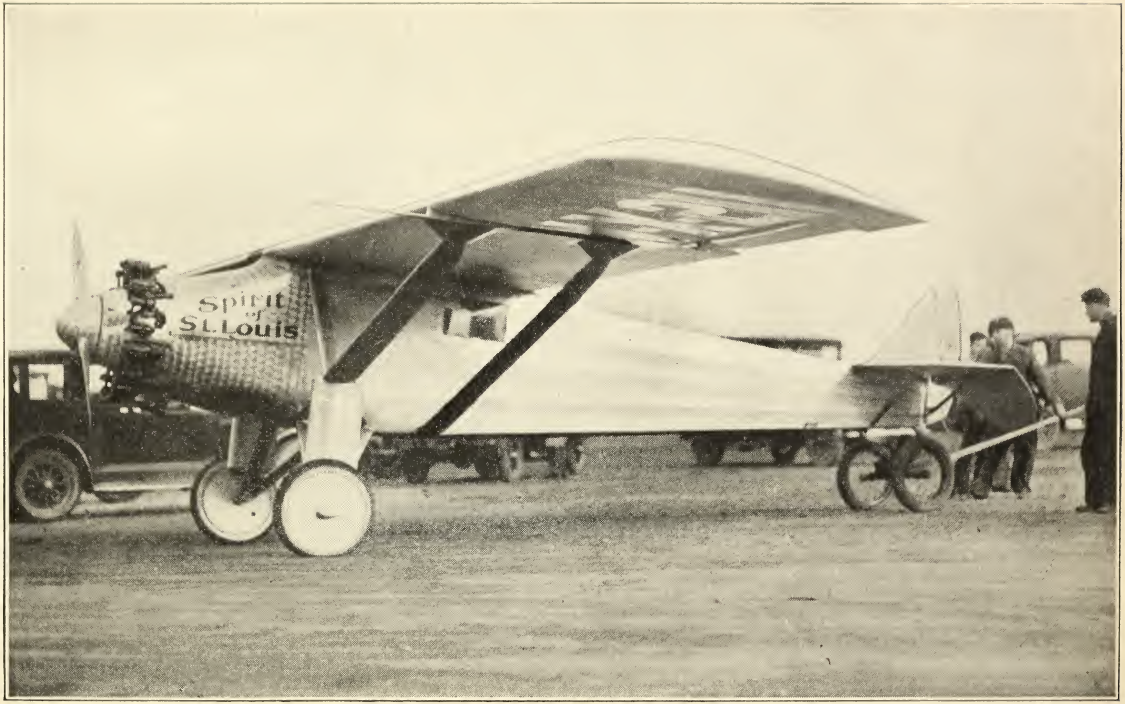
ELEMENTARY SCIENCE READERS

PAYNE · BARROWS · SCHMERBER

THIRD BOOK

BENJ. H. SANBORN & CO.



Photograph by Underwood and Underwood

The "Spirit of St. Louis" Just Before the Hop-Off for Paris

ELEMENTARY SCIENCE READERS

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THIRD BOOK

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PREFACE

The purpose of the preceding books in this series has been twofold. The first purpose was to provide children with a new type of reading matter in order to develop their reading capacity. The second purpose was to introduce them to a new world of material, to discover and arouse their interest, and to begin the development of a scientific point of view concerning the natural world. The copy included in these books had to be created for the purpose as no adequate reading matter of this kind had been previously prepared for children.

The type of subject matter included in this book has been changed from that presented in the first and second books. While the first two books dealt with the elementary facts of biology, this third book is devoted to the facts of chemistry and bacteriology in their simple form. The purpose of this book, moreover, is not merely to arouse the interest of children in the facts of science, but also to arouse a feeling of appreciation for the achievements of science and of scientific men. These facts are presented for the purpose of creating a feeling of appreciation of the relation of science to life, and to induce the reader to explore further into the applications of science and the accomplishments of scientific men. It is believed that there may be created the beginning of a scientific attitude of mind that will affect not only the child's personal living, but his relation to the community both at the present and in the future.

As a matter of fact, the slowness with which the American people have come to accept scientific practice and apply it in their individual and community living has resulted from ignorance of scientific achievements and unfamiliarity with the bearing of scientific discovery upon social progress. Moreover, this ignorance of science has not been accidental. We have presented to children in an attractive form very little of scientific facts. This third book of the series, therefore, aims not merely to provide attractive material for reading, but reading that will influence the behavior of the reader. Neither is the purpose merely that the reader shall do more reading, but also that his behavior, both his personal and his social habits, will be changed. The object is that the book shall be educative in the most real sense.

Nothing is said about the method for teachers in the use of the text. Perhaps too much has been said about methods of reading. What is needed most is that children be provided with reading matter that is worth while, reading matter that has the possibility of affecting favorably the behavior of the reader. If children are encouraged to explore such material, proper educative results are quite sure to follow.

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Elementary Science Readers

THIRD BOOK

THE CHEMICAL AGE

Not so very long ago in some parts of the world a doctor's life was most uncertain, because, if he failed to cure his patients, he was punished. Often, through no fault of his, his patients, after taking the medicine which he had given, became worse instead of better. If his patient happened to be a poor man, no one bothered much about him; if he was a man of importance the doctor was fined or punished. In some cases, upon the death of an influential person, the doctor even was killed.

Of course, several hundreds of years ago, when such things happened, the doctors did not know very much about the body or about the medicines which they were prescribing. But a great part of their lack of success was due to the presence of impurities and poisons in their drugs. It is not surprising that the doctors knew little about these things, because no one had the faintest idea as to what elements were present in minerals, plants, and animals.

Nowadays, unfortunate doctors are not punished when their patients do not get well, and medicines more often do the work which is expected of them. What has brought about the change? Why is it that there is little danger that poisons will creep into medicine? Let us examine the work of the chemists and see if we cannot find the answers to these questions.

A chemist is a man who works with the materials which are in and on the earth. Sometimes he causes two or more of them to unite and form new substances. Sometimes he breaks them up into their elements, which he uses separately or which he recombines as he wishes.

Much of the work of the chemist seems wonderful, for he appears to create things that did not exist before. But there is really nothing wonderful about it. He merely arranges things so that Nature will bring about certain results.

When we consider the unnumbered ages that man has been on the earth, the period of time during which he has known anything about even our commonest chemicals is short indeed. For thousands of years he just took things as he saw them and made no effort to learn anything more about the materials around him than his fathers had known. Then, as the centuries passed, more by accident than anything else, he gradually learned that by doing various things to certain substances he could make them take an entirely different form. His accidental discovery of glass is an example of how he learned some of the truths of Nature.

His knowledge that sand, limestone, and charcoal when heated would produce glass was the first step. But he soon noticed that some of the glass was better than the rest. Then he tried mixing different proportions of these materials to see which would give the best results. He had begun to experiment. It was in such ways that the science of chemistry had its beginning.

But only in recent times has there been a real science of chemistry. The chemistry of the ancients was not scientific, because the chemists then did not know just what they were doing. They did much experimenting with various chemicals, and more by chance than anything else, they sometimes succeeded in producing valuable substances.

A long time ago there were men called alchemists, who tried in every way to change common metals into gold. Since there were many alchemists, it naturally followed that they learned a great deal about some of the metals. They never succeeded in making gold from the baser metals, as the common ones were called, but the knowledge which they gained was very valuable.

We thought, until recently, that the alchemists were foolish men, but now we know that they were on the right track. We have learned that some metals at least can be changed into others; for instance, radium can be changed into lead. We do not know how far we shall be able to go in the matter of changing metals into other metals, but we have made a beginning.

Today there are very few men who are spending their time trying to make gold from other metals. They are too busy producing chemicals which are needed for a great variety of purposes. Without the knowledge and skill of the chemist we should have only a very few of the necessities and conveniences of life. The chemist has done as much as any other man to make possible the rapid industrial progress of the past few years.

It is in the separation of the various metals from the substances with which they are combined that the chemist has played a most important part. His knowledge is necessary for the choosing of the right amounts of the different elements which must be combined to produce the material for such things as engines, machinery, and tool steel. Unless we knew exactly how much carbon must be united with iron and how to bring about the right combination, we should not be able to produce the same kind of steel twice in succession.

Gold is separated from the rock in which it lies by means of mercury and also by means of another chemical called cyanide of potassium. It was the chemist who learned that these substances could be used for this purpose.

There is scarcely a metal that we use which is not in one way or another dependent upon the chemist at some stage of its preparation. His knowledge may be needed for removing it from the rocks, for purifying it, or for combining it with other metals.

Until a short time ago, all of our perfumes were obtained from plants and animals. Most of the plant perfumes were extracted by boiling the plants or their flowers. The animal perfumes, such as musk from the musk deer, were used in about the same condition that they were found in nature.

But now, instead of relying upon plant and animal products, which are not always the same as to odor and strength, the chemists are able to make exactly the same perfumes from coal-tar and petroleum. It is possible to separate these substances into their elements and by using some of them to produce perfumes which are always the same.

Thousands of different perfumes can thus be made and in far greater quantities and at a much less cost than they can be obtained from plants or animals. Rare odors that do not occur in nature can also be made.

Most of our common flavors and dyes used to be obtained from plants and animals in the same way that the perfumes were obtained. But now the chemists make them from coal-tar and other substances in the same way that they prepare the perfumes.

Just as the chemist is able to manufacture perfumes, dyes, and flavors, so is he able to make medicines. In years past, man depended upon the plant and animal worlds for his drugs, and the methods which he used were very crude and unreliable. But worst of all, he did not know of what his medicines consisted and he was not able to tell whether or not they were poisonous.

The chemist now produces many medicines that were never known in the past, and he has made others that formerly were found only in plants and animals. And more than this, he is able to make medicines that are free from poisons and other undesirable substances.

Of course, we still use great numbers of drugs that are present in nature, but the chemist now enters into their preparation. We no longer pound up plants and squeeze out their juices, trusting to luck that they contain what we are looking for and are free from poisons. We test them carefully, to see just how much of each element is present in each case.

A great deal of our food, such as canned goods, is subjected to chemical examination. In fact, there are very strict laws in almost every country, the purpose of which is to prevent the selling of impure or poisonous foods. Men are frequently punished severely for selling anything that is injurious to the health of the purchaser. Without the chemist we should not be able to tell which food is wholesome and which is not.

Another way in which the chemist guards the health of the community is in the examination and purification of our water supplies. All cities and large towns depend upon water which is piped to them from such sources as reservoirs, lakes, and rivers. In order to determine whether water is free from impurities it is necessary to make a chemical examination of it. All modern cities and towns have forces of men whose duty it is to keep a close watch on its water supply.

Photograph by Wide World Photos

Chemists at Work in Laboratory

When it is found that there are impurities in the water, the necessary steps are taken to remove them. Sometimes this is brought about by the addition of chemicals which destroy the injurious substances or unite with them in such a way that they can do no harm. The chemist has contributed greatly to the health of the world by keeping its water supply pure.

It has been said that the World War was a war of chemists. There is a great deal that can be said in support of this statement. Every one is familiar with the poisonous gases which both sides let loose on their enemies. The explosives of all kinds, from those used in mines and giant guns to those employed in revolvers, were all the products of the chemist's skill. The hand of the chemist was seen in the manufacture of gas masks, smoke screens, and colored signal lights. In fact the chemist played an important part in almost every move made by either side.

It is fortunate that the substances made by the chemists for purposes of war can be used for other purposes than killing men. Explosives are employed in mining, in blasting passages for railroads, in digging excavations for buildings, and in everything that requires the clearing away of rock. Explosives are also used for removing stumps and for clearing away trees around burning forests. They are also used by farmers in some regions for turning up the soil so that the ground will be more fertile, and for digging ditches so that water may be brought into dry regions.

Even the gas masks used in the war are now employed in chemical factories and manufacturing plants where injurious gases are present.

Chemistry also enters into the making of leather, rubber, and cloth of all kinds. Without this science we should not have paper nor any of the other things that are made from wood fiber. It is necessary for the preparation of paints, oils, inks, and hundreds of other substances of everyday use.

Without the chemist we should have no gasoline and no automobiles, no electricity nor gas. Besides the things which we have mentioned, there are thousands of others which are possible because of the work of this scientist.

The chemist is one of the most important figures of our age, for he is the man who has made it possible for us to use so many of the elements which Nature has given us. In later chapters you will learn more about what he has done for human welfare.

QUESTIONS AND TOPICS FOR DISCUSSION

1. Why are doctors more successful in treating disease today than formerly?
2. Who were the alchemists and what did they try to do?
3. Describe some ways in which the chemist has aided the progress of civilization.
4. How does the making of most flavors and perfumes differ today from methods employed long ago?
5. In what ways does the chemist help to protect public health?
6. Name several things made by the chemist for use in peace and war.
7. Make a list of things in common use that depend upon chemistry for their existence.

COAL AND WORLD ACHIEVEMENT

Why do you suppose it was that Great Britain ever became the great world power that she is today? As you know, her possessions are in all parts of the globe. Some of them, like Canada and Australia, cover much more territory than does Great Britain herself. How does it happen that she and not some other power controls so much of the earth's surface? Spain, for example, was at one time a greater sea power than England. What has made the difference that now exists between them?

There are many reasons for England's greatness. One of the most important is the abundance of coal within her borders. Cheap coal made it possible for her to discard sailing vessels and to employ steamships earlier than most nations, and therefore to establish trade on a large scale with all parts of the globe before the other nations were able to do so. This gave her wealth and power and it put her in close contact with many countries which later became parts of her kingdom.

It was a simple matter for England, with her experience in steamship building and her abundance of coal, to build up a great navy and to protect her possessions.

Another reason for her greatness is the presence of rich iron mines within her shores. Iron made it possible for her to make machinery earlier than most countries and therefore to become a great manufacturing nation, thus adding to her wealth and power. But here the value of her coal can again be seen, for it is necessary for the manufacture of iron and steel.

Thus England, one of the greatest nations on the earth, owes much to this substance which she digs out of the ground —to this gift from the distant past.

The coal that we burn today had its beginning in swamps which existed millions of years ago, long before there were human beings on the globe. In fact, when the making of coal was first begun, there were no four-footed animals except those related to the frog and the salamander. These spent part of their lives in the water as do the frog and salamander today. There were no birds nor other flying creatures except certain insects which had just come into being. The plant world, too, was very different from what it is today, for there were none of the flowering plants and trees with which we are familiar. In their stead there were very large plants and trees which looked a great deal like ferns and palms.

The real beginning of coal was in a gas called carbon dioxide which formed part of the air. The strange fernlike plants, like plants today, absorbed this gas and took the carbon from it and then used it as one of the elements in making plant tissue (stems, leaves, roots, etc.). These plants died and settled at the bottom of the swamps in which they had lived. Then others grew and died and settled upon those that had gone before. Century after century this continued until the mass of half-decayed vegetation filled the swamps. This thick layer of vegetable matter decaying under water formed a more or less peatlike mass.

Later, great quantities of sand and clay were deposited on this mass and by means of pressure and heat were converted into rocks. The heat of the earth, the weight of these rocks above it, and the chemical changes that took place in the peatlike mass gradually turned it into the substance which we call

Photograph by Brown Brothers

GEOLOGICAL LANDSCAPE, DEVONIAN PERIOD

soft, or bituminous, coal. Then, in some places heat, resulting largely from earth movements, changed the soft coal after thousands of years into hard, or anthracite, coal.

It is easy to tell hard and soft coal apart, because hard coal is shiny and jet black, while soft coal has a dull appearance and is lighter in color. Hard coal does not give off as much smoke, while the burning of soft coal often results in great clouds of thick, smudgy smoke which blackens everything with which it comes in contact. You have probably seen smoke from soft coal coming from factory chimneys and from the smokestacks of steam engines and boats. The difference between hard and soft coal is due to the presence of larger quantities of other substances than carbon in soft coal.

Coal is being formed today. In swamps in many parts of the earth dead plants are accumulating and will in time become coal. In other regions, peat has been formed, and in some places it is being dug up and used as fuel. In our own country there are huge beds of it, but we do not use it much because coal is a more satisfactory form of fuel and is still plentiful. But a time will probably come when we shall have to turn to the peat beds for our fuel. Thus we see that the different stages seen in the formation of coal can be found at the present time.

Now let us see in what ways coal is used. When we think of coal we usually have in mind the kind that we burn in our furnaces, that is, coal as it comes from the ground. Some of it is hard and some of it is soft.

Coal in the form in which it comes from the ground is used for heating and furnishing power. Most of our manufacturing plants, steam railroads, and other industries use it in this form. In our country alone over three hundred million tons of coal are used each year.

A good deal of coal, during the process of mining and shipping, is broken up into fine pieces, called coal dust, which cannot be burned in that condition. We are beginning to press this coal dust into bricks and to burn them in the same way that we burn lump coal.

We sometimes grind coal very fine and use it in a special kind of burner which gives a flame very similar to the flame that comes from burning gas. Lump coal that is broken up into very small pieces is often used in this way.

Another way to use coal is to turn it into gas. This is done by heating it to a very high temperature in air, resulting in the production of an artificial gas, which can be burned in the same manner as natural gas. Sometimes another kind of gas, called water gas, is made by adding steam to the air.

The use of coal in its natural condition and as a gas results in a great waste of carbon and other heat-producing substances that it contains, since great quantities of these pass into the air in the form of gases and smoke. There is another way of using coal which is not so wasteful.

It is in the making of coke that coal can be used to the best advantage, for, in addition to coke, the other substance

Photograph by Underwood and Underwood

By-Product Plant, Lehigh Coke Co., Bethlehem, Pa.

of which coal consists can be saved. Coke is the substance which remains after all or most all of the volatile materials have been driven off from coal. It is made by heating coal to a very high temperature without having air present.

Coke is necessary for the making of iron and steel of the kind and in the quantities that we use today. We can make iron and steel by using charcoal which is obtained from wood, but we could not make enough of it, nor of the quality which is required.

In this country, up to the time of the World War, we used almost entirely an oven called a beehive oven for making coke. It was a very wasteful process, because everything except the coke was allowed to escape into the air. But now we save all of the elements that are in coal, for we use an oven, called a by-product oven, which prevents any of the elements from escaping. When we use a by-product oven we get, in addition to coke, gas, tar, a compound called ammonium sulphate, certain substances known as benzenes, and various other products.

