creates a draft. The hot air rises while the cold air which enters from outside rushes in to take its place. This draft makes the fire burn more rapidly.

Tall chimneys cause the air to move rapidly. The more rapidly air is supplied to a fire, the more rapidly it burns and the more heat it produces. All of this was explained in earlier lessons. In manufacturing, great heat is often needed and tall chimneys are built to provide the necessary draft.

Question. Explain why a window in a heated room should be open both from the top and bottom.

Winds caused by convection currents. Last term you learned how the movement of air causes winds. Heat from the sun is absorbed in some areas more than in others because the surface of the earth is irregular. The heated air expands and, being lighter, it rises. Cooler air flows in from other places, causing a circulation. This movement of air is known as wind. Air moves from places of high pressure (heavy air) into places of low pressure (lighter air).

The sun, our chief source of heat. The most important source of heat on earth is the sun. This enormous body, a million and a quarter times as big in volume as the earth and ninety-three million miles away, has a surface temperature of about 10,000 degrees Fahrenheit. And yet, as we ascend a high mountain or rise in a balloon, instead of getting warmer as we approach the sun, the air grows colder and colder. Scientists assure us that beyond the atmosphere that surrounds us, the space between the earth and the sun is fearfully and unbelievably cold.

How the sun's heat reaches us. To explain this, it is necessary to understand how heat from the sun reaches us. Heat leaves the sun in the form of heat waves. These waves move in straight lines from the sun in every direction. Such a movement is known as *radiation*, and heat which travels in this way is known as *radiant heat*. Radiant heat has the power to pass freely through transparent substances and is changed into heat only when *absorbed*[1] by *opaque*[2] substances. Traveling with the speed of light, these radiant heat waves pass through the transparent vacuum that is thought to exist beyond our atmosphere. At great heights, the air is so thin and clear that it has little power to change the waves into heat. That is why it is so cold at high altitudes. Lower down, the denser and dust-laden air, and still lower, the solid earth, absorb the waves of radiant heat, producing heat. Thus the sun heats the earth by radiation.

Demonstration. To show radiant heat. Hold the hands near and just beneath an electric light. The hands are warmed. The heat is not transmitted to the hands by conduction, for air does not conduct heat readily. The heat is not transmitted by convection, for convection currents rise and the hands are beneath the electric light. The heat reaches the hand by radiation.

Touch the glass bulb of the electric light. It is very hot, yet there is a vacuum between the glowing wire inside the bulb and the glass itself. The glowing wire does not heat the glass by conduction or convection; it heats the glass by radiation through the vacuum.

As an example of how the sun's rays pass through

[1] Absorb (from the Latin word, *sorbere*, to suck in): to take in.
[2] Opaque (ō'pāk'): dark, dull, will not let light pass through.

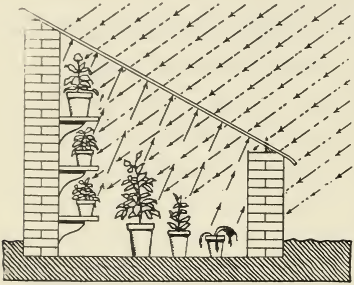
transparent substances without heating them much, note how a window pane, through which the sunlight is streaming, remains fairly cold. And yet the window sill, your body, and other opaque objects on which the sunbeams fall, become warmed.

Heat rays cannot easily escape back through the atmosphere. Once radiant energy is turned into heat, it is no longer able to pass so readily through transparent substances. Thus, the transparent atmosphere allows radiant energy to reach the earth where it is changed into heat. This heat cannot easily escape back through the atmosphere. If it were not for the atmosphere, the earth would become hot during the day, but would lose all this heat at night.

The radiometer (see heading) is an instrument that has been devised to detect the rays of radiant heat. It consists of a glass bulb from which most of the air has been exhausted, and two arms of aluminum crossing each other fastened to a rotating shaft. One side of each vane is black. When the sun's rays strike these vanes, they cause the wheel to spin around. This is due to the fact that the blackened sides absorb more heat and become hotter. The heated air exerts a greater pressure than does the air in contact with the polished sides, and causes the spinning.

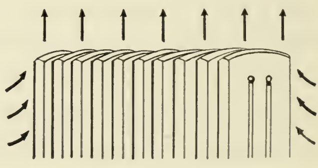
Hothouses. Glass hothouses depend upon the principle of heat by radiation. The sun's rays pass through the glass roof and walls, and are changed into heat only when they are absorbed by the plants and soil within. Once changed into heat, however, the rays cannot get out again through the glass, and the hothouse remains warmer than the air outside.

Stoves and radiators heat objects in a room partly by radiation and partly by convection. If the room were a perfect vacuum, objects would be heated by radiation alone. But as it is, the air in the room helps by setting up convection currents.



Why does the heat remain in the hothouse?

An ideal system of heating. If we could be placed in a vacuum which contained a glowing hot ball, the space in the vacuum would be entirely cold, yet our bodies would become heated by radiation. This, perhaps, would be an ideal system of heating. But such a condition could never exist for the atmosphere is always present about us. The result is that while some of the heat from radiators in a room reaches us by radiation, most of it really comes to us by convection.



How does a radiator heat a room by radiation? by conduction?

Absorption and reflection of heat. Do you know that all substances do not absorb and *reflect*[1] heat equally well? Their power to do so depends, among other things, on their structure and color.

[1] Reflect: to throw off.

Porous substances absorb heat more than do non-porous substances and reflect heat less. That is why wool, in the same room, feels warmer to the touch than does cotton, and wood feels warmer to the touch than stone or metal.

Dark colors absorb heat more readily, and reflect heat less readily, than do light colors. If a black and a white sheet are placed side by side on the snow in the sunshine, it will be found, after a time, that the snow has melted more quickly under the black than under the white sheet. Can you understand, now, why light-colored clothing is best for hot weather and torrid climates? And yet many of us continue to wear dark clothes in midsummer and complain about the heat.

Smooth or polished objects reflect heat more readily than objects having rough surfaces. Polished metal absorbs very little heat; a rough piece of the same kind of metal will absorb a great deal. You can easily prove this for yourself by placing two pieces of metal, one polished and the other rough, at equal distances from a Bunsen burner flame. After a few minutes the rougher piece of metal will be warmer than the polished piece.

Substances vary greatly in their ability to radiate heat. In general, those substances which absorb heat readily also radiate heat quickly. Once the contents of pots and kettles are heated, it is desirable to keep the heat as long as possible. This can best be done by using pots and kettles whose surfaces are highly polished. Thus, the bottom of a coffee percolator should be made of a dull, dark material to absorb heat rapidly, whereas the remainder of the percolator should be polished to prevent radiation.

Soil, rocks, and foliage absorb heat more rapidly than does water. Near a body of water, the land therefore becomes heated more rapidly during the day than does the water. At night, however, the land radiates its heat rapidly and the water gives up its heat more slowly. This causes sea breezes by day, for the air moves from the cooler water to the warmer land, and land breezes at night, when the air moves from the cooler land to the warmer water.

Solar engines. In Russia and in California engines have been built which use heat from the sun as a source of power. Huge reflectors, consisting of hundreds of mirrors, gather the rays of the sun and concentrate them on a boiler containing water. The water is heated sufficiently to make it boil and the steam thus generated is used to operate steam engines. However, such machines are at the present time more interesting than practical.

Summary

Heat applied to a liquid sets up convection currents.

Heat applied to air sets up convection currents.

The sun heats the earth by radiation.

Heat may be absorbed and reflected.

Smooth or polished surfaces reflect heat more readily than rough surfaces.

How Good Is Your Judgment?

In each of the following statements select the one word of the three in parentheses that correctly completes the statement.

1. Heat is transmitted through solids by (convection, conduction, radiation).

2. Heat from the sun reaches us by (radiation, convection, conduction).

3. Air in a heated room is warmest near the (floor, window, ceiling).

4. For good ventilation windows should be open at the (top, bottom, top and bottom).

5. In a hot-water system, return pipes contain water that is (cool, dirty, warm).

6. Chimneys are used to make convection currents move (faster, higher, slower).

7. Winds are caused by (convection, conduction, evaporation).

8. Objects that are (white, black, colored) absorb heat best.

9. The best reflectors of heat are (dark, rough, smooth).

10. Grass absorbs heat (better than, as well as, more slowly than) water.

Can You Answer These?

1. What is the chief difference between transmission of heat by conduction and transmission of heat by convection?

2. Why do African travelers wear white suits and helmets rather than dark clothes?

3. Why does it grow colder as we climb a mountain, in spite of the fact that we approach nearer to the sun?

4. What materials and colors are best for winter wear in northern United States? Why?

5. Why does snow melt more quickly under a fallen twig than out in the open?

6. Why is a brightly polished soup kettle better than a dark, unpolished one?

Supplementary Demonstrations and Projects

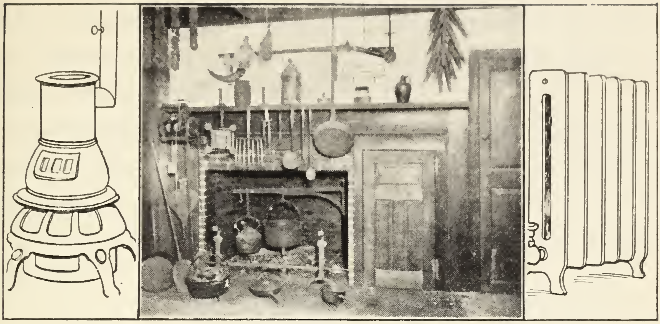
1. Study the ventilation system in your classroom.

2. Describe a simple experiment to demonstrate the direction taken by convection currents in a water boiler.

3. Make a model of a hothouse.

4. Make a toy pinwheel rotate by means of convection currents from a radiator or stove.

5. Locate on a map the Gulf Stream, the Japanese current, and the Labrador current and tell what they have to do with the subject of convection currents.



Courtesy Essex Inst.

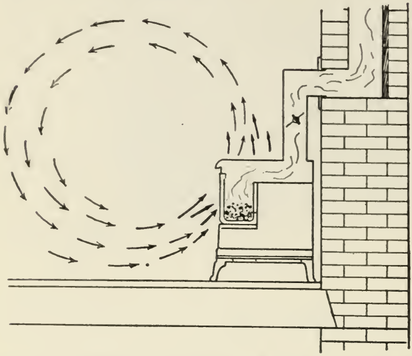
How homes are heated.

PROBLEM IX

WHAT METHODS ARE USED TO HEAT HOMES AND BUILDINGS?

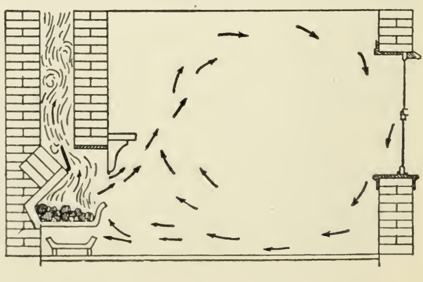
Fireplaces. Some people who live in the country still cling to the picturesque method of heating rooms by means of an open fire in the fireplace. Each room so heated requires a separate fireplace and a good deal of attention. Then, too, a vast amount of wood must be cut and stored, so this method has given way to more modern systems of heating. Although fireplaces are still used, houses no longer depend entirely upon them for heat.

Stoves are used in many homes. The body of the stove is usually cast iron painted black to reflect as much heat as possible. Fresh air is admitted through small openings or doors placed below the grate. Wood or coal is used as fuel. The fuel is placed on the grate and when the fire is started air is allowed to enter underneath the grate. The stove is connected with the chimney by means of a stovepipe in which the damper is located. Because a fresh fire creates a great deal of smoke, the damper is left open, at first, to allow the smoke to escape up through the chimney. When the fire is well under way, the damper is closed or partly closed to regulate the draft and to keep as much heat in the stove as possible. When the fuel is glowing hot, the openings under the grate may be closed to reduce the supply of fresh air and to prevent the fuel from burning up too rapidly. The room is heated by convection currents, as shown in the figure.



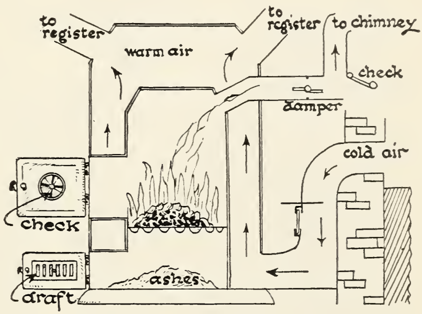
A stove. Locate the damper.

Exercise. Study the illustration. What fuel is generally used in fireplaces? Where does the smoke go? Why does a fireplace fire "smoke" just after the fire is started? What happens after the fire has made some headway?



What causes the change? Which is better, a high or a low chimney? In what way does the draft help? How can the amount of the draft be regulated?

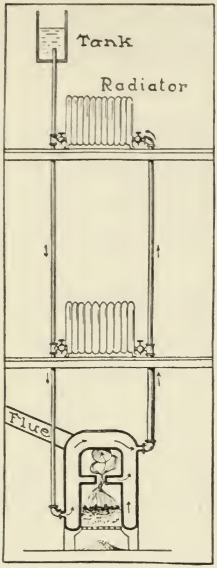
Hot-air heating. For the small house, the cheapest, and perhaps the simplest method of heating is the hot-air system. A large furnace, located in the cellar as near the center of the house as possible, supplies heat to the various rooms by means of metal pipes known as *ducts* that lead out from the furnace and up to the various rooms, where they end in rectangular openings called *registers*. The heated air rises through the ducts, enters the room through the registers, and circulates through the room, warming it. Fresh, cool air is supplied to the furnace through a fresh-air inlet pipe, leading from the outside of the building into the lower part of the furnace (see figure). Hot-air systems are very simple and direct, but they permit dust from the street to enter the rooms.