You have probably heard of TNT, an explosive used in the War. It is one of the by-products resulting from the heating of coal. Much of Germany's early success was due to the fact that she had many by-product ovens which made it possible for her to manufacture this and other explosives on a large scale. The allies were using the beehive oven almost entirely and were therefore losing these chemicals. It was a long time before they were able to build enough by-product ovens to supply sufficient quantities of the needed explosives. The war did at least one good thing for this country—it started our making coke by the by-product method which enables us to save all of the valuable chemical substances which coal contains.

The materials that come from coal are used in peace more than they are in war. Many of the chemicals used for killing bacteria and for making medicines are obtained from coal. Much of our perfumery, many of our food flavors, and most of the dyes which we use for coloring cloth and other substances come from the same source.

From coal we obtain much of the material with which we build our roads, cover our roofs, and protect wood from the weather. There are many other useful products that come from coal and we are discovering new ones every year.

Coal has made the rapid progress of the world possible, for it has given us heat in quantities large enough to operate the countless machines used in a thousand industries, and it has given us an almost endless list of products each of which has contributed its share to our advancement.

It is true that there are other sources of heat besides coal. Wood is still used for heating houses and for running steam engines, but if we had had to depend upon wood for all of our heat and power, all available trees would have been burned long ago. Kerosene and gasoline and other fuels that come from petroleum give us heat and power too, but like the trees they would long since have been exhausted.

We could have removed some of the metal from the rocks with heat obtained from petroleum, wood, and other fuels, but it would have been slow work. We should have only a few machines and they would not be anything like the ones that we have now. Steel, in the quantities that are used today, could not be made without coal and coke.

We should still have other sources of power. Water wheels and other simple sources of energy would enable us to do many things, but only in a small way. It is true the world would have advanced, but its progress would have been very slow compared with what it has been.

QUESTIONS AND TOPICS FOR DISCUSSION

1. How did coal and iron help to promote England's greatness?
2. Explain how coal had its beginning.
3. What is carbon dioxide? How did it help to produce coal?
4. Describe the differences between hard and soft coal.
5. What is peat and how is it formed?
6. In what ways does man make use of coal?
7. What is coke and how is it produced?
8. Make a list of some by-products that come from coke making.
9. What difference did the War make with regard to coke making in the United States?
10. Give several reasons why coal is used to provide most of our heat.

PETROLEUM IN THE SERVICE OF MAN

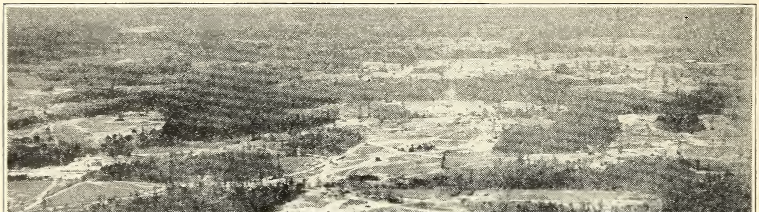
The first automobiles were built over a hundred years ago. They were crude machines propelled by steam and uncomfortable to ride in. It is therefore not surprising that they were not popular means of transportation. It was not until the invention of the gasoline engine that the automobile of the kind we know made its appearance. In 1875 a German, Siegfred Markus, built the first automobile driven by gasoline. About the beginning of the twentieth century the automobile began to come into general use. In 1926 there were over twenty-two million cars in the United States alone, representing a cash value of over three billion dollars.

This mighty industry, which employs hundreds of thousands of men, and which has added so much to our happiness and efficiency, therefore owes its existence to the gasoline engine, which, in turn, is dependent upon gasoline which comes from petroleum, an oil that was stored up in the rocks millions of years ago.

The word petroleum is made up of two words meaning oil and rock. Petroleum, therefore, means oil that comes from the rocks. We do not usually think of rocks as containing liquids, but all rocks, even those which seem perfectly dry, contain some water. Nothing in nature, not even diamonds and iron, is perfectly dry. But it does seem strange that a substance like oil should be found in any of them.

Petroleum has an origin very similar to that of coal. Long ages ago decaying plants and animals yielded carbon and hydrogen. These elements combined to form petroleum and natural gas. They became stored up in muddy rocks and shales which were being formed at that time. Later they were carried by surface water which was under great pressure to porous formations, principally sandstones. It is from these porous rocks, saturated with petroleums, that we get our petroleum today.

In our country, petroleum was first found in Pennsylvania, but it was not long before it was discovered in New York, New Jersey, Ohio, and Indiana. Now we get great quantities of it from Oklahoma and Texas as well as from the Pacific Coast, and some from other regions. There are rich



Photograph by Underwood and Underwood

Airplane View of an Arkansas Oil Field, "Snackover" wells in other parts of the world, particularly in Mexico, Russia, and Asia. The total annual petroleum production of the world amounts to over a billion barrels of forty-two gallons each—the United States furnishing about 770 million and Mexico about 90 million barrels.

Petroleum, as well as natural gas, is obtained by drilling down to the strata of rock containing it. By a very ingenious process iron pipe is fitted into the hole as it is being drilled. Although petroleum sometimes immediately flows out through the pipe, due to the pressure of gas, it is usually necessary to bring it to the surface by artificial means. The commonest and simplest method of doing this is by the use of pumps. Sometimes, however, there is so much sand mixed with the oil that pumps cannot be used. When this condition exists, it is necessary to bring up the oil and the sand together and to separate them above ground. Sometimes, when the oil does not flow, compressed air is forced into the well. The force exerted by this air drives the oil to the surface. At other times the oil is aërated, that is, mixed with air. The oil, when aërated, becomes lighter and more easily flows up the tube. Another method involves the use of an endless porous belt which passes down into the well. Above ground this belt passes between rollers which squeeze out the oil. It frequently happens that even after the oil bed has been reached, no oil can be obtained. It is then necessary to explode a torpedo in the well. The explosion usually has the effect of causing a satisfactory flow of oil. At times the explosion causes such a strong flow that it can be controlled only with difficulty.

It is not always necessary, however, to use artificial means to get the oil to the surface. Sometimes, as has been said, it rises without assistance once the pipe has reached the oil bed. At times it flows out gently and at other times, due to the pressure of underground gases, it gushes with such force that it cannot be controlled, because it is impossible to construct a valve strong enough to hold it in check. When this occurs, vast quantities of oil flow over the land. Not only is the oil lost, but the surrounding area is damaged.

Very little petroleum is used in the condition in which it comes from the well, that is, as crude petroleum, because of the impurities which it contains, and because it is more profitable to remove from it certain chemical compounds which are more valuable than the crude oil. The process of separating these substances from the crude oil, called refining it, is done in a refinery. In most cases the oil is pumped to the refinery through pipes. Sometimes pipe lines are hundreds of miles in length. It has been found that this method of transportation is far cheaper than carrying it in tanks on trains or boats. If it were not for these pipe lines we should have great difficulty in getting gasoline and other petroleum products in sufficient quantities for our needs.

At the refinery the crude oil is gently heated until a gas separates from it. Then the temperature is raised a little higher, with the result that another gas is produced. These two gases that are first obtained in the refining process are used for heating and lighting.

Oil is stored in great tanks. These tanks are sometimes open to the air and occasionally catch fire either from a stroke of lightning or from other causes, resulting in heavy loss. The illustration on page 21 is suggestive: "For the second time in a month, (June, 1926) lightning has struck the oil tanks at Warren, Pa., causing fire to blaze forth and consume the tanks, the damage amounting to several hundred thousand dollars."

Then, after the oil has been heated still more, two liquids, called naphthas, are produced. They are used for such purposes as dissolving rubber and making varnish. These liquids together with others that result upon the application of still more heat give the substance which we know as gasoline.

Photograph by Underwood and Underwood

Storage Oil Tanks on Fire

Gasoline is one of the most valuable of the products that are derived from petroleum, because it has made the use of the gasoline engine, and therefore the automobile, practicable. The automobile is one of the most important machines that man has made, for it enables him to travel freely from one part of the country to another and to carry his goods quickly and cheaply. It was not very long ago that most country people knew very little of the city and few city people were familiar with the country, because it was so hard to travel from one to the other. But now this has all been changed and we are better and happier because of it.

Gasoline as a source of power is used in many branches of industry, because for many purposes gasoline engines are more efficient and economical than those using other kinds of fuel. In addition to being used as a source of power, this liquid is employed to dissolve various substances and for numerous other purposes.

After the liquids of which gasoline consists have been removed, the remaining oils when heated still more yield the liquid which we know as kerosene. This oil was a very important product of petroleum before gas and electricity came into general use, since it was used on a large scale as fuel for stoves and lamps. It is still employed in large quantities for these and other purposes.

In addition to the gases and oils mentioned, gas oil, paraffin, lubricating oils, and coke, which are all thicker than crude petroleum, result from heating the liquid to higher temperatures. After these products have been removed, there remains a black, thick liquid called asphalt.

Gas oil is an important substance derived from petroleum, because it also yields gasoline. If it were not for gas oil there would not be enough gasoline to supply the demand, for the reason that we should have to depend upon the small quantity that comes off when the petroleum is first heated.

Among the most valuable of the petroleum products are the lubricating oils which are necessary for oiling the various machines in use today. All the different grades of lubricants, from thick, paste-like substances to those that flow freely, are derived from petroleum.

Machines can be lubricated with oil made from other substances than petroleum, as whale oil and vegetable oils, but the quantities of these oils available are not sufficient to satisfy the demand. Furthermore, most of them contain impurities, and chemical changes frequently take place in them which interfere with the work that they are expected to do. Lubricating oils obtained from petroleum are free from these defects.

Another product of petroleum which adds much to our comfort is paraffin. Large quantities of this substance are used for making candles, wax for sealing fruit jars, and for similar purposes.

There are many other useful substances derived from petroleum, like vaseline, which is found in every household; mineral oil, a white liquid which the doctors sometimes prescribe when we are not well, and coke, used in the electrical industry.

Men are even trying to make food from petroleum. There seems to be a fair possibility that they will meet with success in this direction, because petroleum contains some of the elements that are present in our food. It is also expected that many things like dyes and perfumes that we now make from coal will some day be produced from this oil.

It is often said that the world's supply of petroleum will be exhausted before many years, but there is really no danger of this happening. There are huge known deposits of petroleum that have never been touched, and as new oil fields are being discovered every year, we have every reason to believe that the supply will not be exhausted for centuries. In addition, there is a source of petroleum which has been little utilized—the oil-bearing shales in different parts of the world. Oil shale contains no petroleum, as such, but when heated yields petroleum, fuel gas, and other substances. In Scotland, petroleum from this source is being used. The cost of obtaining petroleum from shale is high, but the by-products obtained make its production a profitable industry. Vast beds of oil-bearing shale have been discovered in Colorado, Nevada, and Utah.

QUESTIONS AND TOPICS FOR DISCUSSION

1. What can you tell about the growth of the automobile industry?
2. Explain how petroleum is formed.
3. Describe how petroleum is taken from the earth.
4. How is petroleum transported and refined?
5. What is naphtha and how is it obtained?
6. Make a list of products that are obtained from petroleum.
7. Why are lubricating oils made from petroleum better than other kinds?
8. What other useful things is man trying to derive from petroleum?

THE GASES WE USE

One day in the spring of 1925 a certain village in Pennsylvania was the scene of a strange sight. A group of miners was lowering a cage containing a canary down the shaft that led into a coal mine that had long been closed. After the cage had reached the bottom it was allowed to remain a few minutes. Then the miners began to haul it to the surface. Eagerly they awaited the return of the bird and loud were their shouts of joy as it was brought safely to the surface. Had you been present you would have wondered why men should busy themselves with a canary and why they should be so interested in its safe return.

There was a good reason why the bird had been lowered into the mine. It sometimes happens that poisonous gases gather in mines, making them chambers of death to anyone entering them. It was to test the air in the mine that the canary was sent down. If a bird, which is very sensitive to gases, can breathe certain air in safety, human beings can also do so without danger. It may seem unfair to subject a canary to such danger, but it would be far more serious to ask miners to enter an atmosphere which might cause their death. Unnumbered lives have been saved by taking this simple precaution against deadly gases that sometimes form in mines.

There are many gases which are just as poisonous as those found in coal mines, but there are also many others which do us no harm. In fact, there are some that are necessary to life on the globe. But before we tell you about the different kinds of gases, let us see what a gas really is.

The air is made up of several gases. Each of these elements behaves in much the same way that air does, so, if we consider how air acts, we shall understand the nature of a simple gas.

Air will fill up anything that it happens to be in, no matter whether it is a bottle, a room, or the great out-of-doors. It is different from a liquid, because a liquid will fill up whatever it is placed in only as far as it can, just as water will fill up a hollow in the ground.

Air has the power of expanding, that is, of stretching out in all directions, so it will not settle in one place as water does. If a quart or so of air were let into a room that did not contain any, it would fill the whole room, because it would expand. Of course, as it stretched out, it would become very thin.

Each of the gases that combine to make air is very similar to air in its action. The other gases that are not usually present in air are also of the same general nature. Now that you know what a gas is like, let us consider some of the commonest ones.

Air is made up of about one part of oxygen and four parts of other gases, that is, about one-fifth of the volume of air is free oxygen. Furthermore, about eight-ninths of the weight of sea-water and half of the weight of the earth's crusts consists of oxygen. Because there is so much of it on the earth, and because it enters into the composition of so many things, it is the most important of all gases.

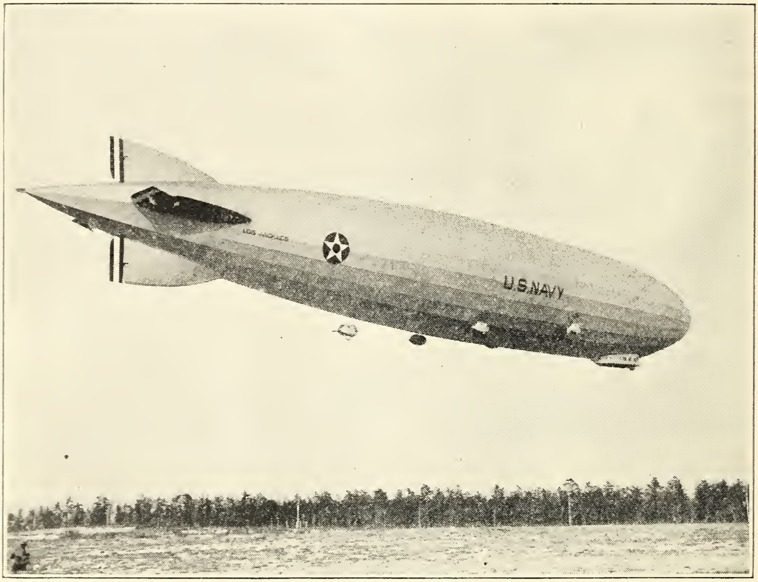
Oxygen itself cannot be burned, as some gases can, but it enables others to burn. If you want to make a furnace fire give out more heat, you open the dampers, which lets in more air, and consequently more oxygen. You would get still more heat if you were to let pure oxygen pass into the furnace. You see, oxygen combines with the coal or wood, and thus produces heat. The greater the amount of oxygen the more intense will be the heat.

When oxygen unites with other substances we say that it oxidizes them. Thus when oxygen combines with iron it oxidizes it, or in other words, it rusts it, forming iron rust which is also called the oxide of iron. Heat is given off when iron rusts, but it is given off so slowly that we do not notice any change in temperature.

Oxygen is used principally in the form of air to make things burn, but it is a very wasteful process, since we have to heat the great amount of nitrogen that is present with the oxygen in the air. But now we are beginning to use oxygen by itself, because we are able to separate it from the other substance with which it is associated. Over a billion cubic feet of this gas are used each year for various purposes, the greater part of it being employed in cutting and fastening together pieces of steel.

Oxygen is often combined with another gas, called hydrogen, in the form of water. Hydrogen is like oxygen in that it cannot be seen, smelled, or tasted. It differs from oxygen in that it can be burned. When it burns in oxygen, intense heat is produced, and water forms from the union of the gases. Since hydrogen is the lightest of the gases, it is often used for filling balloons, but unfortunately, because it burns so readily, its use has resulted in many terrible accidents. For this reason, scientists are trying to find a substitute for it. Another gas, named helium, is being used to some extent for this purpose, but because of its rarity and high cost of production it is not widely employed. However, methods of production have been discovered which will permit of commercial utilization.

Hydrogen forms a part of many very useful compounds, one of which is sulphuric acid, which is hydrogen in combination with oxygen and sulphur. This acid is very useful, and many manufacturing processes are dependent upon it. Another compound which it forms is a gas resulting from the union of hydrogen with another gas named chlorine. This acid dissolved in water is the hydrochloric acid of commerce. It is one of the substances present in the digestive fluids of our stomachs. Like sulphuric acid, hydrochloric acid is extensively used by chemists.



Photograph by Wide World Photos

THE "LOS ANGELES" FILLED WITH HELIUM

The third gas which we shall consider is nitrogen. It is a very important element, since it constitutes about four-fifths of the atmosphere. It, also, cannot be seen, smelled, nor tasted. Thus you see that the three gases which we have mentioned are alike in these three respects. Nitrogen is another element that enters into the formation of all living things, both plant and animal. The cells of plants and animals consist of substances made from these three gases with carbon and some other elements like sulphur and phosphorus which are not so important. It is difficult to get nitrogen to combine with other elements, and the combinations that are made are loosely formed.

We now come to chlorine, which differs from the gases already mentioned in that it can be seen, smelled, and tasted. It is of a yellowish color and has a very unpleasant odor and taste. You take it into your bodies every day for it is present in common salt. But in the form of salt it does not possess the properties that it does when it is by itself, a fact which is true of all of the elements. Chlorine unites with hydrogen and forms hydrochloric acid which, as you have learned, helps us to digest our food. It is therefore necessary to our bodies. Unlike nitrogen, this gas combines very readily with the metals. Chlorine has many uses, one of the most important of which is the purification of water, considered in another chapter. It is also used for making many things such as bleaching powder and chloroform. Chlorine was used on a large scale in the World War for making some of the poisonous gases which were used on both sides. It therefore has its evil as well as its good uses.

Up to the present, we have been talking about gases which are elements. There are two compound gases, that is, gases that are made up of more than one element, that you ought to know something about. These are carbon dioxide and natural gas. The first is one of the substances from which the food of plants, and hence of animals, is derived. The second is a gas which adds greatly to our comfort and efficiency.