Hot-air heating. Explain how it works.

Question. Can you explain why rooms heated by hot air get dusty very quickly?

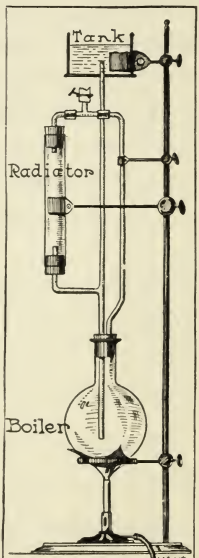
Hot-water heating. In the hot-water heating system, there is a combined furnace and boiler in the cellar.



Hot-water heating. Explain how it works.

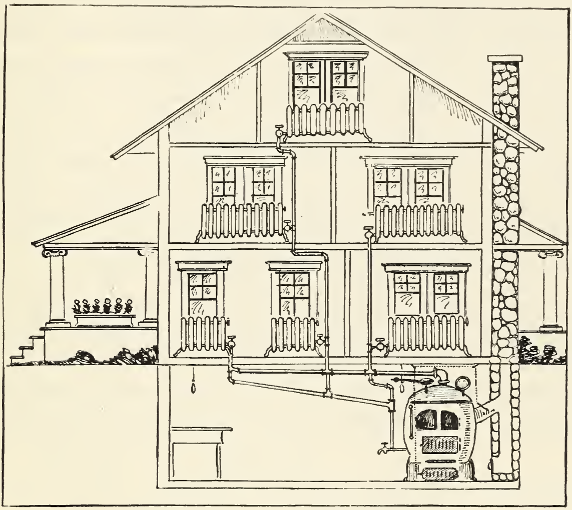
The boiler of water is warmed by the heat from the furnace. The heated water rises through a series of pipes, *risers,* into the various rooms where it enters radiators which heat the rooms by radiation and convection. A set of return pipes leads the cooled water back to the boiler where it is again heated.

A hot-water heater is more expensive to install than a hot-air system but it is superior to the hot-air system in a number of ways. Modern engineers agree that hot water is the best means of heating the average one-family or two-family house.



Demonstration. To show how the hot-water furnace works. Set up the apparatus according to the diagram. Fill the flask and tubes with water by means of the thistle tube. Put a few crystals of potassium permanganate in the flask. Heat the flask. What happens? What parts of a hot-water heating system are represented by the different parts of the apparatus?

Steam heating. Large buildings with many rooms and, therefore, many radiators, cannot be heated by hot-water heating systems. The water in the pipes would become cool long before it reached the upper floors. For heating large buildings, the expansive power of steam is used. When water is heated to the



Steam heating. Explain how it works.

boiling point, 212° F., it changes into hot vapor, or steam. Steam occupies 1600 times as much space as the water from which it is formed. Thus expanded, the steam rises through pipes and enters radiators in all parts of the building. In the radiators the steam gives up its heat, becomes cool, condenses into water, and returns to the boiler by way of return pipes. Each radiator is supplied with a valve which may be turned to shut off the steam.

Some large buildings have no steam-heating systems of their own but get heat from a steam-heating plant near by. This steam is sent from the steam-heating plant under high pressure through pipes to the building very much as gas is supplied to houses from gas plants.

Exercise. Study the illustrations. In what way does the steam-heating system resemble the hot-water system? How do they differ? What sort of fuel may be used in this type of heating plant? How is the steam produced? How does the heat get into the rooms? Which supply more heat, large or small radiators? What would be the objection to supplying radiators that are larger than necessary? What are risers? Locate the boiler, the damper, the grate.

A comparison of the hot-water and steam-heating systems shows that each has its advantages:

Hot-Water System	Steam-Heating System
1. Good for small houses.	1. Can be used for large buildings.
2. Radiators become warm as soon as hot water begins to circulate.	2. Radiators do not become warm until some of the water in the boiler is changed to steam.
3. Boiler must be located in the building that is heated.	3. Steam may be sent to a building through pipes from a steam-heating plant outside the building.

Oil burners. Oil is rapidly taking the place of coal as a fuel, and coal-burning furnaces are giving way to oil-burning furnaces. Before the oil can be burned it must be broken up into very fine particles in the form of spray similar to the spray made by an atomizer. This is done in one of several ways:

1. The oil may be forced through a small opening by means of air or steam pressure.

2. The oil may be made to rotate rapidly on a disk and the fine particles of oil thrown off the edge of the rotating disk.

After the oil has been divided into fine particles, or *atomized,* in this way, the spray is mixed with air and burned. The burning takes place in a large firebox and the burning fuel heats water in a coil (or boiler) just as the coal in a coal-burning furnace does.

Oil burners have decided advantages over coal-burning furnaces. They are clean, easy to operate, and give an even amount of heat. The absence of coal piles, ashes, and dust which go with coal burners makes it possible to keep the cellar of a home heated by oil, clean, sanitary, and attractive.

Summary

Buildings may be heated by open fires, stoves, hot-air furnaces, hot-water furnaces, or steam-heating systems.

Large buildings are generally heated by steam-heating systems.

Questions

1. Name one disadvantage of heating the home by means of an open fire in a fireplace.

2. What two useful purposes are served by the chimney of the open fireplace?

3. Of what use is the damper?

4. Why does a fire " smoke " just after it is started?

5. Tell one way in which the stove is superior to the fireplace.

6. How is fresh air supplied to the stove?

7. How does the heat from a hot-air furnace get into the rooms?

8. How may dust from the street get into rooms that are heated by hot-air furnaces, even when all the windows are closed?

9. In the hot-air system, how is fresh, cool air supplied to the furnace?

10. Mention one important difference between the hot-air furnace and the hot-water furnace.

11. What are the " return pipes " in a steam-heating system?

12. What is meant by " risers "?

13. Mention one advantage of the hot-water system over the steam-heating system.

14. What causes steam to rise in the steam pipes?

15. What is the purpose of the valve on a radiator?

Supplementary Projects

1. Study a thermostat to determine how it works.

2. Find out how the air vent on a radiator works.

3. Study oil burners and make drawings to explain how they work. Get a catalogue giving pictures and diagrams of various types of oil burners.

4. Study the heating system in your own home.

Ewing Galloway

Heat may change substances from one state to another.

PROBLEM X

HOW MAY HEAT CHANGE SUBSTANCES FROM ONE STATE TO ANOTHER?

Changing solids into liquids. Heat may change a substance from a solid to a liquid state or from a liquid to a vapor or gas. We know that when ice, a solid, receives heat, it melts and becomes water, a liquid. Melting snow and ice help to supply the surface of the earth with water. The warmth of spring melts the ice and snow that have been deposited during the winter on the mountain tops and plateaus. This causes the mountain streams to swell and creates spring floods in the valleys below. Often, great damage is done by rivers that overflow their banks in the spring.

Demonstration. To show that, if sufficiently heated, solids melt or become liquids. Heat a small piece of ice in a test tube. Do the same with small quantities of butter, sealing-wax, lead, and fuse wire. What happens in each case? Which of these solids melt rapidly and which melt slowly?

It is important to know which substances melt at high temperatures[1] and which substances melt at low temperatures. Tin and lead, for example, are metals that melt at fairly low temperatures. They cannot, therefore, be used for pots, stoves, or any other devices where a large amount of heat is applied. Radiators and boilers must be made of metals that melt only at high temperatures. On the other hand, metals that melt at low temperatures may be very useful. Lead is melted and made into type for printing. It is also poured into molds to make the numerous lead toys with which children delight to play. The melting point of lead is 327° C., which is low for metals.

Ewing Galloway

If sufficiently heated, metals may be changed to liquids.

Iron may also be melted but only at very high temperatures. The melting point of iron is 1600° C.

[1] The temperature at which a solid melts is known as the melting point of the solid.

Melted iron is poured into molds to make various useful objects. The process of pouring molten (melted) iron is known as *casting* and iron that is made in this way is known as cast iron. Cast iron is used, among other things, for radiators, pipes, and ornamental iron work.

Question. Can you name some other uses of cast iron?

Changing liquids into gases. You have learned that when water, under ordinary conditions, is heated to a temperature of 212° F. (or 100° C.) it is changed to steam. In an earlier lesson you also *converted*[1] mercury into a vapor by heating it. To refresh your memory repeat the demonstration on page 39.

All liquids may be changed to vapor form by heating, but the boiling point[2] is different in every case. It is important to know the boiling points of liquids, for this fact often helps us in our choice of liquids for certain purposes. Thus, as you have learned, water cannot be used in thermometers for measuring temperatures above 212° F. Alcohol, which boils at 173° F. and ether, which boils at 94° F., are very useful for some purposes because they boil at very low temperatures; mercury and linseed oil are useful for other purposes because they boil at high temperatures.

Demonstration. To show that water and other liquids may become vapors. Place a pan of water on a table in the classroom or at home. Mark the level of the water on the

[1] Converted: changed.
[2] The temperature at which a liquid boils is known as the boiling point of the liquid.

inside of the pan or carefully measure its depth with a ruler. After a day has passed, again note the level of the water. What do you observe? What has happened?

Try the same experiment with alcohol. Compare the results of the two demonstrations. What do you discover? What may you conclude?

Wet a portion of the blackboard, using a wet sponge or a wet cloth. After a while the blackboard becomes dry. What has happened to the water?

These demonstrations show that liquids may be changed to vapors at ordinary temperatures. This process is known as *evaporation.* When water evaporates the water vapor passes into the air and makes the air moist. The degree of moisture in the air at any time is known as the *humidity* of the air, from the Latin word *humidus,* moist.

Evaporation explains the drying of wet clothes, the drying of rain-soaked streets, the gradual disappearance of puddles, and the fall of the level of water in ponds and lakes during the summer season. The mystery of the disappearance of water is explained when you realize that water vapor is an invisible gas.

Wind hastens evaporation. On a calm day, when there is no wind, the air near the wet clothes soon becomes filled with moisture, or "saturated," and can take no more moisture from the clothes. On windy days, this saturated air is constantly being moved away, and dry air takes its place to remove more of the moisture from the clothes. Thus, on windy days, wet clothes soon become dry.

Sometimes the vapor of an evaporating liquid is injurious to health. This is true of benzine, gasoline, kerosene, alcohol, and ether. When these liquids are used, care must be taken to avoid inhaling (breathing in) the vapors. Further danger from these liquid vapors is due to the fact that some burn easily and

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What happens to the water that is evaporated?

others explode violently when ignited. The vapors from these liquids give warning because of their strong odors. The liquids named are so commonly used that most people can recognize them by the smell.

Summary

If sufficiently heated, solids melt, or become liquids.

If sufficiently heated, liquids boil, or become gases.

At ordinary temperatures liquids may become vapors.

How Much Have You Learned?

Which of the following statements are true and which are false?

T. F. 1. The temperature at which a solid melts is called the melting point.

T. F. 2. Solids can be changed to liquid form by heating.

T. F. 3. All solids melt at very high temperatures.

T. F. 4. Liquids can be changed to gases.

T. F. 5. The temperature at which a liquid boils is called the boiling point of the liquid.

T. F. 6. Water boils at 100° Centigrade.

T. F. 7. Vapor is another name for gas.

T. F. 8. Evaporation is the process of heating a liquid until it boils.

T. F. 9. Water that evaporates becomes invisible moisture in the air.

T. F. 10. Some solids evaporate at ordinary room temperatures.

T. F. 11. Humidity is another name for evaporation.

T. F. 12. Some liquid vapors produce odors.

T. F. 13. All vapors can burn.

T. F. 14. Lighting a liquid vapor may cause an explosion.

T. F. 15. When water boils it becomes steam, which is a vapor.

Of the three words or numbers in parentheses in each of the following statements, choose the one that correctly completes the statement.

1. Water boils at (212° F., 180° F., 98° F.).
2. A boiling liquid changes into (air, steam, vapor).
3. Evaporation takes place at (freezing, ordinary, melting) temperatures.

4. A solid that melts at low temperatures is (iron, gold, tin).

5. Some vapors may be detected by (color, odor, heat).

6. Evaporation is hastened by (wind, rain, cold).

Supplementary Demonstrations and Projects

1. Distill some water and explain what connection there is between distillation and evaporation.

2. Test the rates of evaporation of one cubic inch each of water, alcohol, gasoline, and lubricating oil.

3. Demonstrate the effect of different degrees of temperature in a room on the rate of evaporation of water.

4. Make a wet and dry bulb thermometer and explain its use.

5. Write a composition about the cause of and the damage resulting from Mississippi floods.

Ewing Galloway

Effects of low temperature. Can you explain them?

PROBLEM XI

HOW IS ICE MADE?

You know that water on wet blackboards, in street puddles, in pans, ponds, and lakes, disappears or evaporates. When water evaporates, it is changed into vapor. Also, you have learned, it requires heat to change a liquid into a vapor. Evaporation, then, is caused by heat; and the greater the heat, the more rapid is the process of evaporation.

Demonstration. To show that heat hastens evaporation. Write, heavily, with ink on two pieces of paper. Hold one paper over a hot radiator and lay the other paper on the table. On which paper does the ink dry more quickly? Perform the demonstration several times to convince yourself of the result.

Apply water, with a brush, to two pieces of iron, one of which has been heated. Which dries more quickly?

Effect of evaporation. It takes heat to cause evaporation. When wet objects in a room become dry, where does the heat which causes the evaporation come from? It comes from the air and other objects in the room. And, as these objects give up some of their heat they become cooler.

Demonstration. To show that evaporation lowers the temperature of objects from which evaporation takes place. Read the temperature of a room on a thermometer. Wrap a moist cloth around the bulb of the thermometer and, after a time, read the thermometer again. What do you observe?

Make a similar test with a cloth moistened with alcohol. Alcohol evaporates more quickly than water. Compare the temperature readings.

As the water evaporates from the cloth wrapped around the bulb, the temperature indicated on the thermometer becomes lower. The objects near the cloth, that is, the air and the thermometer bulb, have given up some of their heat to help evaporate the water in the cloth. They have therefore become cooler.

When alcohol, instead of water, is used, the evaporation is more rapid and so, too, is the drop in temperature.

We may conclude, therefore, that:

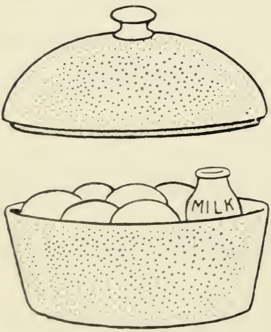
a. Evaporation causes bodies in contact with the evaporating liquid to become cooler, and

b. The more rapid the evaporation, the more rapid is the cooling process.

Evaporation, therefore, has the effect of cooling the surface which it dries. We make use of this phenomenon in many ways. When the streets are hot, we sprinkle them with water. Some of the heat of the pavement, and of the surrounding air, is used up in drying the water, and thus the air becomes a little cooler. We fan our warm, perspiring faces, and the evaporation of the perspiration reduces the temperature of the skin, thus bringing relief.

Wet clothes drying on the body reduce the temperature of the body. Sometimes this drying is so rapid that the body becomes chilled. This is especially true in windy weather because wind, as you have learned, hastens evaporation. A person may also become chilled if, when perspiring, he sit in the draft caused by an open window. Sudden chilling of the body is likely to bring on a cold.

Question. Have you ever been cautioned, when perspiring freely, to change at once into dry clothes and to keep away from electric fan air currents? Why should one obey this caution?



An iceless cooler. Why is the cooler made of porous material?

Iceless coolers. We make use of the principle of cooling by evaporation in the earthenware iceless cooler. We constantly moisten the porous substance of which the cooler is made. The slow evaporation which results lowers the temperature of the contents of the cooler so that no ice is necessary.

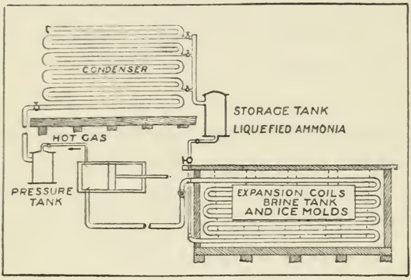
How campers cool water. In hot weather, campers in the woods often make use of the principle of evaporation to keep their drinking water cool. Water is kept in "bottles" made of closely woven, but slightly porous cloth, such as canvas. The bottles are soaked in water so that they become thoroughly wet on the outside and are then hung on branches of trees where they may be exposed to the free circulation of air. The slow evaporation of moisture from the surface of the bottles keeps the water cool.

Demonstration. To show that water may be frozen by rapid evaporation of a liquid. Put a drop of water on a small block of wood. Place a thin watch glass, hollow side up, on the drop of water. Pour a small quantity of Carbona cleaning fluid into the glass and pump a stream of air into it or fan it vigorously to make it evaporate rapidly. After a few minutes examine the drop of water. What has happened? Can you explain this result?

Caution: Perform the demonstration near an open window so that the Carbona vapor does not remain in the classroom. This vapor has a strong, unpleasant odor.

Liquids that evaporate rapidly are useful refrigerants. A *refrigerant* is a substance which may be used to produce low temperatures. Some liquids, as you have learned, evaporate very rapidly at low temperatures and at normal air pressure. When the air pressure surrounding such liquids is reduced the rate of evaporation is considerably increased. Alcohol, ether, liquid ammonia, liquid carbonic acid, gas, and liquid sulphur dioxide are all liquids which evaporate rapidly at ordinary temperatures.

In an ice-making plant, the evaporation of a refrigerant freezes water. In country communities a good deal of the ice that is used is cut from frozen ponds during the winter and stored for use in summer. In cities, however, most of the ice used is manufactured.



An ice-making plant. Can you explain how it operates?

Perhaps the most common refrigerant is liquid ammonia.

A supply of ammonia gas is compressed by pumps and thus changed into liquid ammonia. The liquid ammonia is then forced into coiled pipes that are imbedded in a tank of brine (a mixture of water and salt). When the liquid ammonia evaporates, it draws sufficient heat from the brine to reduce the temperature of the brine below the freezing point of water. The salt in the brine, however, prevents the brine from becoming solid, because the freezing point of brine is considerably lower than the freezing point of water. Suspended in the brine are containers filled with water. As the brine becomes very cold, it freezes the water in the containers into blocks of ice which are then removed for commercial use. The gaseous ammonia is again compressed into a liquid, and the process is repeated.

Demonstration. To show that a mixture of water and salt freezes at a lower temperature than fresh water. Fill a glass jar more than half full of small pieces of ice. Insert a thermometer into the ice and watch the mercury until it becomes stationary. What is the temperature of the ice? Insert the thermometer into a mixture of ice and salt. Use about four to five parts of ice to one of salt. Watch the mercury until it becomes stationary. What is the temperature now? Why do ice-cream makers add salt to the ice in their freezers?

Refrigeration adds to man's convenience, comfort, and pleasure. Iced drinks and ice cream are refreshing in summer. People have become so accustomed to these refreshments that they would miss them if, for some reason or other, they were no longer obtainable. Furthermore, the manufacture of ice cream and of drinks made to be served cold has become so large an industry that many thousands of people are dependent upon it for a living.

The manufacture of ice makes it possible to preserve perishable foods, that is, foods that decay or spoil rapidly. Among such foods are milk, meats, sea-food, butter, eggs, and fruit. Of these, fish and meat are sometimes frozen to preserve them. For some time, attempts at freezing these products failed because the ice crystals which formed within the food were too large and ruptured (broke) the tissues. A recent process has been invented, however, by means of which very minute crystals are formed within the bodies of these products and will keep the food fresh for some time without injuring its flavor or texture in any way.

Small refrigerating plants are being installed in a great many homes and soon the familiar ice wagon will become a rare sight in the streets of the city. These home refrigerators are operated on the same principle as the larger commercial ice-making plants. The necessary low temperature is produced by rapid evaporation of a refrigerant, usually sulphur dioxide. The compression pump is operated either by gas or electricity. Evaporation of the sulphur dioxide reduces the temperature of the food in the food compartments and thus helps to keep the food fresh. Ice is made in small blocks by filling metal forms with water. This water becomes ice when the temperature in the compartment falls below 32° F. Because this ice is made from purified drinking water, it may be placed directly in drinks that are to be served cold without any danger to health. Natural ice cut from rivers or ponds may not be pure enough for such use.

More and more, refrigerating plants are being installed to keep buildings cool in summer. At first only theaters, banks, and some public buildings were artificially cooled but today a number of apartment-house builders are considering the advisability of installing cooling plants. The time is not far off when it will be quite as common to cool the home artificially in summer as it now is to heat it in winter.

Summary

Liquids and bodies in contact with them lose heat during evaporation.

Liquids that evaporate rapidly are useful refrigerants.

In an ice-making plant, the evaporation of a refrigerant freezes water.

Refrigeration adds to man's convenience, comfort, and pleasure.

Questions

1. Describe, briefly, a demonstration to prove that heat causes evaporation.

2. What happens to the temperature of a surface from which moisture is evaporated?

3. Why is it advisable to keep out of drafts while perspiring freely?

4. Explain the principle of the iceless cooler.

5. Housekeepers often sprinkle salt on icy sidewalks to melt the ice. How does the salt accomplish the desired result?

6. Why do fresh-water ponds and streams often freeze in winter while salt-water streams and marshes seldom freeze?

7. Why is salt added to the ice in ice-cream freezers?

8. Name two liquids that evaporate rapidly at ordinary temperatures and at normal air pressure.

9. Refrigerants add to man's comfort, convenience, and pleasure; list five examples of this to show that the statement is true.

10. Mention one advantage of manufactured ice over natural ice.

Can You Also Answer These?

11. Why do automobile owners add alcohol to the water in the radiator of the automobile on extremely cold days?

12. Natives of certain towns in southern Arizona, where the temperature is occasionally as high as 110° F. in summer, sometimes wrap themselves in moist sheets to obtain comfort. Explain how this brings relief.

Rewrite the following statements in completed form. Use a sheet of paper so as not to mar the book.

1. One good refrigerant is ——.
2. Salt water freezes at a —— temperature than fresh water.
3. When evaporation takes place the temperature of a liquid becomes ——.
4. —— may be used to preserve perishable food.
5. A porous container, the contents of which are kept cool by evaporation of water from its pores, is known as an —— ——.

Supplementary Demonstrations and Projects

1. Study the essential parts of a household electric or gas refrigerator and explain their use.
2. Make a simple ice-cream freezer.
3. Write a composition on the use of refrigerators for preserving food.
4. Prepare an anti-freeze mixture for use in automobile radiators.

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Forms of condensation of water vapor.

PROBLEM XII

HOW MAY LIQUIDS CHANGE TO SOLIDS AND VAPORS TO LIQUIDS?

When Jack Frost visits the land, he performs many pranks. Sometimes he delights us with wonderful feathery paintings of tropical forests on the window pane, but often he is mischievous and plays annoying practical jokes. When we take in the morning bottle of milk, we find a plug of frozen cream projecting from the neck of the bottle. Often we discover sealed bottles, exploded into many bits by the frost. Water pipes exposed to the cold frequently burst and cause much damage by flooding parts of the house before the spouting water can be stopped. Great fragments of rock have been known to break away from their natural bed because of the freezing of water that was lodged in cracks.

But the pranks of Jack Frost are not always annoying. We have learned to make good use of his tricks for commercial purposes as well as for amusement. He freezes our ponds from which we cut blocks of ice to sell to the public. With this ice we are able to keep food from spoiling during the warm summer months. We are able to relieve suffering patients by the application of ice bags when such treatment is

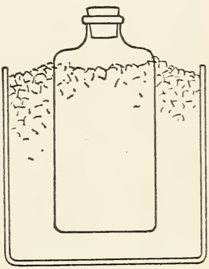
What other things can you do in winter?

necessary. And we are able to make millions of children happy through the manufacture of ice cream and other frozen dainties.

And need I tell you the joy that Jack Frost brings when he makes it possible for thousands of healthy, happy folk, old and young, to glide merrily over the smooth ice of a frozen pond or a glassy stream? What joy it is to fly over the mirror-like surface with the speed of the wind; to be free as a bird, darting this way and that, at will; to feel the warm blood tingling through the veins! O yes, Jack Frost is a mischievous fellow, but there is no better friend of the young folks than he.

Demonstration. To show why water becomes ice. Place a test tube, half filled with water, in a basin filled with a mixture of crushed ice and salt. After a time examine the test tube. What has happened to the water? What caused this change? Why was salt mixed with the crushed ice?

Demonstration. To show the effect of cold on water. Fill a small bottle with water and cork it as tightly as possible. Be sure that the bottle is quite full. Place the bottle in a basin containing a mixture of crushed ice and salt. See that the mixture is packed tightly around the bottle, covering it almost entirely.



What happens to the bottle after a short time? What causes this? Which occupies more room, water before, or water after, freezing? If the cork had been loosely inserted into the mouth of the bottle, what would have happened? Try an experiment with a loose cork to see what happens. If the bottle had been only partly filled with water, what would have happened? Prove to your own satisfaction what would happen in such a case.

What causes pipes to burst in freezing weather?

Freezing. Under normal air pressure, water freezes at 32° F. Observe a shallow pool of water on the street when the temperature is falling below the freezing point. When the thermometer reaches 39° F. water, as you have learned, begins to expand and the cold particles of water, being lighter than the warmer particles, rise to the surface. This continues until the thermometer reaches 32°. The surface of the pool then freezes and forms a film of ice. As the temperature falls still lower, more and more of the water freezes until the water in the pool is frozen solid.

In very cold weather, the surfaces of lakes freeze to a certain depth, forming a layer of ice. This ice is often cut into blocks for commercial use in refrigeration. The ice on the surface of the lake protects the water underneath from the cold and so fishes and other forms of aquatic life are not frozen in winter. It is interesting to know that even in Arctic regions fresh water beneath the ice never gets as cold as 32° F. In a similar way, snow protects soil from freezing by preventing radiation of heat from the soil. This keeps plants from freezing during the winter.

Small amounts of water in the crevices (cracks) of rocks expand when they freeze and this expansion may cause pieces of the rock to break off. This breaking-up of rocks is known as *disintegration.*

The expansion of freezing water sometimes causes pipes to burst in freezing weather. That freezing water has the power to burst vessels which contain it has been shown by the demonstration on page 121.