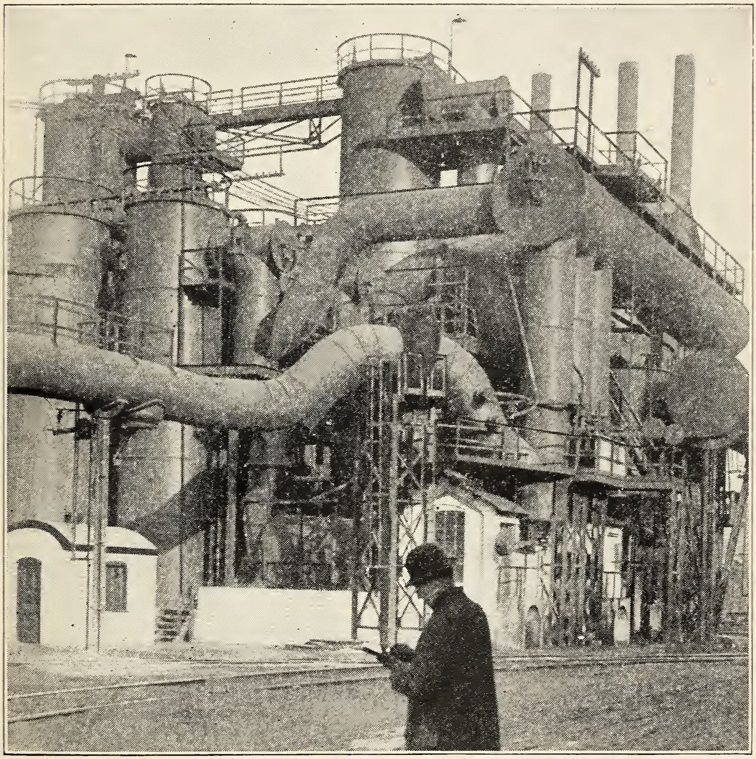
Carbon dioxide, you probably remember, is one of the waste products of animals. It is this gas which the plants remove from the air and break up into its elements—carbon and oxygen. It is, therefore, the source of carbon which is so necessary to the existence of all plant and animal life.

The bubbles in ginger ale and soda water are nothing but carbon dioxide which has been forced into these liquids. But carbon dioxide used for this purpose is produced in a different way from that which is given off by animals when they breathe. It is obtained by burning coal and by placing marble dust in an acid. Baking powder and washing soda, made by burning limestone, also contain this gas.

The other compound gas that needs to be considered is natural gas, which is found in the ground. All that we have to do when we know that it is present is to drill a hole into the earth's crust and then let the gas rise to the surface. It is used principally for heating and lighting purposes, but it has many other uses, such as the production of high grade gasoline and other chemicals. Several hundred billion cubic feet of natural gas are produced in our country each year. Gases used for heating and lighting are stored in huge tanks, and delivered to the place of need under pressure.

One thing that you have probably noticed is that when different elements combine to make new substances, the new compounds are very different from the things of which they are made. Thus you saw that chlorine which is yellow and disagreeable to the taste helps to form salt which is white and has an agreeable taste.

Another thing which you will be interested to learn is that the same chemicals, when combined in different proportions, give very different results. Sugar is made up of carbon, hy-



Photograph by Underwood and Underwood

Storage Plant and Machinery to Supply Gas to Blast Furnaces drogen, and oxygen. Fats are also composed of the same three elements. No one would ever guess that these substances so totally unlike contained the same elements.

We do not usually think of gases as being as important as liquids and solids, but when we realize that everything upon the earth is composed of gases or things that can be turned into gases, these substances take on a new importance for us.

QUESTIONS AND TOPICS FOR DISCUSSION

1. Why do miners sometimes lower canary birds into a mine shaft before entering?
2. How does a gas differ from a liquid?
3. Describe oxygen and tell how it is used.
4. How does hydrogen differ from oxygen?
5. What are some of the compounds of hydrogen?
6. How does nitrogen differ from the other gases mentioned?
7. Write a composition on chlorine and its uses.
8. Why do ginger ale and soda water bubble?
9. What is meant by a compound gas?
10. Why is it important to know about gases?

THE CONQUEST OF THE AIR

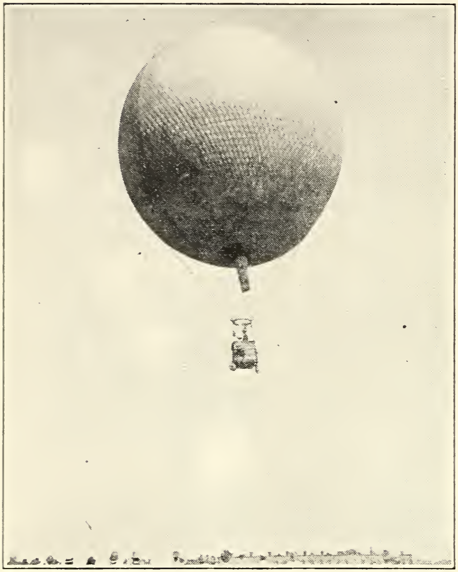
It is probable that as soon as man first observed the flight of birds he dreamed of navigating the air. The mythological account of Icarus who flew so near the sun that his wings of wax melted attests to the fact that the imagination of the ancient Greeks pictured man as soaring upon artificial wings. Through long ages man was content for the most part with dreaming, though now and then he did make feeble attempts to fly.

A little over a century ago certain scientists began to study, somewhat seriously, the problem of aërial flight. Their experiments were based upon two very different principles. One group devoted its efforts to the making of craft that would rise because they contained gases that were lighter than air. They were the fathers of the dirigible balloon. The other group strove to make machines heavier than air which would rise above the ground by the power generated in them. It was the latter group that finally produced the modern airplane. From the first, the balloon makers met with a considerable degree of success. This was not true with the makers of airplanes. Balloons were sailing the skies long before the first airplane left the ground. It is therefore proper that we should first trace the history of the balloon.

Though many nations have played a part in the development of lighter than air craft, the French, almost exclusively, are identified with the first hundred years of their development.

The first balloon of which we have record was made by

Joseph and Stephen Montgolfier of Paris in 1783. It was shaped somewhat like a huge ball made of paper and linen and filled with hot air. Though this balloon rose to a considerable height, it soon descended because it lost its buoyancy as the air within it cooled.



Photograph by Underwood and Underwood

FREE BALLOON

During the same year, M. Charles, a French physicist, employed hydrogen gas instead of hot air. His balloon was superior to that of the Montgolfier brothers because it remained in the air, irrespective of the surrounding temperature, since hydrogen is lighter than air. He also employed a valve by means of which he could release a quantity of hydrogen and thus cause the balloon to descend. Another of his improvements was the installation of a bag containing sand. The liberation of part of its contents lightened the balloon and allowed it to rise.

Since balloons of this type are at the mercy of the wind, they are called "free balloons." Free balloons very similar to those described are still used for such purposes as determining the temperature of the upper air, the direction of the wind, and the disposition of the enemies' forces in time of war. They are sometimes tethered to the ground by ropes. The observer who rides in a basket suspended beneath the balloon can be lowered to the earth upon completion of his work. "Captive" balloons are familiar objects at fairs and similar exhibitions. They are sometimes used for racing, the object of the contest being to see which balloon can remain in the air the longest or soar the highest.

A few months after Charles' experiment, the Robert brothers succeeded in constructing a dirigible balloon, that is, one that could be steered. Suspended beneath the bag was a basket in which sat the operator who guided the craft by means of a rudder and slowly propelled it through the air by means of huge oars. This method of propulsion was totally inadequate save in still air. It, however, was the first step in the construction of balloons which could be propelled.

The next great advance in balloon making was the work of another Frenchman named Henri Gifford in 1852. His dirigible was equipped with a screw propeller and motivated by a three horse power steam engine. Though he made short flights with his balloon, it cannot be called a success, because the steam engine, on account of its great weight, is not a satisfactory source of power for air ships.

Thirty years later, Captain Renard drove his dirigible, La France, at a speed of fifteen miles an hour by means of an electric motor. While unsuited to air craft, the electric motor was an improvement over the steam engine. The airmen were still handicapped by the lack of an engine suited to their needs. It was not until the advent of the gasoline engine, late in the nineteenth century, that a suitable motor was available.

In 1901 Santos Dumont, a Brazilian, after the construction of several gasoline-driven dirigibles, finally succeeded in producing one in which he won the Deutsch trophy by encircling the Eiffel Tower. Dumont's airship was the first gasoline-driven balloon, and was the forerunner of the great dirigibles of modern times.

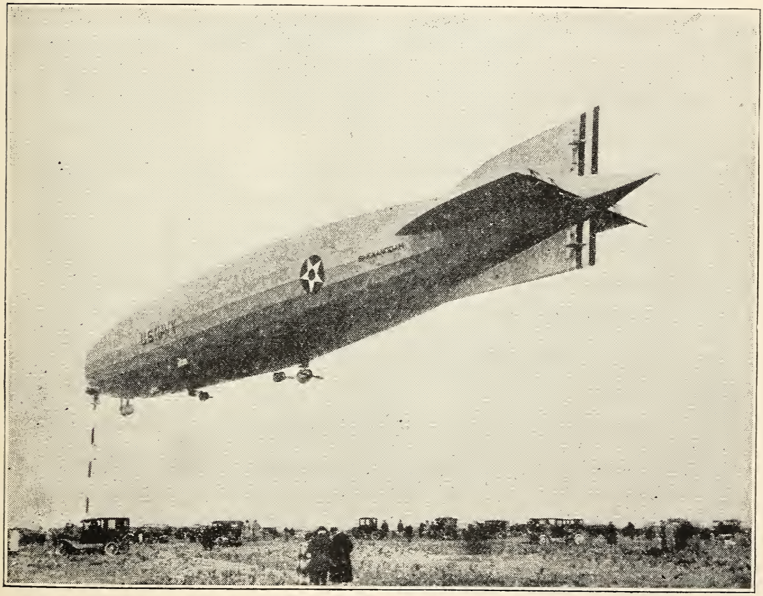
The dirigibles thus far considered were of the non-rigid variety—that is, they did not have a supporting framework to keep them from being distorted by the uneven pressure of the air. It was not long before two other kinds of dirigibles appeared—the rigid dirigible, or Zeppelin, with a framework of metal, and the semi-rigid, of Italian origin, with a stiff keel which gave the gas containing bag a certain measure of support.

One year before Dumont made his memorable flight, Count Ferdinand von Zeppelin of Germany built the first rigid dirigible. This balloon differed from the preceding type in that it consisted of an aluminum alloy framework over which the fabric was stretched. It was supported in the air by hydrogen gas confined in bags within the metal framework. This airship attained a speed of 20 miles per hour.

From this beginning came the rigid dirigible of modern times. The L-72, built by Germany, was over 700 feet long and 75 feet in diameter. It contained over two million feet of gas and could lift 73 tons. The speed attained by this ship was 66 miles per hour. Another famous dirigible of the rigid type was the British R-34 which, in 1919, crossed from England to America in 108 hours and returned in 75 hours.

The semi-rigid type of balloon, as has been said, is characterized by the presence of a rigid keel which runs along the under side of the vessel from end to end. The tremendous weight of the rigid dirigible is thus avoided. That the rigid keel gives sufficient support is proved by the achievement of the Norge which sailed from Italy to Teller, Alaska, in 1926.

Because of its inflammable nature, hydrogen is a most unsatisfactory gas for balloons. Its use has resulted in several serious accidents. Scientists long sought a substitute and finally succeeded in utilizing helium gas, which has the advantages of hydrogen without possessing its dangerous qualities. The loss of life on the Shenandoah which collapsed in a whirlwind, in 1926, would probably have been much greater



Photograph by Underwood and Underwood

THE "SHENANDOAH" MOORED AT TACOMA, WASHINGTON had hydrogen been used. The only reason why helium has not wholly displaced hydrogen is the difficulty of procuring it in sufficient quantities.

From a small bag filled with warm air the balloon has developed into a gigantic structure capable of carrying thousands of pounds across the oceans at a speed of more than a mile a minute. It played an impressive part in the World War and has assumed an important rôle in carrying on the commerce of the world. We will now leave the balloon to turn our attention to the development of the airplane, which, as has been said, ran parallel in point of time with that of the lighter than air craft.

The history of the airplane has been similar in many respects to that of the balloon. For over a hundred years all attempts to devise a heavier than air machine were thwarted by the lack of a suitable source of power. However, during that period the principles governing aërial navigation were discovered, so that with the appearance of the gasoline engine the progress to the present stage of development was rapid.

As early as 1796 Sir George Cayley, an Englishman, built a machine which in principle closely resembled those of today. It is said that a man running on the ground holding the machine above him would at times be lifted and be carried a short distance. Cayley, because of the lack of a proper engine, was unable to proceed further with his invention.

In 1840 W. S. Hensen made a small model of a monoplane with two screw propellers behind the wings. The power used was a steel spring. This model made several successful flights. He then built a machine with a twenty foot span, equipped with a steam engine, but as it was not properly balanced it could not leave the ground. However, as the plane embodied most of the principles found in modern airplanes, it is evident that the experimenters of that early date were on the right track.

About 1848 Stringfellow, who had worked with Hensen, made a model with a ten foot span which was equipped with a steam engine. The machine made a flight of forty yards. We thus must give Stringfellow credit for being the first man to make a workable power driven airplane.

For the next fifty years men in many different lands were at work—some upon gliders with no means of propulsion and some upon power driven machines. Some, like Wenham, though failing in actual flight, learned important facts concerning the size and shape of wings. Others, like Lilienthal, endeavored to find some other means of controlling the direction of flight than the shifting of the body of the steersman which was the only method employed at that time. It is probable that he would have added to the knowledge of airplane control had he lived a few years longer, but, unfortunately, he was killed by the collapse of his glider.

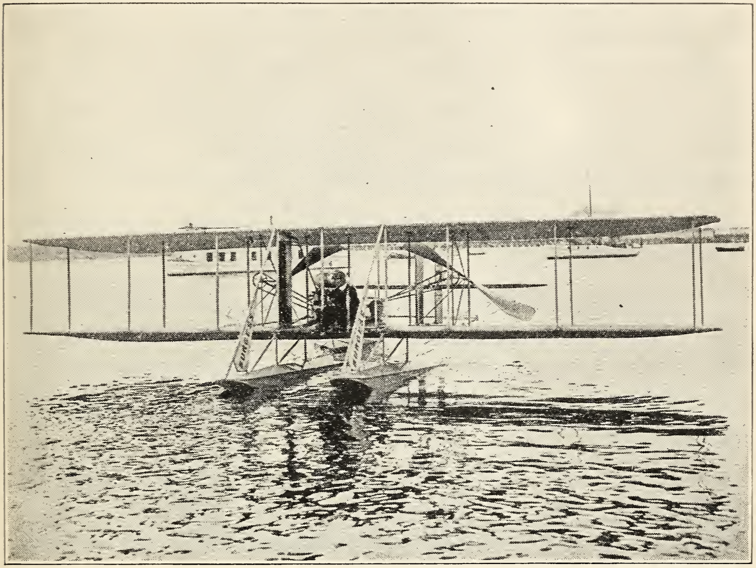
One of the most interesting experiments was that by Hiram Maxim in 1893. He constructed an airplane of gigantic proportions. It weighed in the neighborhood of 7000 pounds and was equipped with a 359 horse power steam engine. However, science at that period was not sufficiently advanced to enable him to control this monster, and he was unable to raise it from the ground.

A most noteworthy accomplishment was that of Professor Samuel P. Langley of the Smithsonian Institution who, in 1903, constructed a model propelled by a gasoline engine that made a successful flight. Encouraged by his success, he built a large machine capable of carrying a man. But, because of accidents at the time of launching, he was never able to raise it from the ground. To Langley belongs the credit of first employing the gasoline engine to drive an airplane, even though it was but a model. The importance of Langley's achievement cannot be overestimated because the use of the gasoline engine for propelling air craft made possible the subsequent development of aërial navigation.

We now come to the two men who actually succeeded in conquering the air. Orville and Wilbur Wright during the late nineties began experimenting with gliders. They soon saw that the method of control then in vogue, the shifting of the body, was faulty. After many experiments they found that by using a movable rudder and by twisting the wings they could control the direction of flight. After a thousand flights in their gliders they were ready for the real test. They then built a biplane equipped with a 16 horse power engine. At Kitty Hawk, N. C., Orville made a flight which lasted fifty-nine seconds. Within two years the brothers were flying for half an hour at a time. In 1908 Wilbur Wright went to France where he remained in the air for over two hours. He was not, of course, the first man to fly in an airplane in Europe, for Santos Dumont, the man who drove the first successful gasoline-driven dirigible, had made several flights in a biplane two years before.

The illustration on page 41 presents this historic machine as a hydroplane, but it was a land plane with the pontoons added for floating in case a landing on water should be necessary. Note, also, that in this plane the motor is directly behind the pilot, the reverse of the present practice. In practically all the early planes this was the location.

The flights of the Wright brothers, however, was the real beginning of airplane flying in its modern sense. Their success gave such impetus to the science that within a few years many nations were vying with each other in the building of airplanes. Improvement after improvement followed until the machine with which we are familar today resulted.



Photograph by Underwood and Underwood

THE FIRST WRIGHT AIRPLANE

The modern biplane, which embodies the principles that gave success to the Wright brothers, consists primarily of a long body pointed at both ends with a pair of transverse wings attached to the forward end. The body also contains the motor and governing apparatus together with a space in which the operator and passengers sit. Connected with the motor is the fan-like propeller which is placed at the front end of the body. The rear end of the body is equipped with a horizontal plane which is hinged in the center. By raising and lowering that part of this plane which projects behind the body the machine can be made to rise or to descend. The rudder is a vertical plane which also extends beyond the body. By turning it from side to side the machine may be made to change its course. The wings of a biplane are equipped with small auxiliary wings called ailerons. By changing the slant of these structures the operator is able to balance his airplane. Sometimes both wings are equipped with ailerons, sometimes only the upper one. The pilot by means of levers is able to control the angle of the horizontal plane, called the elevator, the rudder, and the ailerons, and thus can cause the plane to ascend, to descend, to maintain even keel, and to keep or to change its course.

One of the most difficult problems in connection with the operation of airplanes is that of gaining sufficient speed on the ground to enable the plane to rise into the air. Another is to make a landing which will not wreck the machine, because it is in comparatively rapid motion when it strikes the ground. To make both of these operations possible, wheels are placed under the body, one on each side, while the tail is supported by a skid which slides along the ground. Shock absorbers are also provided to prevent jarring when landing.

The airplanes of today are all constructed on the same general plan as the biplane just described. They, nevertheless, vary greatly as to size, power, and in other important characteristics. Some are equipped with two or three engines and with as many propellers. Some are monoplanes while others are biplanes or even triplanes. Some carry but one individual, while others carry many. Seaplanes are equipped with floats for landing on the water. Those intended for use in the Arctic regions have runners instead of wheels for alighting on snow or ice. Lindbergh used a monoplane equipped with one engine while Byrd chose a monoplane with three engines. Both used monoplanes because they are speedier than the other types. The standard plane of the United States Army is the biplane, because it has been considered the most satisfactory type for general usage. As knowledge is acquired, models change. We may, therefore, see an entirely new kind of machine in the ascendency tomorrow.

The airplane and the dirigible, though constructed on entirely different principles, have accomplished many things in common. They have crossed the oceans, flown around the world, and visited the North Pole. Both are utilized for military, commercial, and scientific purposes. They are employed to give us amusement and recreation. We have merely touched upon the achievements of the navigators of the air. A further consideration of their exploits will follow in the fourth book of this series.

Much has been done toward the furtherance of aviation in the United States. Our military dirigibles and planes compare favorably with those of any other country, our mail service is unexcelled, and the achievements of individual fliers have been unequalled. Nevertheless, much remains to be done. Our commercial air service is far behind that of some other countries, particularly Germany. This is due primarily to the fact that our government has not granted subsidies as have some of the others. As a result our accomplishments have been the result of individual effort. But the greatest need at the present time is for landing fields in all cities and along all air lines. Until these are provided aviation can never come into its own. The education of the public in matters pertaining to aviation and the improvement of aircraft are necessary to the advancement of the science. Certain public spirited individuals and organizations, like Rodman Wanamaker and the Guggenheim Foundation have already made a great beginning toward the encouragement of the development of aviation. But a few cannot do the work of many. Public interest and governmental assistance must coöperate if we are to take our rightful place in the air.

QUESTIONS AND TOPICS FOR DISCUSSION

1. Why was the early development of the balloon so slow?
2. What did Langley contribute to aviation?
3. Why will the Wright brothers be long remembered?
4. What is a semi-rigid balloon?
5. Who first flew in a gasoline motor driven balloon?
6. How does America compare with Germany in commercial aviation?
7. Name the principal parts of an airplane.
8. What is the best kind of gas for balloons? Why?
9. What must be done if aviation is to develop as rapidly as it should?
10. What is one of the greatest needs of aviation?

THE AGE OF STEEL

The Woolworth building in New York City, rising fifty-six stories above the ground, appears to be nothing but a mass of masonry. But hidden by the stone and mortar is a framework of steel which extends to the building's top.

If you ever observed such a building under process of construction, you saw that the first to be built was the steel work and that the walls and partitions were added later. The steel work is the real support of a "skyscraper." The masonry could be removed without causing the building to fall. In fact, masonry is a source of weakness, because of its great weight. The San Francisco earthquake in 1907 shook the brick and stone from many of the tall buildings and left the steel pillars and beams standing. This shows where lies the real strength of a skyscraper.

If no steel were used in such buildings, the lower partitions and walls, in order to support the weight of the upper stories, would have to be so thick that there would be little space for rooms between them.

Steel, which is so important in the construction of buildings, is a form of iron, a metal useful to us in many ways. But before we consider the different purposes for which iron is used, let us see how it is necessary to us in an entirely different way.

Our lives depend upon the iron that is within us. How can this be so? How can it be that a metal is necessary to life? The answer to this question is to be found in the red cells of the blood stream.

Within each of our red blood cells is present a chemical substance, called hemoglobin, which is a compound of iron. The work of hemoglobin is to unite with the oxygen which enters our lungs so that this gas can be carried by the blood to all parts of the body. Without oxygen we should die. The importance of hemoglobin can thus be realized, and therefore of the iron, which enters into its composition.

Plants also depend upon iron. Without this element there would be no green plants, for the green matter in them, known as chlorophyll, is a compound of iron. It is only by means of chlorophyll that plants are able to manufacture their food from the elements. Thus the plants depend upon iron just as do man and the animals.

The iron in our bodies is not like the iron that you know, because it is combined with other elements. But if it were separated from them it would be exactly like the metal that we call iron.

This metal, when in the presence of oxygen, always combines with it. Since oxygen is present everywhere in the earth's crust, it always comes in contact with any iron that may be present and forms combinations with it. The compounds which are formed by the union of oxygen with iron are called oxides of iron. Since iron combines so readily with other substances, it seldom occurs in the metallic form in nature.

Iron is the commonest metal that we have today, but there were long centuries after men were using some of the other metals, like copper and gold, before they learned to get it from the rocks. The reason for this is that some of the other metals are found in nature in the metallic state.

Tools and weapons of iron made by men who lived five thousand years ago have been found in Egyptian ruins. But we do not know just when this metal was first known to them. Since iron unites with oxygen so easily, that is to say, since it rusts so easily, it is very probable that the iron which was first used by the Egyptians disappeared long ago.

It is known that the Greeks and Romans used iron many centuries before Christ. When the Romans conquered Britain, now England, two thousand years ago, they found the Britons in possession of the secret of extracting this metal from the rocks.

The ancient peoples employed methods of extracting iron from the ore very similar to those in use today. They built furnaces of stone several feet across and a few feet deep, inside of which they placed several layers of charcoal and ore. After they had heaped a pile of charcoal upon the top of the oven, they lighted it and then drove air through the mass by means of bellows. In this way they created a very hot fire which caused the molten iron to flow to the bottom of the pit. When this had cooled it formed a lump of iron to which a mass of cinders clung. The cinders were broken off from the iron which was then ready for use.

The process just described was a very wasteful one, because considerable quantities of metal were lost with the cinders. In England, until a short time ago, there were mounds of cinders which had been made many hundred years ago. There was so much iron among these cinders that it was found profitable to melt them over again.

For a long time charcoal was used in iron furnaces, but as wood became less plentiful, coal was employed in its place. But coal was not a very satisfactory fuel, as, among other reasons, it was too soft to hold up the heavy ore. Finally it was discovered that coke, which is the substance that remains after the gases have been driven off from coal, was a good substitute for charcoal. Now coke is used almost entirely for this purpose.

As early as 1624, iron was produced in this country, and soon after that date furnaces were established in some of the Eastern states. The making of iron spread rapidly as the country became populated. Now we get most of our iron ore from the region around Lake Superior. There is one mine in that district from which more than a million tons of ore are obtained each year.

As a general thing, iron is not now extracted from the ore at the place where it is mined, but the ore is transported to various centers located near large cities, like Pittsburgh and Chicago.

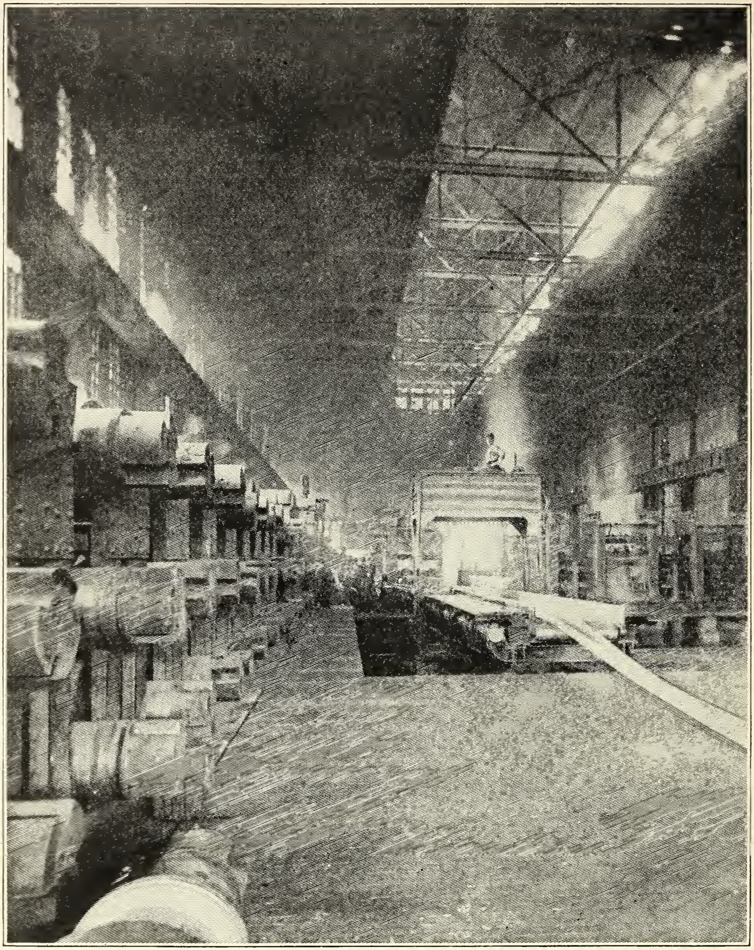
The furnaces used for extracting, or smelting, the ore are called blast furnaces. Some of them are a hundred feet high and are capable of producing from 600 to 700 tons of iron in a single day. Iron ore is dumped into the top of one of the furnaces and then a blast of air heated to a very high temperature is forced through it. The intense heat melts the ore, and the molten iron flows to the bottom of the furnace. Later, it is allowed to flow out into troughs where it cools off. The iron in these troughs is called pig iron, because someone long ago thought that the troughs filled with iron looked like little pigs.

Some of the pig iron is merely heated again and molded into bases for pillars and similar things, but most of it is used for making other kinds of iron and steel. Let us see what some of these products are.

Wrought iron is made by melting pig iron to which a quantity of iron oxide and another iron compound known as "hammer slag" have been added. When the molten mass collects under the furnace, it is stirred by a man called a "puddler," who rolls the iron and cinders into balls. The balls are then removed and put into a pressing machine which squeezes out most of the impurities. This type of iron is very serviceable where moisture is present, because it does not rust rapidly.

A quite different kind of iron, called malleable iron, is also made from pig iron. This is softer and less brittle than other kinds of iron and can easily be pounded into various shapes. It is often used in electrical machines.

What is the difference between iron and steel? They are both made of iron with small amounts of other elements, but the proportions of these other elements which are used are not the same. The greatest difference, however, between iron and steel is in the crystals of which they are composed. In steel the tiny crystals, which cannot be seen without the aid of a microscope, are more regularly arranged than they are in iron. They are also more closely packed together and their flat edges fit together more exactly than do those of which iron consists. This arrangement of the crystals makes steel much tougher and stronger than iron. You know how different the steel in a knife blade or in a needle is from the iron in a bolt or a hinge. You could not make a knife blade or a needle from iron, for iron will not take a sharp edge as steel will.



Photograph by Underwood and Underwood

Interior of Steel Plant

Steel varies greatly as to quality and as to the process by which it is made. The differences between the various kinds of steel are caused principally by the different amounts of carbon, manganese, and silicon that they contain.

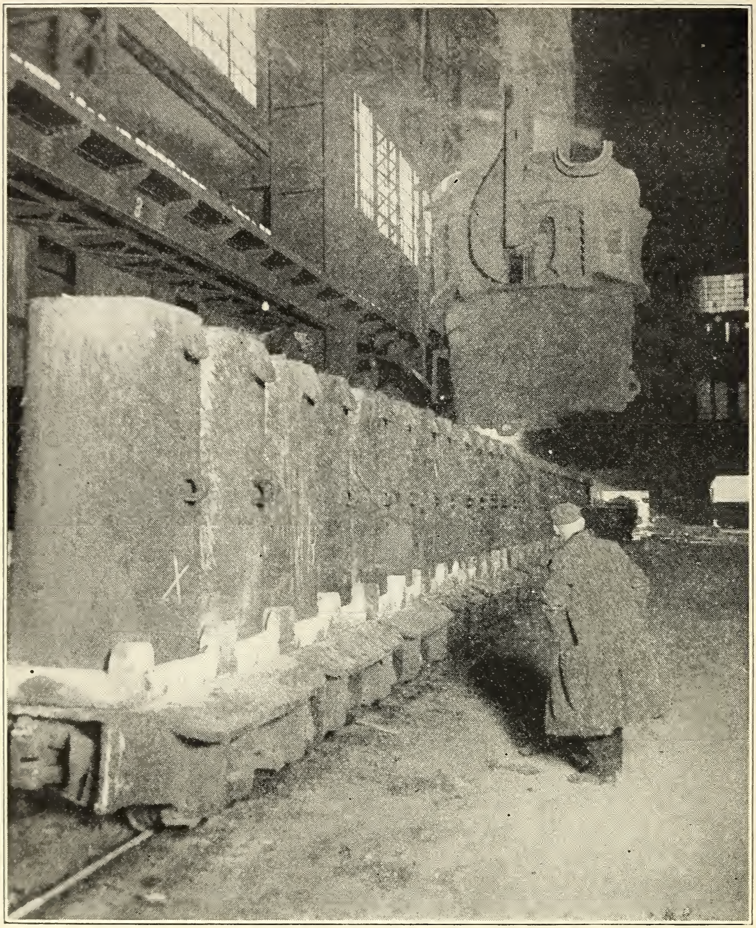
The method of making steel that is in most general use is called the basic open-hearth process. Scrap iron, pig iron, and lime are heated in a furnace. The purpose of the scrap iron and the lime is to combine with the impurities in the iron so that it can be separated from them. After about ten hours the molten metal is allowed to run out into molds, and after it has partially hardened, the ingots, as the masses of steel in the molds are called, are placed in an oven heated to a temperature of about 2000 degrees. The steel is now rolled out into rails, flat plates, and objects of many other shapes.

The Bessemer process is also employed on a large scale. Instead of adding scrap iron and lime to the molten pig iron to remove the carbon and other foreign substances, hot air is blown through it. The air accomplishes the same thing and it does it in a more thorough manner. The result is that all of the carbon, manganese, and silicon are removed, which makes it necessary to add the requisite amounts of each of these elements to the molten mass.

The best grade of steel is made by heating pig iron by an electric furnace. This method is therefore similar to the Bessemer process in that the impurities are removed by heat. Very satisfactory results are obtained because the heating can be better controlled than when other means are used.

Although still other methods of making both iron and steel are employed, there are no great differences between them and those which have been described.

It has been said that we live in an age of steel. In one



Photograph by Underwood and Underwood

Pouring Liquid Steel into Molds

sense this is true, for there is scarcely anything which we possess, or which we do, that does not, in one way or another, depend upon this metal. It would be impossible to supply the people of the world with enough food if we did not have the steel machinery which is necessary for farming on a large scale. Our clothing, whether it be wool, silk, cotton, or some other substance, is worked into cloth by means of machines made of steel. Steel enters into the construction of our homes and other buildings in many ways. If not actually used as building material, it is used in tools with which the buildings are constructed. We should have no railroads, automobiles, airplanes, or steamships if we did not have this metal. There are thousands of other things which could not be made without it. Without steel and iron the world would be a far different place from what it is today.

QUESTIONS AND TOPICS FOR DISCUSSION

1. Give the reason for using steel in buildings.
2. Tell how plants and animals depend upon iron.
3. Explain how the iron in our bodies differs from the more familiar form of iron.
4. How did ancient people extract iron from iron ore?
5. Describe other methods of producing iron.
6. What is wrought iron and how is it made?
7. Explain the difference between iron and steel.
8. Describe the Bessemer method of making steel.
9. What can you tell about other ways of producing steel?
10. Make a list of common uses for iron and steel.

THE PRECIOUS METAL

After the discovery of America, tales were carried back to Europe of untold riches in the new lands. Some of the returning voyagers said that the natives of America possessed gold in abundance.

Stirred by these reports, Spain and other nations sent forth many expeditions in search of this treasure. In 1519, Hernando Cortez, a Spaniard, in command of eleven ships and four hundred men, landed on the shore of Mexico. After burning his ships, in order that his men might not return to Spain should they become discouraged, he led his force into the interior of the country.

Montezuma, the king of the Mexicans, fearing the Spaniards, sent Cortez four cart-loads of gold and begged him to leave the land. This only encouraged the unwelcome visitors to speed their advance. The Mexicans then assembled in great numbers and attacked the Spaniards. In a battle, in which thousands of the natives were slain, the invaders were victorious, for their armor, fire arms, and horses made them superior to the almost defenseless Mexicans. At last, after killing Montezuma, the Spaniards made themselves masters of the country and seized all the gold that the Mexicans possessed.

The Spaniards were not the first people who made war for gold. Many of the conquests carried on by the ancient peoples, such as the Assyrians and the Persians, were undertaken in order to obtain the gold which their neighbors possessed. Much of the wealth of the great nations of the past was obtained in this way. Rome rose to the height of luxury and wealth by means of the gold which she took from conquered nations.

Although silver and other metals and rare gems have been held in high esteem, gold has always been the symbol of worldly wealth. Even today the principal currency of the powers of the earth is gold.

Gold possesses certain qualities which make it very different from other metals. It is one of the heaviest of metals, but it is so soft that it is rarely used without being mixed with another metal to give it hardness. If jewelry and coins were made of pure gold they would last only a short time because they would be worn away so rapidly.

One of the most remarkable things about this metal is that it can be pounded into sheets so thin that it would take over two hundred thousand of them to make a pile one inch in height. Gold leaf, as these sheets are called, is used for covering picture frames, furniture, church domes, and many other things where a highly polished surface is desired. A very little of it will go a long way when used in this manner.

This metal is particularly well adapted to covering other things, because it never unites with the oxygen in the air as iron and steel do to form rust which causes them to wear away.

Much of our jewelry is composed of a low-priced metal like brass which is covered by a thin layer of gold, that is to say, it is gold-plated. The gold covering of such jewelry is not gold leaf, like that used for picture frames, for gold leaf would not cling to another metal tightly enough and it would be too thin. Gold plate consists of very small particles of the metal that are made to cling to the other substances by the use of electricity and other means.

The gold that was first mined was made into ornaments. Later, when men began to use coins instead of exchanging one thing for another, it was one of the metals that were used for this purpose.

This metal is widely scattered over the earth's surface. In fact, there is hardly a country in which it has not been found, but it is only in a few places that there is enough of it to make mining profitable. Most of the present supply comes from South Africa, the United States, including Alaska, Australia, Mexico, and Canada. South Africa contributes more than any of the other countries. The value of all the gold that is mined each year varies between three and five hundred million dollars.

Gold is one of the few metals that is usually found in a pure condition. That is to say, it is not combined with other elements. Platinum, silver, and copper sometimes occur in this form, but the rest of the metals are usually united with different substances in various ways. A high degree of skill is required to separate a metal from other elements with which it is combined.