Demonstration. To show that liquid lead solidifies at ordinary temperatures. Heat lead in an iron ladle until it melts. Withdraw the ladle from the heat and observe the lead. What happens? What may you conclude?

Most metals behave in this way and valuable use has been made of this fact. You have already learned how lead is first melted and then poured into molds to make type for printing, toys, and other useful or ornamental objects. Iron also may be cast in molds to make pipes, ornamental parts such as railings and shields, and many important machine parts.

Gelatine solidifies at ordinary temperature.

Demonstration. To show why vapors become liquids. Hold a piece of cold glass or a cold plate over the jet of steam that issues from a pot of boiling water. After a few moments, note the surface of the glass or plate. How was this formed?

Condensation. Steam is formed by heating water until it expands and changes into invisible water vapor. In the demonstration just performed, the process has been reversed. The hot steam coming into contact with a cold surface contracts, or *condenses,* forming very small drops of water vapor at first visible in the air as a cloud and then on the glass as drops of hot water.

Water vapor in the air condenses in various forms when its temperature is reduced. You have seen drops of water on the outside of a cold water pipe or on the outside of a glass filled with cold water. These drops of water are formed by the condensation of the water vapor in the air surrounding the pipe or the glass. The cold water in the pipe in the glass reduces the temperature of the water vapor and causes it to change to liquid form.

Demonstration. To show when water vapor condenses into water. Breathe into the air. Is your breath visible?

Breathe on the surface of a cold mirror. What is formed on the mirror? Where did it come from? Heat the mirror slightly and try the experiment again. Do you get the same results? Why?

Dew and fogs are formed by condensation of water vapor. Grass and other plants give off heat more

F. Ellerman, Mt. Wilson Observatory

Cirrus clouds form at very high altitudes. Why?

rapidly than does air. At night, when the temperature falls, the grass and plants become cooler than the air in contact with them. The cool plants reduce the temperature of the water vapor in the air and the water vapor condenses on the ground and plants in the form of dew. On a clear night the earth loses its heat very rapidly and a heavy dew is formed. If the temperature

Stratus clouds are very low.

Cumulus clouds. How are they formed?

F. Ellerman, Mt. Wilson Observatory

Nimbus clouds bring rain.

is below 32° F., the moisture will be deposited as frost. Clouds are also formed by condensation of water vapor in the air. Air containing water vapor rises and, when sufficient heat is lost, the vapor condenses on the billions of dust particles floating in the air. The mass of tiny drops that is thus formed is seen as a cloud. Fog is a cloud near the surface of the earth and is formed when a warm layer of air comes in contact with a much cooler surface of land.

Mist and rain occur when water vapor condenses in such quantities that the drops become so large that they cannot be held up in the air, and they fall to earth. If these drops, in falling, pass through layers of air which are below 32° F., they fall to the ground as hail or sleet. When the temperature of the air in which the condensation takes place is lower than 32° F., the vapor, in condensing, changes to a solid and falls in the form of snow.

Summary

After losing sufficient heat, liquids become solids.

After losing sufficient heat, vapors become liquids.

How Much Have You Learned?

Which of the following statements are true and which are false?

T. F. 1. Vapors can be changed to liquids.

T. F. 2. Vapors lose heat when they condense.

T. F. 3. Water vapor is invisible.

T. F. 4. When a liquid condenses it becomes a solid.

T. F. 5. The change from a liquid to a solid is called freezing.

T. F. 6. Freezing water expands.

T. F. 7. Some liquids solidify at ordinary temperatures.

T. F. 8. Ice begins to form at the bottom of a pond where the water is coldest.

T. F. 9. Snow is always colder than the air around it.

T. F. 10. Snow is rain that freezes when it approaches the ground.

T. F. 11. Dew is formed by condensation of water vapor.

T. F. 12. On cloudy nights dew forms more rapidly than on clear nights.

Questions

1. How may frost cause disintegration of rocks?

2. Under normal air pressure, at what temperature does water freeze?

3. How does the freezing point of salt water compare with the freezing point of fresh water?

4. Explain how fish escape freezing in a lake in winter.

5. Why do water pipes sometimes burst in winter?

6. How does snow keep the soil warm?

7. Name three liquids that solidify at ordinary temperatures.

8. Explain the formation of any one of the following: dew, clouds, rain, snow.

9. How do clouds prevent formation of dew?

10. Why does snow occur more often on mountains than in valleys?

Supplementary Projects

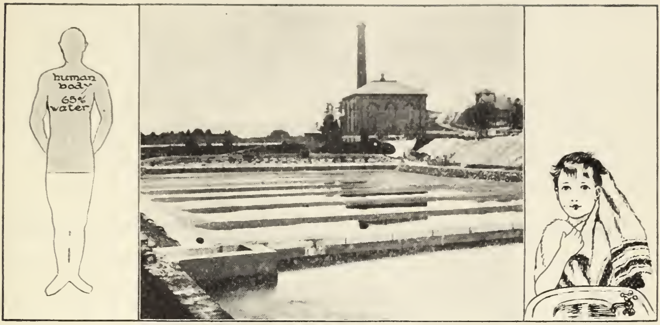
1. Take the temperature of snow on a very cold day (if possible).

2. Find out if water becomes hotter while boiling.

3. Bring to the classroom photographs or other pictures of various types of clouds.

4. Read, in the encyclopedia, about liquid air and its uses.

5. Write a composition on the uses of liquids that solidify at ordinary temperatures.



Water is closely related to health.

PROBLEM XIII

HOW SHOULD WATER BE USED TO PROMOTE HEALTH?

Why we drink water. Our bodies are composed, in large part, of water, or of fluids that contain water. Breathing, digestion and absorption of food, and the *elimination*[1] of waste matter from the body, depend to a large extent upon water.

Demonstration. To show that water is given off in breathing. Breathe on the surface of a cold mirror and note the condensation of water vapor. Where did this water vapor come from?

All the water we breathe out, all the water we lose through evaporation from the pores of the skin, and all the water that is in any other way eliminated by the body must be replaced. Every person should

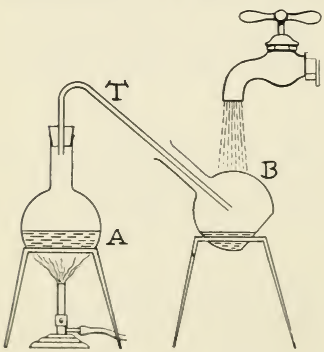
[1] elimination (ē lĭm′ĭ nā′shŭn): act of giving off or expelling.

drink at least five glasses of water a day. This water should be pure, that is, free from harmful micro-organisms. In many cities, drinking water is purified before it reaches the home. When water is not purified before reaching the home, it may be filtered before using or it may be boiled or distilled.

Demonstration. To show how filtration aids in purifying water. Place a piece of absorbent cotton in the neck (narrow end) of a funnel and pour muddy water (water that has a sediment of soil and sand) into the funnel. Catch the water that comes out of the neck of the funnel in a clean glass.

How does the water in the glass compare, in appearance, with the water that was poured into the funnel? Examine the absorbent cotton. What do you find? What may you conclude from the demonstration?

Demonstration. To show that water may be purified by distillation. By means of a bent glass tube, *T*, passing through a one-hole stopper in a flask, *A*, connect the flask with another flask, *B*, as shown in the illustration. Heat some muddy water in flask, *A*. When the water boils, what happens? Cool flask *B* by means of cold water from a faucet. What is formed in flask *B*?



Examine this water and compare it with the muddy water in the first flask. What may you conclude about distillation as a means of purifying water?

Distillation not only makes water clear but kills any harmful microörganisms that may be present. Boiling water produces the same results and is, therefore, another good way to make water safe for drinking.

You may recall these methods of purifying water from your work of last term.

Temperature of water. The temperature of drinking water should always be moderate. Ice water is so much lower in temperature than the lining of the digestive tract that it chills the stomach and interferes with the proper working of the organs of digestion. The cooler the water, the slower it should be drunk so as to give it a chance to become warmed to the temperature of the stomach.

Some people wonder whether water should be drunk during meals. Water may be drunk in small quantities during meals provided the food is thoroughly chewed and that the water is not used to wash the food down. Tea, coffee, and drinks containing alcohol should not be substituted for water as all of these are injurious to health.

Water as a cleansing agent. Water promotes health when used as a cleanser for the skin, as well as for the digestive system. The cells of the body are constantly breaking down and being rebuilt. Much of the waste and poisonous matter thus formed comes out through the pores of the skin and, if not washed away, will clog the pores and cause blackheads.

Bathe regularly and often. One reason why people who spend a vacation at the seashore usually enjoy good health is that they bathe frequently. Be sure to wash the hands often, especially before meals. Disease-producing bacteria are sometimes taken into the body on food that is *contaminated* [1] by dirty hands. Often, too, disease is caused by harmful microörganisms that get into the body through the nose or mouth when these are touched by dirty hands.

Dirt and *microbes* [2] from clothing, and other things with which we daily come into contact, settle on the skin and must be washed off in order to prevent harmful effects. Bathing, and frequent change of underwear, reduce the danger. Especially is this true if we have been in contact with persons who are sick. Touching unclean or diseased persons, or handling things used by them, may cause or spread disease.

Where disease germs (harmful microörganisms) are present, ordinary water is not a safeguard against them. Certain substances, some of which are used with and some without water, have the power to render germs harmless and therefore serve to protect the body against disease. Among these substances are soap, alcohol, borax, alum, carbolic acid, and iodine. These substances are known as *antiseptics.* An antiseptic is a substance which may be used to destroy germs without harming the body.

Water sports. Water sports promote health. Boating and swimming provide splendid outdoor exercise

[1] Contaminate (kŏn tăm'ĭ nāt): to infect, or poison.

[2] Microbe is another name for microörganism. Microbes may be minute animal or plant forms. The minute plant forms are known as bacteria.

Water sports are healthful.

and help to keep the body fit. Indulge in water sports if it is possible for you to do so.

Summary

Drink five or six glasses of water every day.

Water used for cleansing promotes health and prevents disease.

Water sports promote health.

Questions

1. How can you show that water is given off in breathing?
2. What is perspiration?
3. What are microörganisms?
4. Name two methods of purifying water.
5. Name a method of purifying water that destroys germs.

6. Explain the process known as distillation.

7. Why is it bad to drink ice-cold water?

8. What precaution is necessary when drinking water during meals?

9. Why should tea or coffee not be used as a substitute for water?

10. Why is it necessary to bathe regularly and often?

11. The hands should be washed before meals. Why?

12. Tell one way in which disease may be spread.

13. What is an antiseptic?

14. In what way do water sports promote health?

Supplementary Demonstrations and Projects

1. Examine water under a microscope.

2. Read and report on how soap is made.

3. Learn how antiseptics are used to treat cuts.

4. Prepare an antiseptic mouth gargle.

5. Read and report on the stories about disease fighters. (See biographies at end of this book.)

6. Write a composition on the value of water sports in promoting health.

The air we breathe affects our health.

PROBLEM XIV

HOW DOES THE AIR WE BREATHE AFFECT OUR HEALTH?

It was a bitter cold morning in January, but the boys of 7B did not seem to mind it in the least. In fact, they were quite warm, for the doors and windows of the classroom were shut tight and the big radiators under the windows were hissing like serpents, while the valves sent out clouds of steam that covered the window panes with vapor so dense that it shut from view the blizzard that was raging outside.

The teacher had not yet arrived. She was, no doubt, delayed by the heavy snowfall that had crippled traffic since the night before. She was now more than half an hour late, and 7B was enjoying the unusual freedom her absence made possible. The boys were not boisterous, however, for the class was well-trained and the president had distributed the library books to help pass the time usefully. The room became warmer and warmer. In fact it was quite hot. The few disturbers had become interested in their stories and all were now absorbed in their books. The president seated himself in the chair before the desk, opened a book and soon he, too, forgot his surroundings.

After a time his eyes began to feel heavy. He opened them with difficulty and continued to read. But the lids insisted on closing. The words danced crazily about over the page. He felt drowsy and shook himself with an effort. He looked out at the boys before him and thought he noticed one or two of them nodding. Were they, too, drowsy? What was wrong? The room was certainly cozy, and the day had hardly begun. Why should he feel tired? He began walking briskly up and down in front of the room in an effort to keep awake but his legs were too heavy for him to drag, and once again he took to the chair and slumped down in the seat. It seemed as if he were about to fall asleep when suddenly the door opened and in walked Miss Preston, the teacher.

"Good morning, boys." There was a shuffling, a general rousing as out of a trance, and then the boys staggered to their feet.

"Good morning, Miss Preston."

"Why, boys, how hot it is here! The air is vile. Good gracious, no wonder; not a window open! Louis, open the windows wide at the bottom. You're half stifled in here. Class stand. Breathing in. 2, 3, 4;

Out. 2, 3, 4. Stretching: Bend. Shoulders. Stretch. Higher. Down. Knee bending: Begin. 1, 2, 3, 4, 5, 6, 7, Repeat. Breathing in. 2, 3, 4. Out. 2, 3, 4."

And so Miss Preston put the boys through a two-minute drill. After the class was seated, she ordered the windows left open just a little at both top and bottom and began the work of the day. How refreshed the boys were! How good the air felt after the heavy drowsiness of the shut-up room! It is safe to say that if Miss Preston had not arrived when she did, some of the boys would have fallen fast asleep.

Healthful air. In the famous Black Hole of Calcutta, 146 Englishmen were imprisoned for one night in a room twenty feet square, and provided with but one tiny window. Next morning only 23 remained alive. This horrible incident is often related to illustrate the effects of extremely bad ventilation.