The fact that gold is found in the metallic condition accounts for its having been known so early in the history of the world. The ancient peoples never suspected the presence of most of the metals in the rocks because they could not see them. Even had they known that metals were present they would not have known how to extract them.

Gold, as a usual thing, is found in streaks or veins of quartz, which fill cracks in other kinds of rocks. Gold-bearing quartz is very beautiful because the yellow metal lies among the crystals, some of which are as clear as diamonds.

In some places, streams passing over rocks containing gold-bearing quartz veins have worn channels through them and have carried away fragments of the quartz. These fragments and gold nuggets from them have settled in the stream beds farther down the valley. Very rich deposits of this kind have been found. Only the simplest types of mining methods are necessary when gold is found in stream beds.

Some of the richest mines have been discovered by first finding the gold on the surface of the ground in places where it had been deposited by the streams. By following the stream beds upward the miners located the veins from whence it originally came. They were then in a position to mine the "mother lode" as such a vein is called.

The gold-bearing rock from such deposits is shoveled into long troughs through which water flows. As the rock

Photograph by Underwood and Underwood

Placer Mining near Grants Pass, Oregon

is carried down stream, the heavy gold settles in pockets in the bottom of the troughs, while the rest of the material passes onward. Often streams of water from huge hose are played upon the gold-bearing earth and rock which is thus washed into the troughs.

Placer mining, as this process is called, is very wasteful because much gold is washed away with the gravel. This was the method used by most of the miners in the great California gold rush in 1849. It is still employed in many mines in our country and Alaska.

Some of the great gold mines, like those in South Africa, extend several thousand feet down into the earth. It is therefore necessary to employ heavy machinery in order to bring the ore to the surface and to handle it afterwards.

Great machines are necessary to raise and lower the elevators in the shafts, which in some cases are a mile long. Electric power plants furnish power and light for the work underground. The crushing of the rock requires heavy machines above ground. Since a great deal of the work done in extracting gold from ore is done by chemicals, elaborate chemical apparatus is needed.

One of these mines consists of a great shaft which is dug straight downward into the ground with tunnels branching sideways that lead to the veins of ore. Along the floor of one of these tunnels are the tracks over which run the cars that carry the ore to the elevators in the main shaft. These tracks are extended as fast as the tunnels grow in length, so that it is always possible to load the ore directly on to the cars. The tunnels are equipped with electric light lines which are built as fast as the tunnels increase in length.

In order to loosen the rock from the tunnel walls the miners drill holes into it. They then fill these holes with dynamite, the explosion of which tears the rocks apart. The work of the miners is very dangerous because of the flying rocks caused by the explosions. In addition, there is also danger from the falling rocks which might close the tunnel and imprison the miners.

When the gold-bearing rock has been carried to the surface it is placed on sorting tables. Here it is examined by men who are skillful in separating the rock which contains gold from that which does not. The gold-bearing rock is then carried to a place where it is broken up into smaller pieces by a crushing machine. The purpose of this machine is to reduce the size of the pieces of rock so that they can be put into the "stamping" machine.

This machine has plungers weighing several hundreds of pounds which strike the pieces of rock and break them up into small fragments. After the stamping machine has done its work, the fragments are ground between rollers which reduce them to the size of sand grains. This sand after being mixed with water is ready for the "mercury" treatment.

The mixture is caused to flow onto a table which constantly vibrates. On this table is a quantity of mercury, or quicksilver, with which the gold unites and forms a chemical combination, called an amalgam. Since this amalgam consists of two heavy metals it can easily be separated from the worthless sand, because when they are shaken the amalgam sinks to the bottom.

After the amalgam has been separated from the sand, it is heated to a high temperature. This causes the mercury to form a vapor, which rises from the mass a good deal as steam might. The gold meanwhile remains as a molten metal. The mercury vapor is drawn off into a vessel, or compartment, leaving the gold uncombined with anything else. It is next run into molds where it hardens into bars, called ingots. In this form it is shipped to all parts of the earth.

Not all of the gold which was in the sand after it came from the rollers combines with the mercury into an amalgam. Some of it still remains with the sand. This gold is separated from the sand by an entirely different procedure, called the "cyanide" process. The gold-bearing sand is put into a vat containing a chemical, called cyanide of potassium. This chemical unites with the gold and removes it from the sand. The gold now has to be separated from this cyanide compound. The separation is sometimes made by means of electricity and, at other times, by the use of zinc. When the latter process is to be used, the gold-cyanide compound is put into a tank containing zinc shavings. As soon as this is done, the gold leaves the cyanide and unites with the zinc. It is then removed from the tanks and placed in crucibles, which are vessels that will not melt when heated very hot. The extreme heat causes the gold to separate from the zinc just as the gold which had united with the mercury separated from it. After the gold has been separated from the zinc, it is ready to be formed into ingots.

Sometimes the gold that is combined with the mercury and that combined with the zinc are put into the same crucible. The separation of the gold from both chemicals is thus brought about at the same time.

The methods just described are of recent origin, because it has been only in the past few years that we have understood the chemical processes which are involved. Until a few years ago the placer method, the method first described, was used, or the gold-bearing rock was heated until the molten gold ran to the bottom of the containing vessel. Another process commonly used in the West is the chlorination process.

Photograph by Underwood and Underwood

John Stark and His One-Man Gold Mine

Since gold is so highly prized, there are many men in search of it in all parts of the world. Whenever a new deposit is found, hordes of eager people rush to that region, and in a short time great mines are busy day and night removing it from the ground.

Although there is such a fierce struggle to possess this metal, the supply will never give out, as is the case with some other minerals, like coal. The reason for this is that gold is widely scattered over the earth's surface—there is hardly a country in which it has not been found. In all probability, there are deposits of gold in many parts of the earth far greater than any yet discovered. It is therefore barely possible that gold may some day become as cheap as copper or tin, but it will always be sought because of its usefulness and beauty.

The last illustration shows John Stark of Stark mountain, in the Kalispell district of Glacier National Park, at the opening of his gold mine claim. This is the only one-man gold mine in the national parks and it is in the haunts of thousands of tourists. Mr. Stark has a mining claim antedating the Act of Congress of 1910, creating the national park, and does enough work annually to hold his claim. While tourists proclaim the mountain a thing of beauty, John Stark calls it a mountain of gold.

QUESTIONS AND TOPICS FOR DISCUSSION

1. Tell the story of Montezuma, the king of the Mexicans.
2. How was much of the wealth of the great nations of the past obtained?
3. Name some of the important qualities possessed by gold.
4. Where and how is gold generally found?
5. Explain some of the methods by which gold is mined.

6. Describe the interior of a gold mine.
7. Explain how gold is separated from rock.
8. What is the cyanide process?
9. Why is gold so important to man?

Radium is the most costly substance in the world. A single pound of this metal would be worth in the neighborhood of a hundred million dollars. It is obtainable in such small quantities that no one has ever been in possession of more than a few grains of it. The mere fact that it is extremely hard to get does not account for the high price men are willing to pay for it. Its value lies in the remarkable properties which it possesses.

This metal is the greatest source of power known to man. The rays which a single car-load of it would give off would furnish enough power to run all the engines in the world for a long period of time, and, in addition, would give all the heat that is needed for every other purpose. One of the most interesting things about it is that it can be produced from another metal, named uranium, and that it can be changed into lead. It thus proves that one metal can be transformed into another, which is the very thing that the alchemists of old were trying to do when they sought to make gold from other substances.

Radium is capable of destroying living animal cells. For this reason, scientists hope to find in it a cure for cancer, which is a disease resulting from the too-rapid growth of cells in a particular region of the body. Sufficient success has been achieved in stopping this rapid growth of cells to lead the physician to expect great things from radium in the future.

This metal is found everywhere in nature. The waters of the world, the atmosphere, clay and other minerals contain it in minute quantities, but it is so thinly distributed that man is able to obtain it only after great labor and only in the smallest particles. It is possible that much of the good which we get from sunlight, fresh air, and mineral waters comes from the minute particles of radium that they contain.

Though we know of no other metal as valuable or as interesting as radium, there are many others that have properties that make them valuable to man. You have already been told about iron and gold. Among the remaining metals are silver and platinum, which are also valued for their beauty and peculiar qualities, and copper and aluminum, which, next to iron, contribute most to our daily needs. There are others also, which we shall consider later.

Silver, like gold, is found in many parts of the world, but most of it comes from the United States, Mexico, and South America. While some silver is found in the metallic form, much of it occurs as an ore. A large portion of the silver mined today is in rock that contains copper. In fact, many of the mines from which silver is obtained are really copper mines, the silver occurring in small quantities.

One of the most noted silver mines of the world is the Cerro de Pasco, of Peru, South America. This mine has large historic interest. It was being worked by the native Incas as far back as the early part of the sixteenth century at the time of Pizarro's conquest of Peru. From it was taken much of the silver which he sent back to Spain. The mountain is claimed to be a mass of practically solid silver, and is very easily worked.

Silver is fairly soft, and, next to gold, can be most easily worked into desired shapes, a characteristic which renders it particularly useful for making jewelry and other ornaments. It can even be drawn out into fine threads which are woven into cloth, as is often done with gold.

This metal does not rust as iron does when it is exposed to moisture, though it does turn dark, or tarnish, when substances containing sulphur come in contact with it. It is because of the sulphur compounds in the air that silver has to be polished so often. If you have ever polished silver, you know that tarnish is easily removed.

Photograph by Underwood and Underwood

THE CERRO DEPASCO SILVER MINE

Chemicals known as alkalies do not react upon this metal. Chemists when working with alkalies sometimes employ vessels made of silver, because there is no danger of chemical combinations forming between the silver vessels and the substances that are in them.

In electrical work where it is necessary to have the current flow freely, silver is frequently used, because it is one of the best conductors of electricity known; that is, electricity flows through it very easily. The same thing is true concerning heat, for it travels through silver very rapidly. This is the reason that silver spoons in hot liquids become heated so quickly.

Silver, as you know, is used for making coins, but since it is so soft, it has to be mixed with some other metal, like copper, to give it the proper degree of hardness. If this were not done, coins would very soon wear down to almost nothing.

Large quantities of silver are employed in photography and in the making of mirrors, while certain forms of it are used as medicine.

Platinum is very similar to silver in appearance. It is a very rare metal, being found in only a few parts of the world, the most important of which are Colombia in South America and Russia. It is an extremely costly substance, not only because of its limited supply, but because it is in great demand for making the best grade of jewelry.

Platinum does not rust like iron, nor does it tarnish like silver, because it does not combine with moisture or sulphur. In fact there are a good many chemicals which do not have any effect upon it. For this reason, the chemist finds this metal very valuable because he can use it as a vessel to hold certain chemicals. For example, he can heat acids in platinum vessels without having any chemical change take place in either the acids or the vessels. There is one combination of acids, though, which destroys platinum. This is a mixture of hydrochloric and nitric acids. Platinum is also highly valued by the chemist, because it will withstand high temperatures.

Platinum is like gold in that it can be hammered out into extremely thin sheets and drawn out into very fine wires. Also, like gold, it is usually found pure in nature and consequently can be easily mined.

Since this metal expands and contracts with heat and cold in about the same way that glass does, it is used in the manufacture of electric light globes and other apparatus where it is necessary to pass a metal through glass. A metal which expands or contracts, that is to say, grow larger or smaller, at a different rate than glass does, would not be satisfactory for this purpose, because it would either separate from the glass or would break it. Among the many arts and sciences that make use cf this metal are photography and dentistry.

We now come to copper, one of the most useful of metals. Copper was one of the first metals known to man, since much of it is found in the metallic form in nature. It is easy to believe that the people who first discovered it were quick to realize that many things could be made from it because it could so easily be pounded into various shapes by the crude instruments which they possessed.

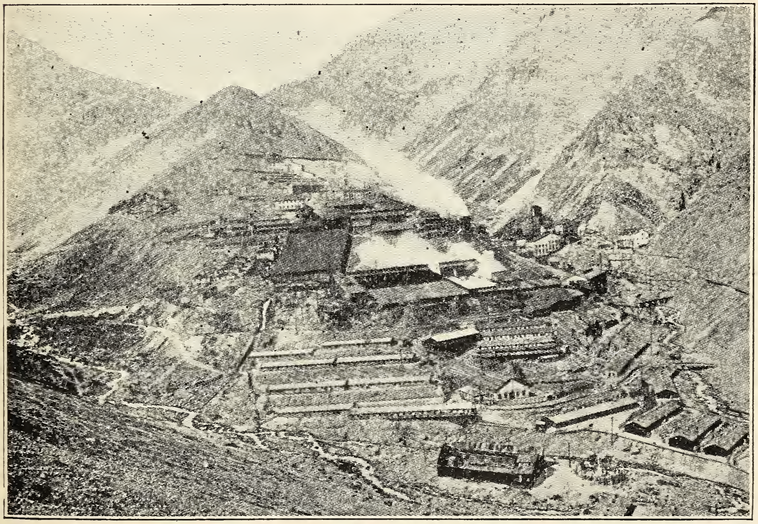
Many copper weapons and tools made by ancient peoples have been found in various countries. Copper was one of the first metals used for making jewelry, ornaments, and coins.

This metal is too soft to be very durable; so even thousands of years ago men learned to mix it with other metals. By combining it with zinc, they produced brass, and by melting it with tin, zinc, and lead, they produced bronze. For ages these two metals have been used for numberless purposes and we still use both of them for making such things as door knobs, hand rails, and statues.

Copper is particularly useful in the electrical industry, because it is an excellent conductor of electricity. Most of our telephone and telegraph wires are made of this metal, as are many parts of radio outfits, electric lighting machines, and other things.

This metal is found in various parts of the earth, but the largest mines are in the Lake Superior region of our own country. South America also provides large quantities where much of it occurs as a metal. Almost a million tons of copper are mined each year throughout the world.

Aluminum is another very useful metal. It is found in all parts of the earth in ordinary rocks and would be the cheapest of all the metals if it were not for the difficulty of extracting it from the minerals with which it is combined. Although



Courtesy Guggenheim Brothers

The Braden Copper Mines, Chili, South America we knew about aluminum long ago, our inability to obtain it on a large scale kept it from coming into general use; but recently the skill of the chemist has taught us how to overcome this difficulty. It is now found in every household, taking the place that was formerly filled by copper and other metals.

The most noticeable thing about aluminum is its lightness. Because of this quality, it is widely used in the construction of air-planes, boats, automobiles, and other machines where the factor of lightness is important. Aluminum has several other desirable qualities. It is tough, does not easily break, and is a good conductor of electricity. It can be hammered out into very thin sheets which are used in the form of aluminum foil for covering food. It can also be drawn out into extremely fine threads, but not to the extent that gold can.

Another very important thing about this metal is that it does not rust easily. As a result, large quantities of it are used for making cooking utensils, chemical apparatus, and vessels for other purposes where moisture is present. Besides, acids do not act very readily on aluminum, which makes it very useful to the chemist.

We are using aluminum more and more for the purposes for which the other metals and wood have been used in the past, because it possesses the valuable qualities which have been described.

Among the other metals that are found in every household are tin, zinc, lead, and mercury.

We are all familiar with tin, because it forms a coating around tin cans, tin cups, etc. Tin is used principally as a protection for other metals. Tin vessels are really thin sheets of iron which have been dipped into melted tin to keep them from rusting. Often copper and brass articles are protected from moisture in the same way.

One form of tin which is a liquid is applied to cotton, silk, and other goods to make them fireproof.

This metal comes principally from England, the East Indies, and Bolivia, there being about 100,000 tons mined each year.

Zinc, like tin, is employed for protecting other metals from moisture. Some of the things for which large quantities of it are used are gutters and leaders for carrying rain water, for covering iron netting, iron roofing, metal tanks, and water pipes. It is used in separating lead from silver when the last two substances are present in the same ore. It also furnishes us with a kind of paint called Chinese white. In addition to these uses there are many more, such as supplying one of the principal parts of electric batteries and furnishing us with zinc ointments used for certain diseases.

Most of the world's supply of zinc comes from Spain and the United States, about a half million tons being mined every year.

Lead is also a very familiar metal, for everyone has seen the lead pipes which bring water into houses. Most everyone has seen lead bullets and lead type which is employed by the printer. It forms a large part of most of our paint, and it enters into the composition of most of our glass. Since it is very heavy it is employed where weight is needed, as in a base for lamps and keels for boats.

Most of the world's supply of lead is found in the United States, Spain, and Mexico, the United States furnishing about one-third of the world's supply. Still, it is found in some other parts of the earth. It is not found in the metallic condition, but usually in a chemical compound called galena. The mining of lead is a great industry, about a million and a quarter tons being produced annually throughout the world.

You are probably familiar with mercury, the shiny metallic liquid used in thermometers. This metal is found mostly in Spain, Italy, and California. It occurs partly in the metallic state and partly combined with other substances.

Mercury plays a very important part in the extraction of gold from its ore, as you have already learned. It is made into an ointment for killing bacteria of certain kinds. But bacteria are not the only forms of life that this element will kill, for it is a deadly poison to man and other animals.

There are many metals besides the ones which we have told you about. Some of them are of no practical value, while others are extremely useful, like tungsten, which is used in electric globes. It is probable that as time goes on uses will be found for some of the metals which are now valueless, like rhodium; and that metals, like tungsten, which are now employed for only a few purposes will eventually be utilized in many new ways. Furthermore, it is probable that in the course of time new metals will be discovered.

QUESTIONS AND TOPICS FOR DISCUSSION

1. What is radium and why is it so valuable?
2. Explain where radium is found and describe its uses.
3. Name some of the qualities of silver.
4. Why does silver need to be polished often if exposed to the air?
5. Make an outline of the uses of silver.
6. How does platinum differ from other metals?
7. List the uses made of platinum.

8. Why do we say that copper is one of the most useful of the metals?
9. Enumerate some interesting facts about aluminum.
10. What can you tell about the use of tin?

The source of San Francisco's water supply is a mountain stream situated over two hundred miles away. In order to conduct the water across the intervening country it was necessary to construct a waterway, or aqueduct, through hills and over valleys. Over one hundred miles of this waterway consists of a great pipe made of steel and concrete. The San Francisco aqueduct is one example of the many important uses to which concrete, one of the most remarkable products of man's genius, has been put.

Concrete looks like stone, but it is not quarried from the ground as stone is, although the substances of which it consists do come from the ground. Crushed stone, cement, sand, and water, and occasionally gravel, are its ingredients. The most important of these is the cement, for it holds the hard substances together.

Anything which holds other substances together is called a cement. Since there are many different materials which must be united, there are various kinds of cement. Cement that will hold two pieces of glass together will not do for rubber. We shall not tell you about all the different kinds of cement, but shall confine our attention in this chapter to the cement that is used for building purposes.

Though the process employed in the manufacture of building cement is fairly simple, the making of this useful material has a history that dates back many centuries. The Egyptians and Babylonians cemented bricks and stones together by means of wet clay, but the buildings thus con-

Photograph by Publishers Photo Service

The Pyramid of Cheops

structed were not very durable, since the clay rapidly crumbled, due to the action of the weather. It is not surprising that such structures did not last long.

You have no doubt read about the great pyramids erected by the kings of Egypt. These huge monuments were made of heavy stones which were cemented together by a white mineral, called gypsum. The Egyptians heated this mineral to a high temperature, and then powdered it up very fine. After moistening it with water and mixing it with sand they spread it between the building stones, where it hardened.

Even to this day we use gypsum for making a particular kind of cement, called plaster of paris. We use it for many purposes for which no other kind of cement is satisfactory. One of the most important uses to which plaster of paris is put is the lining of ceilings and walls of our dwellings.

Centuries after the Egyptians had built the pyramids, the Greeks powdered up granite and mixed it with water and sand and a kind of earth called pozzuolana which they found near volcanoes. This mixture made a very strong cement which could be used where salt water was present.

The Romans were skillful in the preparation of cement. With its aid they constructed sturdy stone buildings, many of which are still standing. After the decline of Rome nothing new concerning the making of cement was learned for hundreds of years.

About the middle of the sixteenth century the English produced cement that again contained pozzuolana, similar to that which the Greeks had made so long before. But it was difficult to get pozzuolana because there were only a few places in the world where it could be obtained. The result was that there was a great deal of experimenting done in order to find a substitute for this mineral.

In 1824, an Englishman, named Joseph Aspdin, took out a patent for a mixture which he called Portland cement for the reason that it looked like limestone quarried at Portland Isle, England. The first results were not very satisfactory, because he did not heat it enough. But he soon found his mistake and corrected it. This was the real beginning of the kind of cement that we use today.

Portland cement has been made in this country since 1872. When we first began to make it, we mixed limestone with shale, a hard form of clay, or we used limestone that contained a considerable amount of clay. At first we were not very careful as to the proportionate amounts of the materials used. We simply used about the same quantities that had given good results before.

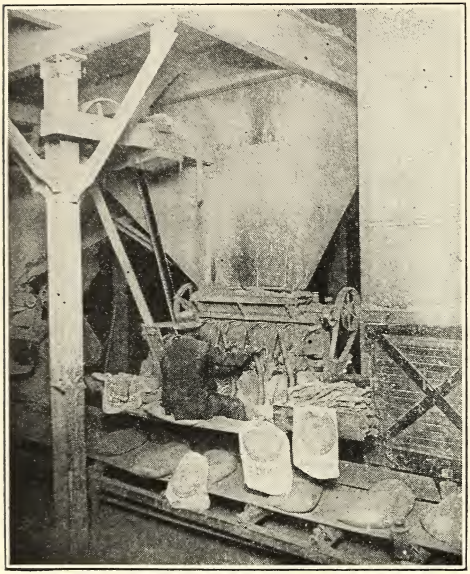
After grinding up this mixture, we moistened it with water and then molded it into bricks which we burned in a coal fire. The clinkers which resulted were removed and ground up into fine powder. The cement thus obtained was not always satisfactory, because the ingredients were not always mixed in the same proportions. Furthermore, the bricks were not equally heated.

After a time we learned to produce a cement which was always of the same quality. We stopped guessing as to the amounts of the substances used and employed chemists to find out just what minerals were in them. We were also more careful to see that they were more thoroughly mixed and that they were properly heated.

At first the English and Germans produced the best grade of cement, but now we make better cement in the United States than is produced in any other part of the world. You can readily understand that the manufacture of cement is one of the most important industries in which we are engaged when you know that there are more than one hundred different cement plants in the country. Each year these plants make over one hundred and fifty million barrels of cement.

In order to make Portland cement it is necessary to have three different minerals—lime, silica, and alumina. The greater part of the earth's crust consists of these substances in various combinations. Though they are widely distributed, it is only in certain places that they occur pure enough or in proportions which render them suitable for making cement.

Usually we employ limestone and clay for making cement, because these minerals contain the three elements required. Sometimes we find clay and limestone mixed, but usually there is not enough of at least one of these minerals, so we have to add the proper amount of any that is lacking. Sometimes these minerals occur in the dry state and sometimes they are moist. We are therefore forced to employ two different methods in making cement.



Photograph by Underwood and Underwood

Bagging Portland Cement

When these minerals occur in the dry state, the rocks containing them are blasted and broken up into pieces small enough to be handled. Then by means of steam shovels the broken pieces of rock are loaded on cars which carry them to the mill. The rock is again broken into smaller fragments. It is next tested to see if the proportions of the required minerals are correct. If so, all is well; if not, the necessary substances are added. The rock is now heated to remove any moisture which may be present and again crushed into still smaller pieces.

The next step is to heat the rock to a very high temperature in an apparatus called a rotary kiln. These kilns are revolving cylinders of steel from one to two hundred feet in length and from six to ten feet in diameter. They are so mounted that one end is higher than the other. This causes the material which is put into the upper end to pass to the lower end as the cylinders turn slowly around.

The heat is produced by burning coal gas or some other fuel at the lower end. The flame which results extends from thirty to forty feet into the cylinder. You can see that as the material passes down the cylinder it keeps getting hotter and hotter. Finally when it reaches the lower end it forms into clinkers. These clinkers, which are considerably less than an inch in diameter, are now ground up into a very fine powder. This powder is Portland cement.

When the materials which contain the lime, silica, and alumina are in the wet condition, different methods have to be employed. Sometimes they are scooped up by means of dredges, at other times they are pumped through pipes to the mill. In either case the mudlike mixture is put into tanks where it is examined by chemists who determine what minerals are present and the quantity of each. Any necessary amounts that are wanting are now added just as was done in the dry process. After being dried the materials are thoroughly mixed so that there will be an even distribution of the minerals throughout. The same method is now employed as was followed in the dry process.

Usually a small amount of gypsum is added to the broken rock before it is ground into powder. This is done to make the cement harden more slowly when it is mixed with water.

You have learned how Portland cement is made. Now let us see what happens when it is used for making concrete. Concrete is made by mixing sand, cement, and water. Sometimes gravel is added, depending upon the use to which the concrete is to be put.

When Portland cement is mixed with water, certain changes take place in some of the chemicals of which it consists. Some of them unite in such a way that they become somewhat like liquid glass. It is this substance that causes the different particles of sand to stick together. Part of the thick liquid turns into crystals, while the rest of it merely hardens. It takes some of the chemical compounds longer to change into the solid state than it does others. When these compounds have all become solid we say that cement has "set."

It is easy to see why man has been so slow in perfecting cement, now that we understand how difficult it has been to learn what substances are necessary, what proportions of them must be mixed together, and what processes must be followed to produce the desired result.

Concrete has numberless uses. It enters into the foundations of most of our buildings. The framework of our great steel structures, rising fifty or more stories above ground, are embedded in masses of concrete which support the great weight. The railroad tunnels under rivers are made partly of concrete, as are the great aqueducts which have been described. Many of our modern dams, bridges, and breakwaters are constructed of this substance. Sidewalks, floors, and similar things are often made of concrete.

We do things today on a large scale. The ease and rapidity with which concrete structures can be built make this substance particularly adapted to this progressive age. But we must remember that concrete owes its existence to cement. Since cement is the product of the labor and thought of our forefathers, we, in turn, owe them a great debt for giving it to us.

QUESTIONS AND TOPICS FOR DISCUSSION

1. Name some examples of the uses made of concrete and cement.
2. Describe what is meant by the following: gypsum, plaster of paris, pozzuolana.
3. Explain the method used by Aspdin in making cement.
4. What can you tell about the cement industry in the United States?
5. Describe two modern methods of making cement.
6. How does concrete differ from cement?
7. What changes take place in Portland cement when mixed with water?
8. Why is it necessary that the ingredients of cement be mixed in definite proportions?
9. Name some uses of concrete.
10. Write a composition on the subject "What modern builders owe the past."

CENTURIES OF GLASS

According to Pliny, a Roman writer who lived about two thousand years ago, Phœnician sailors on one of their voyages to Syria built a wood fire on a sandy beach. Since there were no rocks at hand, they brought lumps of soda from their boat and built a wood fire between them. Then a strong wind made such hot flames that they melted the soda and some of the sand. The fusion of the melted soda and sand with the ashes from the fire produced the first glass known to man.

Whether the Phœnicians were really the first makers of glass we do not know, but, whoever they were, they probably just happened to make it in about the way that Pliny described.

At any rate, we know that the people of Sidon, a city in Asia Minor, were in possession of the secret of the manufacture of glass many centuries before Christ. They guarded their secret so well that they alone for centuries were able to make this substance. Then gradually the peoples that lived around the Mediterranean Sea learned how to make it.

Most of the glass that was made by the ancient peoples was of a poor quality and only small quantities of it were produced, because the makers did not understand just what substances should be used nor in what proportions they should be mixed. Sometimes they were able to produce specimens of very fine glass but more often the products were of a poor grade. Because of these difficulties good glass was rare and costly. Glass was used almost entirely by the ancient peoples for making such things as ornaments, vases, and urns.

Later, when the Romans became skillful in its manufacture, a cheaper grade was produced, and for the first time in history we find it being used in windows, but it was still so costly that only a very few could afford to possess it. The Romans are remembered for the beautifully colored glass which they made as well as for the exquisite workmanship which is seen in their glass vessels.

Then, hundreds of years later, the people of Venice, Italy, produced glass of an unusually beautiful kind. It was not of good quality, because it was filled with imperfections and impurities, but it was nevertheless more beautiful than that which we make today with all of our knowledge and skill. Its imperfections accounted for its beauty, for the rays of light on meeting them produced all colors of the rainbow. The Venetians guarded their secret just as the people of Sidon had done. They even went so far as to send men into foreign countries to kill any of their number who attempted to reveal their secret.

Later, the Bohemians manufactured colored glass of unusual beauty which for years no other people could equal.

It was not until about three hundred years ago that glass was produced which everybody could afford to possess. This was the result of the discovery made by several Englishmen of a kind of glass, called flint glass. From then on this substance was commonly used for window panes, dishes, and similar things.

The English continued to improve in their ability to manufacture glass, and before long they were making heavy plate glass and lenses for instruments like the microscope and the telescope.

Later, the Germans developed the art of making lenses, until their products surpassed anything that the English had made. Until very recently, German-made lenses were the best in the world, but now we Americans are in possession of the secrets of lens-making and are rapidly taking the lead in their manufacture, as we are in other branches of the glass industry.

Let us see how glass is made today. Since this substance is required for such a great variety of purposes, many different methods of manufacturing it are employed. Bottles require one method and window panes another. We cannot make plate glass in the same way that we make lenses for field glasses. Furthermore, the chemicals used vary with the kind of glass that is to be made.

Let us first consider the making of bottles by hand, because this method is the easiest to understand. Most bottles are now made by machinery, but some are still made by the process we are going to describe. A mixture of white sand, limestone, and soda is heated to a very high temperature in earthen vessels until it flows almost like water. While it is very hot, some of the chemicals present pass off in the form of gases. After the hot glass has cooled off until it is just thick enough, a man called a glass blower places one end of a tube in it and then turns it around until a lump of soft glass clings to the tube.

He next blows into the open end of the tube until the glass takes the form of a bubble, just as you used to do when you blew soap bubbles. He continues to blow into the tube until the bubble of glass becomes the size that he wishes, when he places the bubble of glass which still clings to the tube in an

Photograph by Underwood and Underwood

Molten Glass Being Taken from Furnace

iron mold. This mold consists of two pieces of iron, which when placed together have a space between them shaped like a bottle. He again blows into the tube until the bubble has taken the shape of the mold. After the glass has cooled off sufficiently, he removes it from the mold and cuts its neck at the right distance from the bottle. Then after all rough parts have been polished down, the bottle is ready for use.

This method is used for making such things as tumblers, vases, and dishes, but it is not very widely employed nowadays, because much more satisfactory work and bottles in far greater quantities can be produced by machinery.

Now we will see how window panes are made. A bubble of hot glass is stretched out until it becomes a wide tube. This tube is then cut lengthwise, and the curved glass is heated again and flattened out into a sheet which is cut into window panes.

There is another kind of glass used for making large window panes, called plate glass. It is employed also for making mirrors, table tops, and similar things. It is very thick and clear and it is of uniform thickness throughout, while ordinary glass varies in thickness even in the same pane. Plate glass is not first drawn into a cylinder as is ordinary glass. Instead, molten glass is allowed to flow onto a flat surface where it is rolled out by a great roller which makes it all of the same thickness. After being allowed to cool, which sometimes takes several days, depending upon the thickness of the glass, it is polished and cut as desired.

Sometimes it is necessary to employ glass which will not shatter if broken. Glass of this kind is used in windows far above the street where there is danger to people passing

Photograph by Underwood and Underwood

Polishing Plate Glass for Windows

beneath if fragments of broken glass should fall. For this and similar purposes two sheets of plate glass are sometimes cemented together after wire netting has been placed between them.

Some of the so-called bullet-proof glass is made by cementing several sheets of plate glass together. A pane of this glass an inch thick will resist a bullet fired from a gun situated at a distance of a few yards. This kind of glass is particularly useful in banks and in armored motor cars which carry money and other valuables.

The lenses of such things as telescopes, microscopes, and eye-glasses require far purer glass than is needed for ordinary purposes. It is necessary to choose substances for making lenses which will allow rays of light to travel in a straight line. If this is not done these instruments cannot be used for the work for which they are intended.

The making of lenses is a very difficult process, because it is necessary to stir the molten glass for long periods of time in order to prevent the gathering of some of the chemical compounds in streaks. Even the slightest imperfection will ruin a lens designed for delicate work. Sometimes it requires years to obtain a block of glass which is perfect enough for use in large telescopes.

Most kinds of glass will break if subjected to sudden changes in temperature, but there is one kind made from a secret combination of chemicals that will not. Glass of this type can be used in the same way that earthenware dishes are used. While convenient for many purposes, it is particularly valuable to the chemist who frequently has to heat substances to very high temperatures.

Glass of almost every color is produced by adding the oxides of certain metals to the mixture of which it is made.

For example, green glass is sometimes produced by the use of the oxide of chromium.

Not long ago scientists began to make a new kind of glass from a mineral called quartz. This is different from any other kind of glass, since it can be heated very hot and suddenly cooled without breaking. It is different in another very important respect—one can sit in a room covered by ordinary glass for days without getting any life giving rays from the sun, but a person in a quartz-glass inclosed room would get as much benefit from the sun as though he were out of doors.

If you were to look through a bent sheet of quartz glass, you would see the objects on the other side as distinctly as though the glass were flat. This is because the rays of light can pass so freely through it. At the present time the cost of producing this glass is very high, which prevents its being used for many purposes. It is possible that means will be found of manufacturing it on a large scale at a much reduced cost.

Very few people realize just how much glass has done for us. It has enabled us to make microscopes by which we have learned a great deal about our bodies and the nature of many diseases. It has made it possible for us to discover the bacteria and tiny plants and animals that are responsible for much of the sickness in the world. Glass has given us the telescope and thereby the ability to understand a great deal about the sun and other stars and earths around us. It has given us eye-glasses, the X-ray tubes, electric light bulbs, radio tubes, watch crystals, and thousands of other things that have added to our health, happiness, and intellectual advancement.

QUESTIONS AND TOPICS FOR DISCUSSION

1. What was Pliny's story of the first glass making?
2. Explain the difficulties in glass making experienced by early people.
3. How did the Bohemians, Romans, and English improve glass making?
4. Describe a method of making tumblers and vases.
5. In what manner does the making of window glass differ from other methods?
6. Tell how a lens is made.
7. How does quartz glass differ from other glass?
8. Name some of the advances in civilization due to glass.

THE WATER WE DRINK

About 250 years ago a Hollander, named Leeuwenhoek, examined a drop of water with a microscope. To his surprise, he saw minute bell-shaped objects moving in it. He could hardly believe his senses, for no one then dreamed of the existence of living things so small that they could be contained in a drop of water. As he watched, he saw the stalks by which the little bodies were attached suddenly contract, like coiled springs. The contraction caused the bell-shaped portions of the animals to leap through the water. These little animals, because of their resemblance to bells, were later given the name of bell animalcules.

Since Leeuwenhoek's discovery of the bell animalcules, scientists have described thousands of different kinds of microscopic animals. Some of them look like masses of jelly, while others are as elaborate and beautiful as snowflakes. Though most of these simple forms of life do no harm to anyone drinking water that contains them, some of them are capable of producing deadly diseases.

In addition to microscopic animals, scientists soon discovered that water sometimes contains forms of plant life which cannot be seen by the unaided eye. Among these minute plants are bacteria, some of which also carry disease.

For centuries, since no one knew that water could carry disease-producing plants and animals, no attention was paid to the source from which drinking water came. Had just ordinary care been taken to secure pure water, countless lives would have been saved down through the ages.

Water, like food and air, is necessary to our very existence. This is so because it enters into the formation of all parts of our bodies, and because it is the fluid which carries matter to and from the cells of which we are made. Since water is constantly being lost along with the waste matter which it carries to the outside, it is necessary that other water enter our bodies to replace it.

Although Nature, by making us thirsty, lets us know when we need water, she does not always tell us when water contains things that are not good for us. Of course, impure water often has such a disagreeable smell or taste that we avoid it, but sometimes it contains disease-producing germs or poisonous substances which do not affect our senses enough to warn us of their presence.

Sometimes chemicals are present in such small quantities that they do us no harm unless taken into our systems for long periods of time. For example, it is known that one may, and for some considerable time, drink water bearing much lime, without apparent harm. But it is believed by many scientists that if that practice is continued indefinitely, say for years, the slow accumulation of this chemical may have a serious effect on the health.