Man fills his lungs with air many times each minute. Without air he can live for only a very short time. The kind of air we breathe is, therefore, a matter of great importance.

Out-of-doors it is not necessary to think about the supply of air; this takes care of itself. But indoors, especially in winter when the windows are often kept closed, the condition of the air in the rooms we occupy requires our attention. To make it fit to breathe is the problem of ventilation.

In connection with the kind of air we breathe indoors, there are four things that concern us: first, the composition of the air; second, its temperature; third, the amount of moisture present; and fourth, the motion of the air.

Pure air, we have learned, is composed of a number of gases, chiefly *nitrogen* and *oxygen*. Oxygen is the substance most needed by the lungs to help purify the blood. About one fifth of the bulk of pure air is oxygen. The air we exhale contains a small amount of a heavy gas called *carbon dioxide,* and also body waste matter which, in a closed room, causes an unpleasant, "stale" odor. This exhaled air contains, also, less oxygen than the air we inhale.

The temperature, however, is a very important factor in ventilation. The normal temperature of a room should be between 65 and 67 degrees Fahrenheit. If the air is fairly cool, it absorbs some of the heat that is constantly being generated by the body; if the air is very hot, the body heat is not carried off and causes discomfort. It is the heat in a room that causes the occupants to feel drowsy, and which, in extreme cases, results in illness. In the Black Hole of Calcutta, the 123 victims died, most likely, of heat, more than for lack of oxygen.

The third element in ventilation, moisture, is next in importance to heat. The skin is constantly giving off moisture. The exhaled breath also contains moisture. If the air in a room is fairly dry, it is able to absorb the moisture given off by the body, the body heat is reduced, and the occupants of the room feel comfortable. If the air is moist or humid, however, the body moisture is not readily absorbed and the occupants of the room begin to feel uncomfortable. If, in addition to being moist, the air is also very hot, the body temperature rises, perspiration forms on the skin, the heart action becomes more rapid and, in a poorly ventilated room, the feeling of discomfort becomes unbearable. Under such conditions breathing is labored and physical work becomes difficult.

Why does a person mind the heat more on some days than on others?

Air in motion has the power to reduce the body heat by evaporating the moisture that forms on the skin. That is why, on a hot, "sticky" day, we like the air current from a fan and welcome the slightest breeze. Air should circulate so as to bathe the skin of the whole body, rather than any part of it. Air bathing helps blood circulation and thus promotes good health. For this reason, loose, light clothing should be worn in summer and in winter. Tight clothing, or too much clothing, prevents the air from bathing the skin as it should.

Demonstration. To test the circulation of air in a room. Hold a thin strip of cloth near an open window and near a slightly opened door or transom. How does the strip of cloth behave? What does this show? Repeat the test, first closing the window, the door, and the transom. What do you observe? What may you conclude?

Test various rooms in the same way for circulation of air.

Evaporation and health. Heat is generated during the building up or the breaking down of cells in the human body. The body must get rid of some of this heat in order to keep its normal temperature, between ninety-eight and ninety-nine degrees. The desired result is brought about by evaporation. The sweat glands in the skin give off perspiration which moistens the skin. As this moisture is evaporated, the temperature of the body is reduced.

Sometimes the air itself contains much moisture. At such times evaporation of moisture is, of course, slow and causes us some discomfort. If the air is too dry, the body gives up its moisture rapidly and becomes cooled too quickly. The result is a feeling of chillness. Occasionally, when we are not well, the pores of the skin do not give up moisture from the body as rapidly as they should, the body temperature rises, and the result is fever. At such times the heat of the body may be reduced by an alcohol bath. The rapid evaporation of the alcohol causes the body to cool quickly.

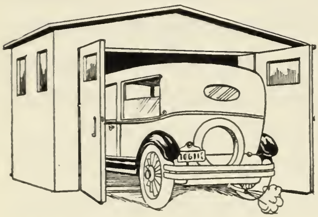
Demonstration. To show the effect of rapid evaporation. On the back of one hand pour a few drops of alcohol or witchhazel, and on the back of the other, a few drops of water. Which hand feels cooler? Which hand dries more quickly? Do some liquids dry more quickly than others? Does a rapidly drying liquid cool a surface more quickly than a slowly drying liquid?

A physician sometimes gets the same result by giving the patient a medicine that causes him to perspire freely. As this perspiration is evaporated, the temperature of the body is lowered.

The effect of moisture in the air on health. The air we breathe contains a considerable amount of moisture or humidity. In summer, with the windows open, the moisture in the classroom or home is about the same as that outside and we feel no discomfort when we go outdoors. In winter, with windows closed and the room often overheated, the air indoors sometimes becomes very dry. To prevent the air in a steam-heated room from becoming too dry, open the windows regularly to allow moist air to enter. The same result may be obtained by placing pans containing water behind or on radiators in the room. Evaporation of the water in these pans keeps the air in the room moist. Air that does not contain enough moisture dries the membranes (delicate surfaces) that line the nose and throat, causing irritation. Thus weakened, the membranes are unable to resist the attacks of germs which may cause colds, pneumonia, and other diseases.

At times the condition is just reversed. When there are many people gathered in a poorly ventilated room, the air may become saturated with the moisture of many exhaled breaths. In this condition the air cannot absorb the perspiration that forms on the skins of the occupants. On leaving such a room and stepping into the drier air outdoors, this perspiration begins to evaporate very rapidly and causes a feeling of chillness. If the body is chilled, its ability to resist the attacks of disease-producing bacteria, always present in the air, is lowered.

Abnormal air conditions may produce unhealthful effects. Bad odors cause loss of appetite, as you probably know from your own experience. This is one of the ill effects of being present for some time in a crowded, poorly ventilated room. Fresh air and good ventilation prevent bad odors.



What dangerous gas is found in the exhaust of automobiles?

Some gases, when present in the air in sufficient quantities, endanger life. *Carbon monoxide*, an odorless gas that is part of the exhaust of automobiles, is one of these deadly gases. A number of automobile drivers have been killed by carbon monoxide gas produced while the motor was in operation in a closed, unventilated garage. Tunnels through which automobiles pass must be well ventilated to carry off this poisonous gas. Many lives have been lost also by inhaling illuminating gas in an unventilated room.

In some factories, harmful smoke or gas is produced which, if not properly carried off, may injure the delicate linings of the nose, throat, and lungs. In extreme cases illness and perhaps death may result. The modern factory is well ventilated to protect its workers. In almost every community there are laws which regulate such matters in order to safeguard the health of the public.

Harmful bacteria are often sprayed into the air by careless sneezers and coughers. Keep away from these dangerous persons and do not become one of them yourself. Always use a handkerchief to cover your cough or sneeze.

Summary

Healthful air must be correct in temperature, contain the right amount of moisture, and must circulate properly.

Evaporation helps to keep the temperature of the body normal.

Air that is too dry or too moist causes discomfort.

For good health, light and loose clothing should be worn.

Air that contains poisonous gases or other impurities is injurious to health.

Questions

1. Name two substances found in good air.
2. What happens to the air in a classroom that is poorly ventilated?
3. Why is deep breathing necessary for good health?
4. How can you show that moisture is given off in breathing?
5. What gas is found in the exhaled breath?

6. Which contains more oxygen, air we inhale or air we exhale?

7. What is meant by respiration?

8. Why should light and loose clothing be worn at all times of the year?

9. What causes fever?

10. How may fever be relieved?

11. How may the air in a heated room be kept moist?

12. Mention one harmful effect of air that is too dry.

13. How may the body become chilled?

14. Name a liquid that evaporates more rapidly than water.

15. How may carbon monoxide get into the air?

16. What does the city do to keep the air fit to breathe?

17. How does careless coughing or sneezing endanger health?

Supplementary Demonstrations and Projects

1. Keep a record of hourly temperatures in the classroom or home.

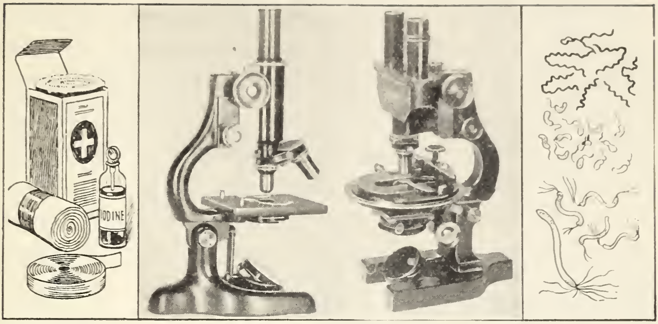
2. Explain the proper way to ventilate a bedroom.

3. Demonstrate the fact that wet objects dry more quickly in a draft than they do in still air.

4. Find out the purpose of open-air classes.

5. Read the ordinance of your city regarding the burning of soft coal and explain the purpose of this ordinance.

6. Write a composition about the value of parks to the health of a community.



Guarding against germs.

PROBLEM XV

HOW CAN WE GUARD AGAINST GERMS?

Microbes are living things that are too small to be seen with the naked eye. They are found almost everywhere. By means of microscopes, microbes can be seen in water, milk, dirt, decaying plants, and animals. They are found in the nose and mouth, on the skin, in and on the bodies of insects and domestic animals, and in the air. They are carried from place to place by air, water, milk, food, insects, and other animals. People may also carry microbes or germs as they are also called.

Demonstration. To show that water contains microbes. If possible, place a drop of water under the eyepiece of a microscope and note the forms of life in the water. Describe what you see.

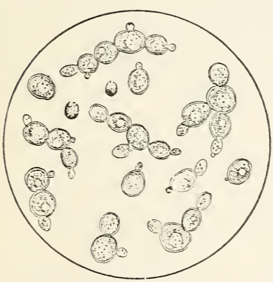
Harmful germs. When the Dutch naturalist Leeuwenhoek, in the seventeenth century, looked through his home-made microscope and saw living things moving about in a drop of water, he took the first step in scientific disease fighting. Unfortunately it was fully two centuries more before scientists began to suspect that these tiny microbes were capable of doing harm. Then, in 1865, Louis Pasteur, a great French microbe hunter, discovered some microbes in sick silkworms and proved that they were the cause of disease.

Some harmful germs (para-typhoid) as they appear when viewed in a microscope.

Since Pasteur's discovery, other scientists have made a study of microbes. Many varieties have been discovered, some harmful, others useful and even necessary for life. They may be divided into two groups; *protozoans*, or one-celled animals, and *bacteria*, or one-celled plants. Bacteria are responsible for most of the known diseases, notably tuberculosis, pneumonia, diphtheria, anthrax, typhoid fever, and influenza. Protozoans are responsible for malaria and sleeping sickness.

Useful bacteria. Certain kinds of bacteria found in soil have the power to break up substances in the soil such as dead animals, manure, and sewage. These substances contain nitrogen and the bacteria change the substances into others known as nitrates. Nitrates dissolved in water are taken up by the fine root hairs of plants and help the plants to grow. Some bacteria give flavor to cheese and butter, while other bacteria are used for fermenting the animal matter from sponges, and in fermenting the fibers of plants used in the manufacture of rope. Yeast, a form of life similar to bacteria, is needed in making bread. In growing, yeasts change the sugar to carbon dioxide which forms bubbles. These bubbles cause the dough to swell and become light.

Useful plant bacteria. What work do they perform?



Growing yeast. Why is yeast useful?

Demonstration. To show that bacteria multiply rapidly. Obtain two small round dishes with covers to fit. Use Petri dishes, if possible. Place the dishes in a pot of clean water and boil the water for about an hour. This *sterilizes* the dishes, that is, makes them free from germs. Melt a tube of nutrient agar (which may be obtained at the druggists), by putting the tube in hot water. Then pour the agar into the dishes. Cover the dishes immediately. When the agar hardens, which is in a very short time, open the cover of one dish to let in some dust from the air. Then cover and place the dishes in a dark warm place. After several days examine both dishes. Which one shows evidence of bacterial growth? How do you account for the difference?

Scientists call the substance on which germs are planted for study a *culture,* because bacteria are cultivated or grown on the substance. The bacteria will be seen to grow on the culture in spots. These spots are called *colonies.* Cultures may be made on slices of potato, instead of nutrient agar.

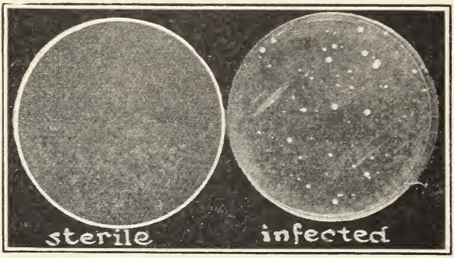
Demonstration. To show the growth of bacteria on potato. Peel and wash a raw potato. Cut it into slices, about one quarter inch thick and place the slices in Petri dishes. Steam the dishes and potato slices for about half an hour and then cover them quickly. When the potatoes are cool, lift the cover of one dish and expose it to the air for a few moments, or rub a soiled finger over the potato slice. After a few days examine the potato slices for bacteria colonies. What do you find?

Instead of exposing the potato slice to the air or rubbing it with a soiled finger, a few drops of dirty water or saliva from the mouth may be spread over the surface of the potato.

Germs increase rapidly. One of the remarkable things about germs is that they multiply rapidly. It is this rapid growth that makes harmful germs so difficult to fight. A single bacterium may give rise to many millions of bacteria in twenty-four hours.