Water, as you know, is used for many other purposes than for supplying our body needs. Some chemical processes require water as pure as that which we use for drinking purposes. Even the water which is used for making steam must be free from minerals like lime, because such substances are deposited on the insides of the boilers when the water changes into steam. A thick coating of lime sometimes interferes with the heating of water to such an extent that much more heat is required than would be needed if there were no such coating. If acid is present in the water used in boilers, it may attack their linings and finally eat them away.

Electric batteries used for automobiles and other purposes require distilled water, which is water that has been freed of all impurities. If there are impurities in water used for such purposes, the action of the chemicals on the battery may be interfered with.

Water which is used for washing clothes must be reasonably free from mineral substances, because some of these may injure the materials which are being washed or interfere with the cleansing of them.

There are other impurities which, while they do no actual harm, are undesirable, because they give water an unpleasant smell or taste. There are certain tiny plants and animals which are sometimes very troublesome in this respect. Several years ago the New York City water contained such large quantities of a species of single-celled animal, called Synura, that they gave it an oily taste. Although these animals did no real harm, they made the water unfit to drink.

How does it happen that impurities get into water? To answer this question we must see where water comes from and what happens to it before it reaches us.

You know that all of our water comes, in the first place, from the ocean. In the form of water vapor it rises into the air, from the sea and from the land, and then falls to the earth as rain, hail, and snow. As these forms of moisture drop downward, they collect any impurities, such as gases, dust, and germs, which may be present in the air. Rain water often has a disagreeable taste due to the presence of such impurities. While all water in its passage through the air collects some impurities, they are seldom absorbed in sufficient quantities to be a source of danger. But after water reaches the earth, it comes in contact with all kinds of substances, some of which pollute it. It may become contaminated by disease germs, like those which cause typhoid fever, if it flows through ground containing these germs. Before we understood how sewerage should be disposed of, and when we used wells that were not protected from water coming from impure sources, this disease was frequently carried by drinking water. Water which flows over ground where there are decaying plants or animals may collect disease-carrying germs or chemical poisons.

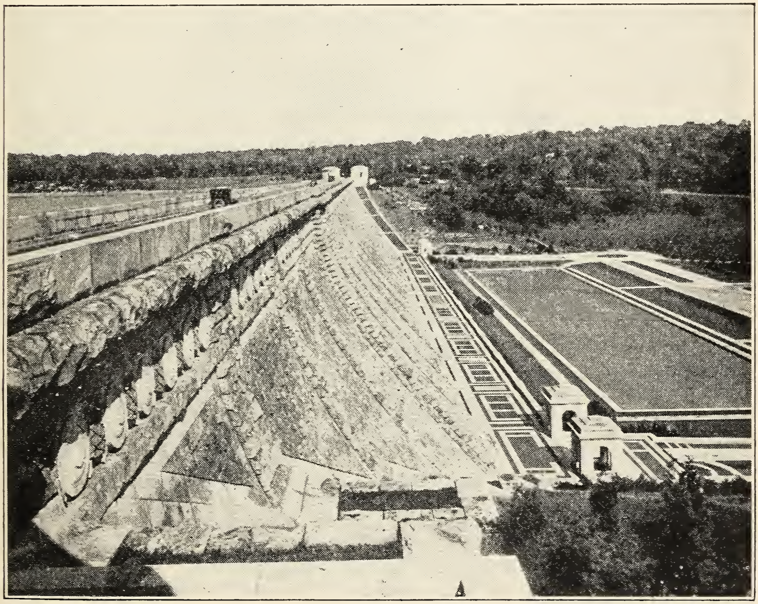
Since almost all of the rain that falls on the earth sinks into the soil, all of this water comes in contact with minerals. If the minerals are such as are easily dissolved, this water very soon becomes heavily loaded with them.

None of the water found in nature is absolutely pure. It is true that most of the impurities do no harm, but it is always necessary for us to be on our guard against them. When we consider the number of uses to which water is put, we must find what impurities are present in it and how many of them there are. Water may seem to be good for drinking, but yet be unsuitable for use when a mineral which it contains forms certain chemical combinations, and so interferes with the work which it is expected to do.

Of all the impurities that are found in water, the one which occurs in the largest quantities is lime. The presence of this mineral results in what is called "hard" water. If you have ever washed your hands in water from a spring that flows through limestone, you know how unsuitable hard water is for cleaning purposes.

The process of getting rid of such minerals as lime is called "softening." In order to soften water we treat it with chemicals which cause the lime to sink to the bottom. This leaves the water free from the lime.

With the growth of cities and towns it has become necessary to provide great reservoirs where water can be stored so that there will always be a constant supply on hand. It often happens that this water becomes filled with great numbers of small plants. While these forms of life do no real



Photograph by Underwood and Underwood

THE KENISCO DAM, KENISCO, NEW YORK

harm, they make the water unfit for drinking and cooking. It has been found that a very small quantity of copper sulphate—one part to a million parts of water—will kill these plants.

At first, some people thought that the copper sulphate would do more harm than the plants which were in the water; but they were wrong. There is usually more of this in the food that we eat regularly than there is in the water after it has been treated by the chemists. Furthermore, most of this substance disappears after it has been put into the water.

We now have other processes whereby we can free our reservoirs from bacteria that carry disease. One is called the chlorine process. Chlorine was made use of in the World War and almost entirely prevented the occurrence of diseases like typhoid fever which have been responsible for so many lives in past wars. It is now being used in many parts of Europe and our own country.

Chlorine, which is a gas at ordinary temperatures, unites very readily with many substances. Some of the compounds which it forms were first used for purifying water. But now this gas is usually first changed into a liquid by changing the temperature and pressure. In this form it is put into steel containers which enable it to be handled more easily.

It sometimes happens that so much chlorine is required to purify water that an unpleasant taste results. When this happens, the water is first treated by other methods, such as filtering, in order to remove most of the impurities. Since the water is now purer than it was, it requires smaller quantities of chlorine. Consequently the unpleasant effects of too much chlorine disappear. The use of chlorine has helped to lower the death rate in localities where it is used.

In some places a gas called ozone is used for killing bacteria. It is very satisfactory because it does not leave an unpleasant odor or taste.

The ultra-violet ray is a kind of light that is given off by an electric lamp that looks somewhat like an ordinary electric light bulb. The light from lamps of this kind is sometimes allowed to play upon water which is to be purified. This light is very effective in killing any bacteria which may be present.

Neither ozone nor the ultra-violet ray is used very widely in the purification of water, because of their high cost and the difficulty of handling them on a large scale.

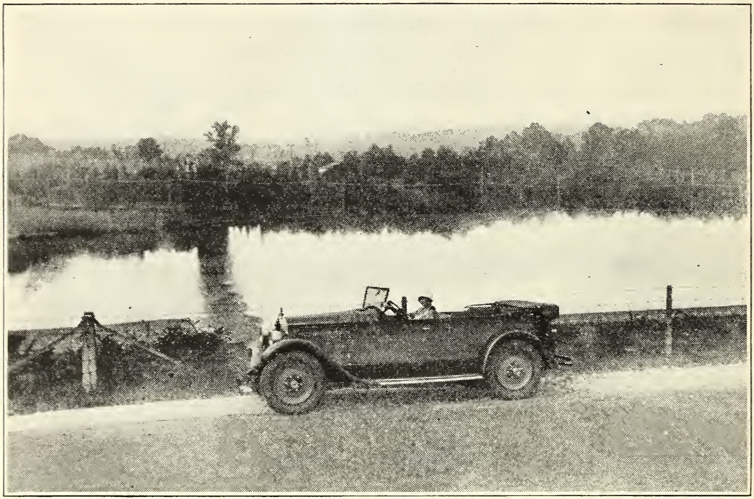
Another chemical which is good for some purposes is iodine. One drop of this element will destroy the bacteria in a quart of water. This substance is particularly useful when comparatively small quantities of water have to be purified.

There are still other methods which are used for removing the impurities from water, but those which are the most often employed have been mentioned.

Unnumbered thousands of human beings have been saved by the chemist who has made it possible for us to guard ourselves against the dangers which lie hidden in our water supplies. He is constantly being called upon to find means of clearing water of troublesome and poisonous substances which have not been met with in the past.

As already suggested, cities are constantly being put to great difficulty and expense in order to provide an adequate supply of pure water for their people. It sometimes has to be brought from long distances in pipes or aqueducts, and huge reservoirs are constructed for its storage.

The illustrations found in this chapter indicate some of the means that New York City is using in solving the great problem of its water supply. The one on page 95 shows a portion of the famous Kenisco Dam with the reservoir at the left. This is a part of the Catskill Water System which is now one of the chief sources of the city's water supply.



Photograph by Underwood and Underwood

Aërating Water from the Kenisco Reservoir

Above is shown an illustration suggesting still another method of purification—that by aëration, or oxygenation, as it is sometimes called. The aërators are seen shooting small geysers of water into the air and thus, by exposing the water to the oxygen, purifying it. The aërators shown at work in this illustration form an important part of the Kenisco Water Works.

QUESTIONS AND TOPICS FOR DISCUSSION

1. What would you expect to see if a drop of impure water were examined under a microscope?
2. Why are many simple forms of life found in water so important?
3. What are some of the ways in which water may carry harmful material?
4. Where does water come from and how does it reach us?
5. What effect does lime have upon water?
6. Describe the copper sulphate method of purifying water.
7. How is chlorine used in the purification of water?
8. What are ultra-violet rays and how are they used?
9. In what ways is the chemist useful in conserving human life?

THE PHOTOGRAPHER'S ART

We are so accustomed to seeing photographs that it is hard for us to realize that the art of photography is only about a hundred years old. Previous to the introduction of photography, drawings, paintings, and similar manual products were the only forms of making pictures known. All our pictures of such men as Washington and Napoleon are, therefore, based upon drawings and paintings made by hand. Very few painters are able to give even a reasonably accurate representation on paper of what they are attempting to copy. For this reason most of the men of history whose faces are firmly fixed in our minds probably looked very different from the supposed likenesses with which we are familiar. It was not until the advent of the photograph that an exact representation on paper of human features was possible.

As far back as 1777 a Swedish chemist, named Scheele, laid the foundation for modern photography. He did this by the discovery of certain salts of silver which are affected by light. In 1813 Joseph Niepce, by using a tin plate covered with bitumen, took the first known permanent photograph. In 1838 a Frenchman, named Daguerre, working upon the discovery of Niepce, produced a product known as a daguerreotype. This consisted of a copper plate coated with silver iodide. After being exposed to the light, this plate was subjected to mercury vapor. The result was a faithful representation of the object photographed. The use of the daguerreotype became widespread. Many families possess daguerreotypes of their ancestors who lived several generations ago.

In Europe the father of modern photography was H. F. Talbot, of England, who made negatives with silver chloride and then made proofs from them just as is done today. But the real father of photography, in its modern sense, was an American, John William Draper, who, in 1839, reproduced a human face.

Let us see what this process which we call photography is. We have been talking about various chemical substances, but we have said nothing as to how these chemicals are used nor about the kind of apparatus employed. Photographs, as you know, are made with a camera. A camera, in its simplest form, is nothing more than a box into which rays of light enter through a small opening in one end. On the inner side of the box is a sensitized substance, which, when acted upon by the rays of light, is so changed that pictures remain of the objects that are outside of the box.

A modern camera, instead of having just an opening in one end, has a lens of glass which causes the rays of light to change their course and fall upon a particular region on the opposite end of the camera. On this end, on which the rays of light fall, is placed a plate of glass or a film of celluloid covered by a chemical substance which is affected by the light. Until he is ready to take a picture, the operator keeps all light excluded from the camera. Then, after pointing the camera in the proper direction and focusing it, that is, moving the lens backward or forward the proper distance, he opens the shutter which controls the lens and lets light in for an instant. The length of time that the shutter is left open depends upon the kind of plate or film he uses.

The next step is to remove the plate or film from the camera. This is done in a dark room in which only red light is permitted to enter, because any other kind of light would spoil the film or plate. After immersing the film or plate in the developing solution until the outlines of the object which has been photographed can be seen, the photographer washes the film, places it in a hypo fixing bath for a few minutes, washes the film again and then permits it to dry. He now has what is called a negative, in which all the details of the picture are just the opposite of what they are in the object pictured. That which is dark in reality appears light colored in the negative and that which really is light appears dark.

Now a piece of sensitized paper is laid behind the negative, which is so placed that the sun or artificial light can shine through the negative. This paper is exposed to the light a certain length of time, depending upon the sensitiveness of the chemical substances with which it is coated. It is then removed and placed in a chemical which prevents further changes from taking place in it. After the paper has been washed and dried it may be mounted. The photograph is finished. The result is a picture showing dark areas that really are dark, and light areas that really are light. It is in fact an exact reproduction of the object photographed.

There are many different kinds of cameras now in use. Some, like the kodak, are so constructed that anyone can use them. Others, like those used for photographing the heavens, are so elaborate and so complicated that only specialists in the art of photography are able to manipulate them.

It is now possible for one to step into a photographic studio, and, after remaining but a few minutes, depart, carrying with him a finished photograph of himself.

The art of photography has so advanced in recent years that photographs of the most exquisite character are produced. They rival in excellence the finest engravings and paintings. We are able, by a very much involved process, to take pictures in colors. For this purpose a composition consisting of particles of starch of various colors is applied to the plate which is to be the negative. A special kind of paper is also used for printing the final picture. Another use to which photography is put is the making of a special kind of plate which can be put into a printing press. It is then used as type is used. Many photogravures, as the resulting pictures are called, can be made from one of these plates. Some of the most remarkable examples of the photographic art are made by this process.

As has been said, the astronomer is able to take photographs of the heavenly bodies. In order to do this, he uses a camera in conjunction with a telescope, which, as you know, is an instrument for magnifying objects situated at a distance. By the use of the camera and telescope, he is able to make pictures of the planets and stars which are far more accurate than any drawings could possibly be. He is also able to make an accurate map of the heavens, showing the stars and planets in the exact positions which they occupy. Without the use of the camera this is impossible, because the earth and the bodies in the sky are all in motion. While the astronomer was indicating the positions of some of these bodies others would be changing their relative positions.

Another use to which the scientist puts the camera is the photographing of objects too small to be seen by the naked eye. For this purpose he uses a camera in conjunction with a microscope. He is able to photograph the tiny cells of which the body consists, showing the various structures in them. This process is particularly valuable when it is desired to obtain an exact representation of these minute structures.

Photograph by Underwood and Underwood

PHOTOGRAPHING AN ECLIPSE FROM THE "LOS ANGELES"

Photographs thus taken can again be enlarged after the negatives have been developed. Objects are then revealed which were not noted before. Even the detailed structure of bacteria can be seen in photographs of this kind.

Everyone is familiar with the moving picture and knows that it is a product of the photographic art; but few understand just what occurs or what has occurred when they see a picture unfolding before their eyes.

A moving picture is taken in much the same manner that any other picture is taken. Instead of one or two pictures, however, many thousand are taken. And the film on which the objects are to be recorded may be several hundred feet in length. Each picture is three-quarters of an inch high and one inch long. Pictures are taken at the rate of sixteen per second, which means that even the slightest movement made by anyone who is being photographed will be recorded. After the film has been taken, another film is made from it because the first one is a negative.

Now that we understand how a film is made, let us see what happens when it is unrolled upon the screen. Since a film is made up of a series of distinct pictures, one might wonder why it is that a moving picture does not appear as a series of separate pictures one following each other. That is, he might wonder why a jerky motion is not observable as one picture succeeds the other. The smooth succession of pictures is due to the fact that when light falls upon the eye its impression remains for a fraction of a second before it disappears. Thus the picture which we first see remains upon the sensitive membrane of the eye until the next one comes. The result is a smooth succession of one picture after another. It might be well to tell you now that the human eye is itself a camera, for it is a sphere at one end of which is a lens and at the other a sensitive membrane. Therefore the same thing happens within the eyes that happens when a picture is being taken. The only difference is that what we see is not permanently recorded while that taken by the camera is.

The moving picture is particularly well adapted to furnishing us with representations of scenes that are taking place in the world today and of preserving them for future generations. Even now in the motion picture theaters pictures taken during the World War are being reproduced. If we had had similar means of observing what happened at the time of the American Revolution, our ideas concerning that period would be much less hazy than they are.

The skill of the moving picture operator enables him to unfold before our eyes scenes of beauty and grandeur, like the waters that pour over Niagara Falls and the ocean during a storm. He is able to show us great bodies of people, and thus to represent such happenings as the French Revolution and Cæsar crossing the Rubicon. Furthermore he can picture such things as angels floating among the clouds and fairies dancing among flowers.

The motion picture and the phonograph are now working together. We can hear what the object on the screen is saying, for we are now able to time them so that they work in harmony.

The motion picture is being used by the scientist for recording the habits of animals. In conjunction with the telescope, the movements of the lion and tiger can be studied in safety. When connected with the microscope, the actions of the minute members of the animal and plant worlds can be recorded. It is possible, by revolving a film slowly, to produce what is called "slow motion." By this means, the exact movements of birds in flight and animals in motion can be analyzed.

Pictures of a different kind are now being made. These are radio photographs. We are able to see what is taking place at a point far distant. The method by which the images are carried to the distant point is unlike that employed by the camera, but the method of making them permanent is the same. To what extent the radio photograph will supplant the photograph made by the camera is a question for the future to answer. However, it is safe to say that the camera will always hold its own, for it can do things that the radio is incapable of.

Photo. by Underwood and Underwood

PHOTOGRAPH SENT BY RADIO

QUESTIONS AND TOPICS FOR DISCUSSION

1. Describe the construction of a modern camera.
2. Why does a plate or film have to be removed in a dark room?
3. Describe how sensitized paper is printed from a negative.
4. How are colored photographs made?
5. Explain how the astronomer is able to take photographs of the heavenly bodies.

6. How are pictures taken of things too small to be seen by the naked eye?
7. Describe the making of a film.
8. Explain why action is continuous in a moving picture.
9. How is the moving picture machine used in the study of animals?
10. Discuss the use of radio photography.

The waters of the world contain many different kinds of animal life that look for all the world like plants. The sea anemone has the appearance of a thick weed with many leaves at the top, the sponge resembles a clump of moss, and the sea lily looks like a land plant. Most of the plant-like animals lie in the sea attached to rocks or to other animals and get their nourishment from the water that flows into them.

Many of these animals are far less sensitive than the venus fly trap, a plant which snaps shut and catches insects when certain hairs are bent, or than the mimosa plant which trembles if a leaf is touched. The cœlentera looks somewhat like the venus fly trap.