It has been found that germs multiply most rapidly in substances having water, food, and warm temperature (60° F. to 120° F.); and where there is little or no sunshine. Thus, many parts of the body, such as the lining of the nose, the mouth, the teeth, the throat, the lungs, and the blood, are good places for rapid growth of germs.

Good health habits. As soon as scientists discovered that germs caused certain diseases they set to work to learn how to prevent the germs from entering the body and how to kill the germs that did get in. The cure of germ diseases is the work of doctors, but the prevention of these diseases is within reach of every one. Tonsillitis, laryngitis, diphtheria, influenza, measles, scarlet fever, typhoid, whooping cough, pneumonia, and tuberculosis are all germ diseases against which we can guard ourselves. Physical exercise, rest, and cleanliness will help to keep the body in good condition so that if it is attacked by disease germs it will be able to fight them successfully.



The Petri dish on the left contains sterile media culture. The dish on the right has been exposed to the air. How do you account for the spots in the one dish?

Germ diseases are spread by persons who have diseases. They may enter the body through the nose, the throat, the digestive system, and openings in the skin caused by cuts or scratches. They may be taken into the mouth with milk or other food. Pencils, finger nails, and common drinking cups are often responsible for the spreading of many diseases. All cuts and scratches on the skin should be kept clean and treated with antiseptics to prevent the growth of any bacteria that might get in.

The following desirable health habits should be observed by every one. Tell how each of these habits helps to prevent the spread of germ disease.

1. Bathe regularly and wash the hands frequently, particularly before meals.
2. Keep foods, articles of clothing, and all parts of buildings and public conveyances clean.
3. Clean the teeth and mouth several times daily.
4. Keep fingers and objects out of the mouth.
5. Eat only clean, unspoiled food. Wash raw foods.
6. Drink only pure water and freshly pasteurized milk.
7. Use private drinking cups or "sanitary" paper cups.
8. Clean all dishes and food utensils in very hot water.
9. Eat cooked foods.
10. Use a handkerchief during and after coughing, sneezing, and spitting.
11. Eliminate the waste matter from the body regularly.
12. Remove promptly all waste materials from the home.
13. Kill vermin, flies, and mosquitoes.
14. Sterilize or burn materials used in sick rooms.
15. Use germicides (germ killers), such as iodine, alcohol, carbolic acid, or salt in the treatment of cuts and wounds.
16. Avoid crowds; live in the open air and sunshine as much as possible.
17. Keep away from those having contagious diseases; observe quarantine regulations.
18. Get vaccinated and inoculated against smallpox, diphtheria, scarlet fever, and typhoid.

Can you add to this list?

Summary

Germs are living things too small to be seen by the unaided eye.

Under favorable conditions, germs increase very rapidly in numbers.

Good health habits help us to resist germs.

Questions

1. Who was the first person to observe and study microbes?
2. Who discovered the fact that microbes may cause disease?
3. Name three diseases caused by bacteria (one-celled plants).
4. Name one disease caused by protozoans (one-celled animals).
5. Some bacteria are useful. Mention one case in which this is so.
6. Under what conditions do microbes multiply rapidly?
7. How may a bottle be sterilized?
8. What do scientists call a substance on which colonies of bacteria are grown?
9. What parts of the body are good breeding ground for germs?
10. Why is it important to wash the hands before eating?
11. The teeth should be cleaned several times a day. Why?
12. Why is cooked food safer to eat than raw food?
13. How is milk pasteurized? What is the value of pasteurization?

14. One should always cough or sneeze into a handkerchief. Why?

15. List three good health habits not already mentioned in your answers to questions 10, 11, 12, 13, and 14.

Supplementary Demonstrations and Projects

1. Read the stories of the disease fighters at the end of the book.
2. Prove that germs are present in the nose and mouth.
3. Compare the number of bacteria that form in samples of pasteurized and non-pasteurized milk.
4. Construct a sanitary pencil holder for classroom use.
5. Study the parts of a microscope and find out how the microscope magnifies microbes and other objects many times.
6. Construct a fly trap.
7. Write a composition about either one of the following topics: *a.* Influenza epidemics; *b.* Infantile paralysis epidemics.
8. Write a composition about the value of Health Day as observed in the schools.
9. Find out what is meant by the nitrogen cycle.

How do these help to protect us against disease?

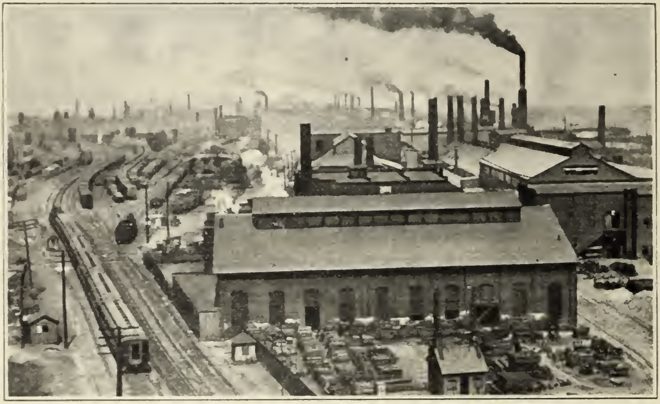
PROBLEM XVI

HOW DOES THE CITY GUARD THE HEALTH OF ITS INHABITANTS?

City air is impure. The air in a city is not as pure as the air in the suburbs or country. Factory chimneys are constantly pouring out heavy smoke that carries with it poisonous gases and fine particles of the black soot which every city inhabitant breathes in. If we approach a great city in such a way as to get a distant view, we see a heavy pall of smoke hanging over the city like a threatening cloud.

In this atmosphere, under a constant threat of disease, great numbers of people live and work. It is true that every city passes ordinances regulating the kind of fuel to be used and punishing offenders who violate the poisonous-gas regulations. But no law can serve to purify the air to any great extent. Think of the harmful fumes (smoke) of the chimneys, the deadly carbon monoxide gas of the automobile exhaust, the myriads of germs that lurk in the dust of the streets and in the decaying food matter of hundreds of thousands of garbage pails, and we see at once, that keeping the air of a great city pure is a vast problem.

The city does much to keep the air fit to breathe. The city provides public parks in which there is a fair



Ewing Galloway

Why is the use of soft coal dangerous to health?

degree of safety from impure air. Here there are wide, green lawns instead of dusty streets and sidewalks; the poisonous fumes of factory chimneys and of the city's garbage do not fill its atmosphere in sufficient quantity to make it unfit to breathe, while trees and other foliage give up oxygen that is needed for breathing. Here, too, one may sit in comfort on a hot day enjoying the shade of the friendly trees, and avoiding the waves of intolerable heat that are reflected from the pavement and the brick walls of the streets.

Tenement house laws have been passed requiring apartment houses to be built in such a way that conditions will be healthful. Courts and shafts must be large enough to give all apartments a fair supply of light and fresh air. The rooms must be large enough

Ewing Galloway

The city protects the health of the thousands who work in these buildings. How?

for comfort and must be provided with window space in accordance with regulations; stairways must be well lighted and ventilated.

The city has also passed ordinances requiring factories to use smoke-consuming devices on chimneys. Laws have also been passed prohibiting the discharge of poisonous or offensive gases of any kind from factories. New York City has forbidden the use of steam locomotives drawing passenger trains within the city limits.

Demonstration. To show that smoking chimneys make the air impure. Visit a section of the city where factories may be found. Observe the smoke that comes from the chimneys. Steam trains carrying freight also give off dense clouds of smoke. This smoke helps to fill the air with impurities.

The National Conference Board of Sanitation reports that during October, of one year, Manhattan Borough lost 38.6 per cent of its sunlight on account of chimney smoke. In August of the same year the loss of sunlight was 28.5 per cent and in September, 29.9 per cent. On some days as much as 79 per cent of the sunlight is lost to this borough and as a result, the inhabitants are cheated of the health-giving rays which they need so much.

The city insures a plentiful supply of wholesome water for all uses. You learned, last term, how the city's supply of drinking water is purified. Some of the methods employed are filtration, chlorination, and aeration.

Demonstration. To show how filtration helps to make water pure. Repeat the filtration demonstration on page 130. What may you conclude from the fact that the water in the glass is clean whereas dirt collects on the absorbent cotton used as a filter?

Other methods of purifying water, you will recall, are distillation and boiling.

Demonstration. To show that water may be purified by distillation. Perform, again, the distillation demonstration on page 130. Compare the water in flask *A* with the water in flask *B*. What may you conclude? In what way is distillation superior to filtration as a means of purifying water. Why is distillation not done on a large scale in connection with purifying the water supply of a city?

Demonstration. To show that water may be purified by boiling. Boil some muddy water in a glass flask, or in a small kettle. After the water has cooled and settled, pour it off carefully into a clean glass. Compare the water before boiling with the water after boiling. Which is cleaner? What is left in the bottom of the flask or kettle? In addition to making the water clean, what other useful service has boiling rendered? How do you know that this is so?

Why is this type of fountain better than the faucet and the common drinking cup? Should the mouth be pressed against the metal of the spout or should it be held just above the spout? Why?

The city takes other measures to protect its inhabitants against possible disease by placing sanitary drinking fountains in the parks and in other public places.

Bathing, you have learned, is necessary for health. Some cities provide public baths and bathing houses for those who have poor facilities for bathing at home. These municipal baths are carefully inspected and are kept clean for the safety of those who use them.

Lakes for healthful water sports may be found in some of the larger public parks. Rowing is allowed and, when the season permits, many people may be seen enjoying this healthful exercise. In winter, when the ice is solid enough to permit skating, hundreds of people go to the public lakes to enjoy the sport.

Ewing Galloway

Streets are cleaned by the street-cleaning department.

The city enforces measures to protect the public against contagious diseases. Ordinances that require housekeepers to cover garbage receptacles and that punish by fine and imprisonment any person who throws refuse into the streets are strictly enforced by city authorities. Streets are cleaned regularly by the Street-cleaning Department and great sewer systems, costing millions of dollars, carry waste and filth to remote places where there is no danger to residents. Dumping garbage in vacant lots or in any other place is strictly forbidden. It is the duty of every person to inform the authorities if these regulations are violated by careless neighbors.

Courtesy Swift & Company

Inspecting our meat supply.

The food supply of the city is carefully inspected by officials of the Health Department. The officials make frequent visits to bakeries, dairies, slaughter-houses, meat product manufacturers, food storage warehouses, butcher and delicatessen stores, fruit markets, fish markets, restaurants, and soda fountains. If the proprietor of any of these is found to be violating the food health ordinances, he may be fined or imprisoned. In some cases his license to operate the place is taken from him.

Laundries and barber shops are also carefully inspected by health officials. Cleanliness is necessary in these places in order to avoid the possible spread of disease. Visit a neighborhood barber shop or a local laundry and note the measures taken to safeguard the health of the public.

The city's milk supply is carefully tested because so many people, especially children and infants, depend upon it for food. Inspection is made at stores where milk is sold and also by chemists in Health Department laboratories. As you have learned, bacteria multiply very rapidly in milk. Pasteurization destroys bacteria in milk and helps to keep the milk wholesome. But even pasteurized milk becomes unfit unless it is used within a day or two of pasteurization. It is important, then, to know when milk is pasteurized.

Exercise. To find out when milk was pasteurized. Examine the label of your bottle of milk when it arrives at your home or when you buy it. Note the date on which it was pasteurized.

The law requires milk-bottle labels to be dated. This protects the public against using milk that is not freshly pasteurized. Observe, also, the large letter, *A*, or *B*, on the label. This indicates the grade of milk or the bacterial content. Grade A, when bottled, contains fewer bacteria per bottle than Grade B.

Demonstration. To show how milk may be pasteurized. Obtain a double boiler, that is, an arrangement consisting of two metal pots, one fitting over the top of the other. Fill the larger pot half full with water and pour some milk into the smaller one. Place the smaller pot within the larger one and heat the water slowly over a gas flame until it reaches a temperature between 131° F. and 155° F. Use a thermometer to test the temperature. Remove the double boiler from the flame and keep the temperature constant for about twenty minutes. If the temperature begins to fall before the end of that period, pour a little hot water into the outer pot to bring the temperature up again.

The process of heating milk in this way is pasteurization. The milk is heated just enough to reduce the number of bacteria sufficiently without destroying certain valuable food bodies, known as vitamins, which the milk contains. Overheating destroys these vitamins and also makes the milk less pleasant to the taste.

Health inspection. Schools, as you know, are constantly guarding the health of pupils. No child is now permitted to enter school unless he has been vaccinated. From time to time doctors visit schools to give the Schick test to see whether or not the pupils are immune to diphtheria. Most schools have nurses who advise pupils regarding their health. In some schools dental clinics are established to care for pupils' teeth, and in every school there is the daily health inspection and the health chart to show how each pupil in the class is progressing in the important matter of health.

The Health Department issues a daily report to all schools listing the addresses at which there are cases of contagious disease. Pupils who live at any of these addresses are excluded from school for a while to protect the other pupils. Those having contagious diseases are quarantined; that is, they are obliged to remain at home and are not permitted to come into contact with other people until the danger of contagion is past.

Demonstration. To show how a daily health notice safeguards the health of the public. Examine carefully the

Examining school children.

daily health notice, sent to school by the Department of Health, and note the information it contains. How many contagious diseases are reported? What are they? Ask your teacher how the addresses and other information are obtained by the Health Department. What is done with this report in the school? How does the report help to safeguard the health of the public?

Public clinics are provided throughout the city by the Health Department. Here advice and treatment may be obtained free of charge or for very small fees. The city also provides hospital service and visiting nurses for those who may need them.

Yes, the city does its share to prevent disease, but the city will fail unless every citizen does his share to aid in this work. The best way to help in this difficult task is to do all the things suggested in the list of health habits on page 150 and to obey the health laws of the community at all times. It is your duty to do so.

Summary

The city enforces laws to keep the city air pure.

The city insures a plentiful supply of wholesome water for all.

The city enforces measures to protect the public against contagious diseases.

Questions

1. Why is the air in a city generally less fit to breathe than the air in the country?
2. Why is the use of soft coal prohibited in most large cities?
3. How do automobiles make the air of a large city impure?
4. Why do cities spend millions of dollars annually for the maintenance of public parks?
5. Explain how trees help to cool the air in summer.
6. Mention two provisions of the Tenement House Law.
7. Name three methods of purifying water.
8. What provision does the city make for public bathing?
9. Give two reasons why water sports are healthful.

10. How is the public guarded against the purchase of impure food?

11. How can you tell whether or not a bottle of milk delivered to you is fresh?

12. What is pasteurization?

13. Why is milk pasteurized rather than boiled?

14. Mention three things which the school does to safeguard the health of its pupils.

15. What is the purpose of the daily health report sent to the schools by the Health Department?

Supplementary Demonstrations and Projects

1. Make a garbage can with a cover that may be raised by pressure on a pedal.

2. Test the purity of milk.

3. Test various foods to see if they are spoiled.

4. Visit a dairy or a slaughter house and learn about measures taken to keep the food pure.

5. Write a composition on the value of city parks.

6. Read a copy of the Tenement House Law and select the sections that have to do with health. List these and bring them to school to be read to your classmates.

DISEASE FIGHTERS

You have learned how microbes were discovered, centuries ago, by Leeuwenhoek, the Dutch lens maker. The fact that microbes cause disease was proved, as you also know, by the French chemist, Pasteur. The next step, of course, would be to learn just which diseases are caused by certain microbes; and then, to fight or to prevent the spread of these microbes. This battle against disease has always been a difficult undertaking. The many men who have taken part in this work are heroes in science; some even martyrs. Since the stories of only a few can be told here, suggestions for additional interesting reading about other famous disease fighters are listed at the back of this book.

WHY ARE YOU VACCINATED?

Do you remember that, when you were vaccinated, your arm became inflamed and you felt sick for a day or two?

Do you know that a successful vaccination is intended to make you a little sick, in order to prevent your getting very sick later?

Do you know that, in a way, it was an English milkmaid who, without knowing it, suggested the idea of vaccination?

In England, during the eighteenth century, one of the most terrible and the most baffling of diseases was smallpox. Doctor after doctor tried to fight it; a number of these earnest pioneers caught the deadly disease and died of it. But there was one, Edward Jenner (1749–1823), who determined to find a cure for it.

Brown Bros.

Edward Jenner.

The story is told that, while Jenner was still a medical student in a Gloucestershire hospital he overheard a conversation between the doctor in charge and a milkmaid who was suspected of having smallpox.

"I cannot possibly have smallpox," the milkmaid protested, "because I have had cowpox!"

The young student listened, and learned of the tradition among country folk that, once you have had cowpox (a mild disease caught from cows), you are *immune* [1] to smallpox. That set him thinking.

First, he investigated. He made many inquiries about people who had had cowpox. Few, or none, of these, he was informed, ever had smallpox. "Now," thought Jenner, "if we can give people a mild case of

[1] Immune: protected against.

cowpox, might we not prevent their getting smallpox?" Edward Jenner was one of the first men bold enough to suggest making people sick, in order to protect them against more serious illness.

Now began Jenner's experiments. With great daring, he tried a terrible thing, in 1796. He took pus from persons sick with cowpox, and injected it under the skin of healthy children. Soon these children became sick with cowpox; but they recovered. For two years he watched them; and then, in 1798, he made the fearful test.

He took these same children, whom he had made sick with cowpox, and *inoculated*[1] them with the dread smallpox pus. Though the dose was enough to give any grown person a bad case of smallpox, these children did not get it. They were really immune.

Jenner called this inoculation for smallpox *vaccination* from the Latin word, *vacca,* which means cow. The substance used for vaccination he called *vaccine.* Today the vaccine is not obtained from people ill with cowpox, but from calves. Young female calves are inoculated with the smallpox virus. *Cysts*[2] are formed at the spot of vaccination and the contents of these cysts are collected, purified, and used for vaccinating people.

What a boon to the world were Jenner's discovery and courageous experiment! Today, smallpox has almost disappeared from all civilized countries.

[1] Inoculate: Infect with a disease by inserting its virus (poison) into the flesh so as to induce a mild form of the disease.

[2] Cyst (sĭst): A closed sac containing fluid.

Since the effects of vaccination may wear off after a number of years, some states require all people to be vaccinated every five years.

Do you understand now why the law requires, almost everywhere, that children have vaccination certificates before entering school?

THE WORK OF LOUIS PASTEUR (1822–1895)

The same great chemist who taught the world how to prevent wine from turning sour, how to keep milk from spoiling, and how to protect silkworms from parasites that destroy them, also invented the cure for that terrifying disease, hydrophobia.

Pasteur.

Louis Pasteur was a Frenchman whose active mind worked busily, from the time he was a boy. Indeed, he was only nine years old when he learned of the horrors of hydrophobia. In his own little village, he saw eight people die, after violent suffering, caused by the bites of a mad wolf. "Why?" he began to ask. The answer to this question he did not discover till he was fifty-eight years old.

After hearing an especially inspiring lecture by the great chemist, Dumas, of the Normal School in Paris one day, Pasteur decided that he, too, would make chemistry his profession. He performed experiment after experiment, just to see what he could do. About this time, the scientific world, interested in microbes for the first time since Leeuwenhoek (1632–1725), was finding them in yeast, in meat, in barley, everywhere. And then Pasteur, at the age of twenty-six, made an interesting discovery which brought him to the attention of the scientific world. He had been made Dean of the Faculty of Sciences at Lille and he became interested in the sugar-beet distilling industry of Lille. He discovered that microbes are the cause of beet sugar changing into alcohol. In other words, microbes are the cause of fermentation.

Shortly after this Pasteur accepted a position in Paris. His fame spread rapidly as he delved deeper and deeper into the study of microbes. He showed that the dust of the air was swarming with microbes; he proved that wines would turn sour or bitter if exposed to certain microbes; and he proved that if wine were heated to a certain temperature, the harmful microbes would die and the wine would remain unspoiled. To the grape-growers of France, and the wine merchants, this was a very important discovery. Soon Pasteur became famous all through this great grape-producing country, as the man who could prevent wine from spoiling. That same process, known as *pasteurization,* is now used everywhere to prevent milk from spoiling.

Southern France has another important industry, the silk industry. Silkworms feed on mulberry leaves. If the mulberry leaves become diseased, the worms will become sick, and the industry will suffer. That is exactly what happened in 1865. But no one knew what ailed the worms, although they were dying by millions. One day, the great Dumas, Pasteur's early inspiration, came to his former pupil to consult with him concerning this serious state of affairs, and to ask his aid. Pasteur worked for three years before he arrived at the cause of the trouble. He told the silkworm growers that they must cure the mulberry leaf, first, if the worms were to grow strong and healthy. He saved the silk industry for France.

In 1880, Pasteur made another great discovery. He found by experiment, that if the weakened germs of a disease were injected into the body of an animal, making the animal just a little sick, the animal would thereafter be immune to that disease; that is, after the animal recovered from the first slight illness, the same disease would not affect it again. On June 2, 1881, Pasteur proved that he was right in an experiment with forty-eight sheep. He injected a deadly dose of germs into all of these; twenty-four that had been previously inoculated remained unharmed, but the other twenty-four died within two days.

Pasteur's crowning triumph came when he applied his great discovery to the prevention of hydrophobia, that dreadful disease about which he had been thinking for years. He prepared a vaccine by drying, crushing, and mixing with water fragments of the brains of rabbits that had died of hydrophobia. On July 6, 1885, he injected this vaccine, just as Jenner had done with smallpox germs, into the body of a little Alsatian boy, who had been terribly bitten by a mad dog. This was Pasteur's first experiment with a human being, and the experiment was successful.

Pasteur died in 1895, honored and revered by all who knew of his work.

KOCH'S WORK ON DISEASES (1843–1910)

While Pasteur, the prophet of the scientific world, was declaring to unbelieving and doubting scientists in Paris that certain germs caused certain diseases, a young German physician, Robert Koch, was busily and conscientiously peering into his microscope.

A mysterious disease was, at that time, killing off herds of cows and sheep. Placing drops of these sick animals' blood under his powerful lens, the young doctor found curious threads and streaks that he did not see in the blood of healthy cattle. It was in this way that, after many patient experiments, he discovered the anthrax germ.

Having discovered the existence of this deadly germ, Koch's next thought was to find out how these bacilli (germs) multiply or increase in number. Into a few drops of blood of a freshly killed, healthy ox, he placed a little of the diseased blood with which he had been experimenting. After a while, as he watched breathlessly, he saw the single drops of diseased blood infect the healthy blood. This was the first time anybody had tried to grow germs outside a living body. Next, to show that these artificially grown bacilli were just as deadly as those in the blood of the sick sheep and cows, he injected some of the microbes into healthy mice. They died of the same disease.

Koch.

Then Koch, still unknown and poor, asked an opportunity to show his findings to the eminent doctors of Germany. He surprised his audience, when he demonstrated to them that germs can be grown, not only inside bodies but outside of them, and, too, that one anthrax germ grows from another.

Not long after, in 1880, he was given an important position in the health department of Berlin, with a splendid laboratory in which to work. Koch allowed nothing to interfere with his work. He was convinced that one kind of germ causes one kind of disease, and that another germ causes another. He was concerned in watching the growth of one kind of germ, isolated from other kinds. This was hard, for germs are sometimes less than a thousandth part of an inch in size, and the air is full of germs, so that the many kinds are easily mixed.

Koch's work finally led him to the discovery of the germ which every year is responsible for one out of every seven deaths, the germ of tuberculosis. How he labored for endless months with his test tubes, how he proved that the germ of tuberculosis can be found only in animals sick or dying of that disease, and how he demonstrated that germs sprayed by the cough or sneeze of a tubercular person can carry the dread disease to healthy persons or animals, is an interesting but long chapter in the story of disease fighting.

In 1883 a dreadful epidemic of cholera spread from India to Egypt and frightened Europe. Koch and his assistants plunged into the task of finding the cholera germ. And Koch found it. He also proved that people can never have cholera unless they have eaten food infected with cholera germs. This discovery made it possible to prevent the epidemic in Egypt from spreading into Europe.

IS DIPHTHERIA PREVENTABLE?

At one time, diphtheria meant almost certain death to its victims. Now, there is a cure for it. It is *antitoxin*, the story of which is most fascinating.

A pupil of Pasteur, named Roux, and a disciple of Koch, named Behring, were both making earnest attempts to find the cause of diphtheria, that they might then effect a cure for that disease. It was another of

Koch's students, Loeffler by name, who finally discovered the diphtheria germ. Loeffler thought that this fatal germ manufactures a poison, or *toxin*, which gets into the blood of the victim and causes the deadly disease. This theory was of great assistance to the other two men. With the enthusiasm that he had learned from Pasteur, Roux set to work. He proved Loeffler's guess correct. But for a while, he went no further.

In the meantime, Emil Behring was hard at work in Koch's laboratory in Berlin. He was attempting to find a chemical that would counteract the effect of the diphtheria germ, or toxin. "Cure" after "cure" he tried, killing hundreds of guinea pigs on which he was performing his experiments. Still he went on. Finally, Behring tried a substance known as iodine trichloride, and he managed to cure a few of the sick guinea pigs, by injecting this chemical into their blood. Then from the blood of these cured animals he made a fluid. (Such fluids made of blood are known as serums.) This he injected into healthy guinea pigs to render them immune to diphtheria. Next, to test his experiment, he injected heavy doses of diphtheria toxin into the blood of these immunized animals. They did *not* get sick! The marvelous serum that he had just compounded, to work against the toxin of diphtheria, he called *antitoxin*.

But there was one serious defect in the serum: its effect wore off after a few days; once again, the animal would be liable to contract the disease. At this critical point Roux came back to the scene. He cultivated his antitoxin serum in horses. Its effect lasted longer than the guinea-pig serum.

While antitoxin does not prove effective in all diphtheria cases, it has saved the lives of millions of children since it was first discovered.

CAN YOU BE MADE IMMUNE TO DIPHTHERIA?

Have you taken the Schick test? Do you know anyone who has?

You have read of Loeffler's discovery of the diphtheria germ, of Behring's discovery of the serum or antitoxin to counteract this germ, and of Roux' improvement upon the antitoxin.

Most physicians were content to accept the discovery of diphtheria antitoxin as the last word in connection with that disease. But Dr. Bela Schick of Vienna was not satisfied. For years it had been known that some people are more likely to get diphtheria than others. Those who are naturally immune to diphtheria seem to develop their own antitoxin which protects them. If only it could be known, thought Schick, which persons are immune and which are not, it would be a simple matter to inoculate those who are not immune. Thus, practically all the world might become immune to diphtheria.

It was a clever thought on the part of Schick. But how was he to work it out? Like all great disease fighters, Schick began a long series of painstaking experiments. Finally, after numerous dosings of guinea pigs and cautious experiments with children, he hit upon the scheme. A very mild dose of toxin, about one fiftieth of the amount sufficient to kill a guinea pig, is injected under the skin of a child. If, after several days, no red spot appears, it means that the child has a sufficient amount of natural antitoxin in his blood to make him immune against diphtheria. If, however, a red spot does appear, the reaction is called "positive." This means that there is not a sufficient amount of antitoxin in the blood to make the child immune. Such a child would be liable to contract diphtheria if exposed to the disease. Those who are not immune should be made so by injections of toxin-antitoxin [1] to make them immune. No further inoculation is necessary for those found immune, that is, for those who show a negative reaction.

WHAT CAUSES MALARIA?

The existence of the malarial microbe had already been discovered when Ronald Ross, a medical man, engaged by the British government to serve in India, began to wonder how that germ is carried from one person to another. In the course of one of his many trips between England and India he met a Doctor Manson, whose experience in China had suggested to

[1] Toxin-antitoxin: mixture of toxin and antitoxin. The antitoxin makes the toxin harmless.

him that there must be some connection between malaria and mosquitoes. Manson based this conclusion on the fact that there were so many mosquitoes and so much malaria in China.

After two years of experimentation, during which time he examined one mosquito after another, Ross learned, to his own surprise, that only one species of mosquito, after biting a malarial patient, contains the malarial germ. Ross was stationed in India during this period of research. It was a good place to study mosquitoes. When he found the species that carries the germ, he had these mosquitoes bite healthy sparrows and other birds. The healthy birds, stung by the malarial mosquitoes, became sick.

In spite of all this work, however, Ross failed to find the truth about malaria, for when these same experiments were tried on men, instead of birds, they did not work. His work was not wasted, for he laid the foundation upon which other disease fighters could build.

A patient, painstaking doctor, whose lot it was to take up the work where Ross could advance no further, was Giovanni Grassi, of Italy. Ross's work with mosquitoes was a matter of hit-or-miss; Grassi, being a zoölogist by profession, knew the various species of mosquitoes. With true scientific judgment, he watched and experimented. He even used himself as a subject for experiments, but without success. He tried his theories on a volunteer patient, Mr. Sola, and he confirmed his suspicion that the species of mosquito responsible for the transmission of malaria is the variety known as the *Anopheles* mosquito. The next thing that Grassi proved was that the malaria mosquito does its deadly work only in the evening.

With money supplied for his experiment by the Queen of Italy, and with one hundred men given him by the railroad officials, he was able, in 1900, to demonstrate perfectly the soundness of his theory. He took his company of men to a spot infested with Anopheles mosquitoes. Evening after evening, he had them remain behind finely-meshed nets. The neighbors all about got malaria, but not a single one of his protected men became ill.

To Ronald Ross was awarded the Nobel Prize for having discovered the malaria mosquito. Rightfully, this honor belonged to Grassi. But, whichever deserves the greater credit, both these men have helped the world to fight a disease which formerly caused widespread suffering.

HOW WAS YELLOW FEVER CONTROLLED?

While the American troops were in Cuba during the Spanish American War, in 1898, one third of General Wood's officers were killed, not in battle with the Spaniards, but by a force far worse than the Spaniards, by the terrible disease, yellow fever. And, every year, natives of Cuba died by the thousand, victims of that plague.

General Wood decided to fight this plague. It was necessary, of course, to make a study of the situation first. For this purpose, Major Walter Reed, an army doctor, was sent from Washington to Cuba. With a squad of earnest workers, including Dr. James Carroll, a young European physician named Jesse Lazear, and a Cuban, Aristides Agramonte — all soldiers — Dr. Reed started at once to attack his problem.

In the heat of a Cuban July, among men sick and dying of yellow fever, these daring men worked grimly at their task. Reed had heard that yellow fever might come from the bite of a mosquito. To prove this, experiments with mosquitoes were necessary. It would have been easy, if animals were subject to the disease; but no animal, outside of man, has ever been known to contract yellow fever. Hence only human beings could serve as subjects in these experiments. In answer to Reed's call for volunteers, it was his comrades who bravely came forward. They knew that it might prove fatal; yet they were ready.

What Reed did, first of all, was to pick out a certain species of mosquito, which he suspected of being the carrier of the yellow-fever germ. Next he had these mosquitoes bite yellow-fever patients. After they had sucked the diseased blood, Reed let the insects loose on his noble volunteers. As a result, Carroll became very ill, and Lazear died, a martyr to the cause.

But Reed needed more volunteers to make his experiments really reliable. He issued his call again; and again men proved themselves willing to die for the sake of humanity. This time the doctor made sure that the volunteers had never been near yellow-fever patients. He then put these men in mosquito-proof cages, so that only the deadly insects with which he was working might enter. When, shortly after he had permitted these mosquitoes to bite his volunteers, four out of five of the men became ill with the plague, Reed was assured that yellow fever is caused by the bite of a certain kind of mosquito.

Am. Museum of Nat. Hist.

Camp Lazear.

Even then, however, Reed was not quite satisfied. It was said that yellow fever can be caught from the clothing of yellow fever victims. To test the truth of this statement, he prepared a special room, filled with the bed clothing of patients that had died of the fever. And into this room he placed two new volunteers. For many days these brave men remained in the room; they slept in the bed clothes of the victims; but they did not catch yellow fever. Thus did Reed prove that yellow fever can come only from the bite of a mosquito that has yellow fever germs.

How Reed's experiments and discovery led to the wiping out of yellow fever from Cuba and, later, from Panama and other regions where yellow fever had for centuries been a fatal disease, is another interesting chapter in the history of disease fighting. It was General Gorgas and others, who did exterminate[1] these pests; but truly, the lion's share of the credit belongs to Reed, who showed them the way.

[1] exterminate (ĕks tûr′mĭ nāt): to destroy utterly.

BOOKS OF GENERAL INFORMATION

Title	Publisher
Book of Popular Science	Grolier Society
Compton's Pictured Encyclopedia	F. E. Compton and Company
Encyclopedia Britannica	The Encyclopedia Britannica Inc.
The Book of Knowledge	Grolier Society
The Story Book of Science	The Century Company
The Wonder Book of Knowledge	John C. Winston
The World Book	W. F. Quarrie Publishing Company

OTHER BOOKS

Author	Title	Publisher
Bigelow, M. A., and Broadhurst, J.	*Health for Every Day*	Silver Burdett and Company
Cohn, H. W.	*The Story of Germ Life*	D. Appleton and Company
De Kruif, Paul	*Microbe Hunters*	Harcourt, Brace and Company
Fisk, E. L., and Fisher, I.	*How to Live*	Funk and Wagnalls Company
Gibson, Charles R.	*Romance of Coal*	J. B. Lippincott Company
Hallock, G. T.	*A Tale of Soap and Water*	Cleanliness Institute, New York City
Harris, D. F.	*Edward Jenner and Vaccination*	Scientific Monthly, Vol. I, 1915, Lancaster, Pa.
Holmes, S. J.	*Louis Pasteur*	Harcourt, Brace and Company
McFee, Inez N.	*Food and Health*	Thomas Y. Crowell Company
Rinehart, S. M.	*The Common Sense of Health*	Doubleday, Doran and Company
Tower, W. S.	*The Story of Oil*	D. Appleton and Company
Week, Aland Deyett	*The Avoidance of Fires*	D. C. Heath and Company
Zingher, Abraham	*The Schick Test*	Health Department, New York City, 1922

DEFINITIONS OF IMPORTANT WORDS

ab sorb′: (From the Latin, *absorbere,* to suck in.) To take in. Heat is absorbed by substances.

an′thra cite: (From the Greek, *anthrax,* coal.) Hard coal.

an′ti sep′tic: A substance which may be used to destroy bacteria with little or no harmful effect on the body.

an′ti tox′in: A serum that counteracts the effect of toxin (poison) in the body.

at′o mize: (From the Greek, *temnos,* cut.) To reduce liquids to a fine spray. An instrument that reduces liquids in this way is known as an atomizer.

bac te′ri a: Microörganisms of a vegetable type. Some bacteria are useful and even necessary for life, others are harmful and cause disease.

bi car′bon ate of soda: A salt containing carbonic acid and soda.

bi tu′mi nous coal: Soft coal. So called because it contains a large percentage of the mineral, bitumen.

Bun′sen burner: A gas burner in which air enters through a small hole near the base to mix with the gas.

carbon di ox′ide: A heavy, odorless gas that does not support combustion. It is given off in the breathing of animals and in the decay of plant and animal life.

carbon mo nox′ide: A colorless, odorless gas, very poisonous. It is one of the gases that result from combustion in the gasoline engine and is present in the exhaust of automobiles.

car′bu ret′or: The device in a gasoline engine which combines air with the gas vapor to form an explosive mixture.

cast′ing: Shaping in a mould. Casting metal means pouring molten (melted) metal into moulds.

Cen′ti grade: Graduated to a scale of 100. The type of thermometer on which the freezing point of water is 0 degrees and the boiling point is 100 degrees.

com bus′tion: The act of burning. Union of some substance with oxygen producing heat and light.

con duc′tion: (From the Latin, *ducere*, to lead.) Transmission through, or by means of a conductor. A conductor is any substance that is capable of transmitting energy.

con tam′in ate: To infect, or poison.

con vec′tion: (From the Latin, *vehere*, to carry.) The transmission of heat by means of currents in liquids or in gases.

con vert′ed: (From the Latin, *vertere*, to turn.) To turn; to change.

cyst: A pouch or sac. Usually refers to a diseased growth.

damp′er: A device to regulate and to check the draft in a furnace, a fireplace, or a stove.

dis in′te gra′tion: The act of reducing to fragments or powder.

draft: The current of air entering a furnace, fireplace, or stove.

duct: (From the Latin, *ducere*, to lead.) A pipe for carrying fresh air into, or foul air out of, rooms in a ventilating system. Also a pipe for carrying water or sewage.

e lim′i na′tion: The act of giving off or expelling.

e vap′o ra′tion: The process by which a liquid is changed to a vapor.

ex tin′guish: To put out, as a light or fire.

fric′tion: The act of rubbing one body against another.

fumes: Vapor, gases, or smoke, like that given off by a chimney.

gen′er a tor: An apparatus in which vapor or gas is formed from a liquid or solid by heat, as a steam boiler.

grate: A frame of iron bars for holding fuel while burning.

hu mid′i ty: (From the Latin, *humidus*, moist.) The percentage of moisture (water vapor) in the air.

il lu′mi nat′ing gas: Any gas used for producing light. Ordinary illuminating gas is made by heating coal.

im mune′: Protected against, as immune to disease.

in oc′u late: To communicate a mild form of disease in a person by inserting its virus (poison) into the skin or flesh, in order to make the person immune.

in′su late: (From the Latin, *insula*, island.) To separate a conductor from other conducting bodies.

kind′ling temperature: The temperature at which a substance burns.

melt′ing: Reducing from a solid to a liquid state, usually by means of heat.

mi′crobe: A form of plant or animal life so small that it is visible only with a microscope; a microörganism. The minute plant forms are known as bacteria.

mol′e cule: A minute particle; the smallest portion of a substance that moves about as a whole.

ni′tro gen: One of the gases of which air is composed. It constitutes about four fifths of the volume of the air.

non-lu′min ous: Not shining; not giving light.

o paque′: (From the Latin, *opacus*, shady, dark.) Not permitting rays of light to pass through.

ore: Any mineral containing metal.

ox′i da′tion: The act of uniting with oxygen. In the case of iron or steel, the result is rust. Oxidation is really slow combustion.

ox′y gen: One of the gases of which air is composed. It constitutes about one-fifth of the volume of the air and is necessary for the support of all forms of life.

pas′teur i za′tion: Heating a liquid, usually milk, to a temperature of 130 degrees to 158 degrees and keeping it at that temperature for about twenty minutes to reduce the number of microörganisms that may be present.

pe tro′le um: Natural oil; obtained by digging wells until the source of oil is reached.

po′rous: Containing fine holes, or pores. Every substance is porous to some degree.

ra′di a′tion: (in heat) The transmission of heat in the form of rays. The sun heats the earth in this way.

re flect′: (From the Latin, *flectere*, bend.) To bend back.

re frig′er ant: A substance which may be used to produce low temperatures. Ice is a refrigerant.

reg′is ters: Openings in a wall or a floor through which air enters or leaves. Registers are the endings of air ducts.

ri′sers: Vertical supply or return pipes for radiators.

smelt′ing: The process of separating metal from its ore by means of heat.

spon ta′ne ous combustion: Burning without application of heat; oily rags may cause spontaneous combustion.

ster′i lize: To make free from disease germs, usually by heating.

sul phu′ric acid: A poisonous acid containing the elements hydrogen, sulphur, and oxygen. It is used as the acid in electric cells.

te pee′: An American Indian wigwam or tent made of poles covered with skins.

ther mom′e ter: (From the Greek, *thermi*, heat, and *metron*, measure.) An instrument for measuring the degree of heat.

vac′ci na′tion: To inoculate with a vaccine to prevent disease, especially smallpox. A vaccine is any substance that is used for inoculation.

vac′u um: (From the Latin, *vacuus*, empty.) A space in which no matter exists.

vol′a tile: Changing readily to vapor.

INDEX