Courtesy American Museum of Natural History

Cœlentera

Because of their appearance and habits, men for ages thought that these animals belonged to the vegetable kingdom. It was not until the biologist investigated their structures and habits that their true nature was discovered.

Courtesy American Museum of Natural History

SYNURA

It is not only in the low forms of life, like those mentioned, that the biologist is interested. He devotes himself to the study of all living things—that is, to plants and animals. There is none, from the simplest to the most complex, that he overlooks.

He examines them to see what they are made of, what their different parts do, how they come into being, and, in fact, everything that pertains to them. All his studies have one purpose in view—an understanding of man.

One of the most important achievements of the biologist is the collection of facts concerning the structure of our bodies and the work performed by them. These facts are of value to us because, through knowing them, we are the better able to take care of ourselves and therefore to become better members of the group in which we live.

Until only a few hundred years ago, man knew very little concerning the nature of his body, nor did he make any great effort to learn about it. Because of his ignorance, he imagined it to be a kind of machine run by spirits, some of which were good and some of which were bad. When he was in good health, the good spirits were said to be in control; but when he was sick the evil ones were thought to be in command. So, when anyone was sick, his friends, not knowing what else to do, tried to frighten the evil spirits away by loud noises, evil-smelling things, and by other useless means.

Later, as he became more intelligent, man realized that sickness was not due to spirits. He thought it was the result of the improper functioning of some part of his body. But, still ignorant as to how he was constructed, he did many things, in his efforts to cure the sick, which resulted in pain, unhappiness, and death; for example, when one was very weak from sickness, his friends tried to cure him by cutting a blood vessel and letting out some of his blood. They would not have done this had they known how necessary his blood was to him and that they were only making him worse.

Though his remedies, for a long time, often did more harm than good, at least man was working in the right direction. He was trying to apply remedies to diseased conditions, instead of trying to frighten away evil spirits. It was only after the actual structure of the body, and what takes place within, were understood, that he was in a position to apply effective remedies to diseased conditions.

Now, thanks to the painstaking work of the biologist, the doctor knows pretty well what to do when our bodies are out of order, because he is dealing with something that he understands.

Since we have the knowledge which the biologist has given us concerning the needs of our bodies as to food, and what happens to the food after it enters our stomachs, we are in a position to know what is good for us to eat and what is not. This knowledge is particularly valuable in case of sickness. Sometimes the doctor tells us not to eat sugar, because he knows that we cannot take care of it; sometimes he will not let us eat sour things because there is already too much acid in our systems. All our knowledge concerning food and drink is based upon the results of studies made by the biologist.

When we have severe headaches, are very nervous, and act queerly, the doctor realizes that there is something within us which is not doing the work that it should. He does not do as the medicine men did long ago, when they tried to drive out evil spirits, nor as the people of Salem, Massachusetts, did less than three hundred years ago, when they killed some of their number because it was thought that evil spirits had entered into their bodies. The doctor, nowadays, since he knows a great deal about the workings of the body, is often able to relieve suffering, and even to remove the cause of the trouble. This knowledge is just another gift of the biologist.

By making a study of children from the time that they are born until they grow up, the biologist has enabled us to know many of the changes which occur during the period of growth. We are therefore in a position, not only to help their bodies develop as they should, but we are able to assist in training their minds in the way that is best for them. Thus this scientist is an important figure in the field of education.

As we study man as an individual, so we study him as a member of society. Since no one lives absolutely alone, it would not be right if we failed to consider what effect the actions of an individual have upon the conduct of his fellows, and what effect theirs have upon him. We call one who studies these things a sociologist. But the work of the sociologist, since he is studying human beings, is closely related to, if, indeed, not directly based upon, that of the biologist.

It is in the field of personal health, however, that we are here most interested in the work of the biologist. And it is in this field, perhaps, in which he has performed his best service. It was the biologist who discovered bacteria, those very tiny members of the plant kingdom many of which cause diseases, such as pneumonia and tuberculosis. After he found that these germs existed, he began to study the habits of each kind in an effort to discover the specific diseases caused by each. As a result of this study he has been able, in many cases, to tell us what to do to prevent their entering our bodies and also what to do in case some of them do gain a foothold within us.

In addition to the bacteria, he found that there were also tiny animal parasites which were responsible for diseases like sleeping sickness and malaria. He learned that these disease producers spent part of their lives in insects like the malarial mosquito and the tsetse fly. Having discovered this fact, it was a fairly easy matter for him to control the diseases by destroying the insects that carried them.

Besides these small plants and animals, he discovered larger, but still tiny, animals, mostly worms, which cause many diseases, such as trichinosis, which is due to the presence in the body of a small worm that comes from diseased pork, and the hook-worm disease, resulting from the presence of the hook-worm which enters the body through the skin. Again, by teaching us the habits of these animals, the biologist has enabled us to guard ourselves against them. These diseases and many others have been practically stamped out in certain regions because the biologist has learned the habits of the animals responsible for them.

People have known for centuries that children are apt to be more like their parents and grandparents than like other people—that is, that children often inherit their parents' qualities. The biologist has studied plants and animals as well as people, and has found out that they all inherit certain things in accordance with definite laws. From what he has taught us about these laws, we are able to take two differently colored sweet peas, for example, and raise from them a new flower of a different color. And, furthermore, we can tell beforehand something as to the probable color of the new flower.

It is possible, in the same way, to tell what kinds of colts or calves will be born if we know what qualities their parents and more remote ancestors possess.

Knowledge of this kind has been very useful to the farmer, for he has been able to improve the quality of his crops, like wheat, fruit trees, and berries, as well as his livestock.

Since we know that children inherit characteristics from their parents and grandparents we are often able to find out what is the matter with children who do not develop as they should, or who come into the world with certain peculiarities.

The biologist has aided us in the preservation of our forests, for he has studied the needs of the various trees, and he has learned about the habits of insects and other enemies which destroy them. He has taught us the best time to transplant trees from one place to another, as well as how and when trees should be trimmed, and many other facts about them.

He has taught us that certain plants have to have the pollen carried from one to another by particular kinds of insects or there will be no fruit and so no new plants of that species. Some time ago certain men brought fig trees from Asia into this country. Many attempts were made to make the trees grow and bear figs here, but without success. Finally, a certain little wasp, which in Asia carried the pollen from one fig flower to another but which did not live in America, was brought to this country. The result was that the fig trees at once began to bear and now bear as well here as in Asia.

Sometimes it has been impossible to control certain insects which destroy plants and trees, until the biologist has discovered some other insect that feeds upon the ones that do the damage. By bringing these enemies of the harmful insects into the region where the trees are being destroyed, it has been possible to kill the harmful ones.

We have mentioned only a few of the things that the biologist has done. His researches extend into every branch of science and industry that has to do with living things. From what you have learned concerning his achievements in the field of medicine, you can see how important his work is. It is not ended, for he is continually at work and is discovering new facts concerning nature every day.

QUESTIONS AND TOPICS FOR DISCUSSION

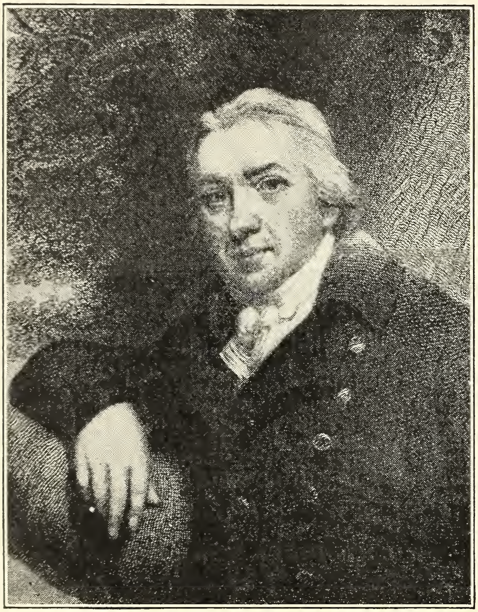
1. Describe some of the plant-like animals that live in water.
2. Why does the biologist study living things?
3. Explain the old and new ideas concerning sickness.
4. Discuss some of the knowledge of our bodies that the biologist has gathered.
5. What are bacteria and how do they affect health?
6. List some diseases that are caused by worms entering the body.
7. In what ways has the farmer benefited through the work of the biologist?
8. Discuss the conservation of forests and the help the biologist has rendered.
9. Name some harmful insects whose spread can now be controlled.
10. In what other ways has the biologist been of service?

EDWARD JENNER AND THE STORY OF SMALLPOX

Smallpox is scarcely feared today. In seventeen states, in the year 1925, not a single death resulted from the disease, and there were for that year only 803 deaths in the whole United States. The reduction of smallpox has been consistent from the date of the Declaration of Independence, one hundred and fifty years ago. At that time, one death in every ten resulted from smallpox, and out of every one hundred deaths of children who died before reaching their tenth year, thirty-three were caused by smallpox. More than half of all the people living were scarred and disfigured by it. It is estimated that 60,000,000 of the inhabitants of Europe died from smallpox in the eighteenth century. The infection attacked persons of all ranks from the peasant to the king.

According to tradition, smallpox had its origin in India and spread from there throughout Asia. Ultimately it reached Europe where the first epidemic of the disease occurred in the 16th century. It became so common that during the eighteenth century scarcely a person escaped its ravages. It was so common that if a criminal escaped the disease and the disfigurement that accompanied it, this fact was indicated in the description of the fugitive as a mark of identification. Perhaps you have never seen a person who has had the smallpox. How has this change been brought about?

In all progressive communities vaccination is required of all children who enter school. Perhaps you have been vaccinated. If you have you may have objected at first to the sore arm, thinking it unnecessary. But when you learn that vaccination has largely eliminated smallpox from this country, and that in a few years this once dreaded disease will probably be unknown, you will be glad that the community was wise enough to take the necessary precaution against this menace.



Photograph by Brown Brothers

Dr. Edward Jenner

Before we tell you of our hero, Edward Jenner, and his development of vaccination as a means of preventing smallpox, we shall tell you something of the history of inoculation previous to his time. Inoculation is said to have been practiced in India over 1,000 years before the birth of Christ. The practice of inoculation passed from Asia into Europe by way of Constantinople where the disease was raging in the seventeenth century. Inoculation as a method of preventing disease was introduced into England in 1717 and into America in 1721.

The method of inoculation was crude. A statement from a letter written in 1717 will give some notion of the way inoculation was performed. The letter runs: "They meet for this purpose, and when they are met (commonly fifteen or sixteen in number together) the old woman comes with a nutshell full of the matter of the best sort of smallpox, and asks what veins to please to have opened. She immediately rips open that which you offer to her with a large needle which gives you no more pain than a common scratch, and puts into the vein as much venom as can lie upon the end of the needle, and after binds up the little wound with a hollow bit of shell, and in this manner open four or five veins. The children or young patients play together all the rest of the day and are in perfect health until the eighth day, then fever seizes them and they keep their beds two days, very seldom three. They have rarely about twenty or thirty pocks on their faces which never mark, and in eight days time they are as well as before their illness."

You can see readily what happened from this kind of inoculation. The patient had a light case of smallpox which made him immune to the disease. That is, after having the slight case he did not contract the disease again. Although this was a crude method of preventing the severe cases, you can readily see from the ravages of the disease in its worst form that people would rather have the light disease from inoculation than the real disease in the natural way. Although inoculation was a crude method, it was widely practiced.

The next step in the development of the means of preventing smallpox led to vaccination as we know it today. This step was taken by Edward Jenner, an English physician, in the latter part of the eighteenth century. A disease among cows, called cowpox, had been known for some time. It became known, too, that people were also subject to this disease and that it was probably communicated from the diseased cow at milking time, if the milker had an open sore on the hand. It was also noticed that people who had had cowpox did not have smallpox.

Courtesy National Tuberculosis Association
Dr. Jenner Inoculating His Son

Jenner collected data of many cases of persons who had had cowpox and thus had become immune to smallpox. He concluded that if cowpox could make a person immune, he could prevent smallpox by inoculation with the virus from cows that had cowpox. He put his theories to the test. He selected a healthy boy of eight years, and took matter from a sore on the hand of a milkmaid, Sarah Nelmes, and inserted it into the arm of the boy, by means of two scratches, each about one-half inch long. This was on May 14, 1796. If you have been vaccinated, you know that this is the method that is used at the present time. The experiment was wholly successful.

The result of the work of Jenner was to demonstrate that vaccination is an effective means for the prevention of the dreaded disease of smallpox. Many people oppose vaccination, and, for that reason, the laws requiring it are not fully enforced and some of the laws requiring vaccination are inadequate. It is strange that such an effective method of preventing so dreadful a scourge should not be universally used and that laws should not be made requiring its universal application.

We have already indicated some of the dangers and consequences of the disease in the days before vaccination was practiced. Boston's experience in 1721 may be cited as a further example. In this year there was a total of 5,989 cases of this disease in a population of 11,000—one in every two of the inhabitants was stricken. This was not an unusual occurrence.

A recent statement from the American Association for Medical Progress is interesting and illustrates the situation. It is as follows: "Smallpox exists in every country. In some lands it attacks with full virulence, claiming a heavy toll of human lives; in others, as in parts of the United States and Canada, it persists as a mild disease causing little public concern, but from time to time for reasons not yet understood appearing in the more deadly form. In unvaccinated countries smallpox is even now taking its toll of thousands of human lives each year. It is one of the main causes of death in China and India. Between the years 1918 and 1923, 663,553 deaths were reported from this disease in India, where there is a saying among the agricultural, and even wealthier classes, never to count children as permanent members of the family until they have been attacked with, and have recovered from smallpox. In the Peninsula of Arabia from fifty to seventy-five per cent of the children born die of this disease, and in Russia between 1902 and 1914 over a million people contracted smallpox and over half a million died of it."

Smallpox is unnecessary. It ought to be a public disgrace for it to appear in a community, and when we are more intelligent and have the wisdom and courage to make laws and enforce them, smallpox will be entirely wiped out of this country. The extent of the ravages of epidemics of smallpox is almost solely determined by the number of unvaccinated persons in the community into which the foreign case enters. The only sure means of its prevention is vaccination.

While the number of cases in the United States is, on the whole, decreasing, because of better laws and more effective vaccination, smallpox has by no means entirely disappeared from this country. Let us present a table of the cases for a number of states and the District of Columbia to show what the situation is:

Number of Cases and Deaths from Smallpox in the United States 1916–1924

Year	Area	Cases	Deaths
1916	30 states & D. C.	15,532	82
1917	38 states & D. C.	47,507	313
1918	39 states & D. C.	76,831	396
1919	43 states & D. C.	58,348	328
1920	47 states & D. C.	108,835	514
1921	42 states & D. C.	91,335	657
1922	42 states & D. C.	27,928	791
1923	42 states & D. C.	25,943	163
1924	40 states & D. C.	49,587	871

In spite of the fact that there were seventeen states with no deaths in the period from 1921–1924, other states showed an amazing lack of control over the situation. Massachusetts has good laws well enforced. That state had only thirty-seven cases in the four years and only two deaths from smallpox. While Massachusetts made this good record, California had 5,581 cases and 55 deaths; Michigan had 4,537 cases and 227 deaths; Minnesota had 9,375 cases and 307 deaths; and Ohio had 7,286 cases and 58 deaths. The number of cases in these and other states represents the effectiveness of the laws and their administration.

We cannot do better than to close this chapter with a statement from the American Association for Medical Progress as follows:

"Smallpox is a preventable disease and the will of the people determines whether or not it shall invade a community. Smallpox can be prevented by vaccination, and by vaccination only. It has been contended by those opposed to vaccination that the disease is one of filth and that it can be prevented and controlled by sanitation alone. But the facts do not bear out their contentions. Smallpox attacks people of every race and every nationality; sparing neither the young nor the old, the exalted nor the lowly, the clean nor the squalid. It spreads and thrives in communities enjoying all the benefits of modern sanitation, as has been demonstrated recently in the outbreaks of the disease in the state of California, in Denver, Detroit, Minneapolis, and St. Paul. On the other hand it has been prevented by vaccination alone in most unsanitary districts, as proved by the records of the central provinces of India, where as yet it has been impossible to improve the living conditions of the apathetic and fatalistic native population. Effective vaccination was introduced into these provinces, and the people allowed free communication with the unvaccinated areas surrounding them. The disease has been greatly diminished in the vaccinated areas."

Edward Jenner, born May 17, 1749, at Berkeley in Gloucestershire, England, must have the credit for introducing and applying the practice of vaccination as a protection against smallpox. If we were really conscious of the millions of lives he has saved and the suffering he has prevented, we would celebrate that day in our schools throughout the world. His name would be reverenced and his life cherished. The world owes him a debt of gratitude it can never pay.

QUESTIONS AND TOPICS FOR DISCUSSION

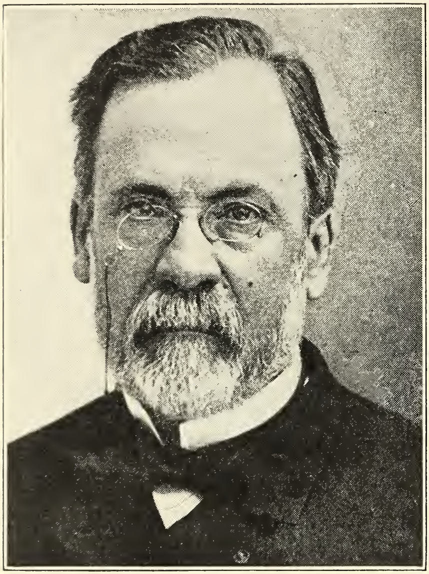
1. Where did smallpox originate and where did the first epidemic occur in Europe?
2. What is vaccination?
3. What was the method of inoculation in the eighteenth century?
4. What is the mortality from smallpox in countries where vaccination is not practiced?
5. What were the results of the work of Jenner?
6. What led Jenner to make his first inoculation?
7. Why are there so many cases of smallpox in California, Michigan, Minnesota, and Ohio?
8. How can smallpox be entirely stamped out?

LOUIS PASTEUR AND THE CONTROL OF DISEASE

One of the strange beliefs that people have held in the past is that life can be created out of nothing. The theory that life could be created out of nothing was called spontaneous generation. A common superstition during the past generation was that if you put a human hair into a sealed bottle of water it would develop into a snake. This, of course, was the belief of uneducated people, but if we go back to 1860–1875 of the past century, we find that spontaneous generation was a theory held by many educated people as well.

The opposite theory is that life develops only from seeds or eggs in which the germ of life already exists. Pasteur and other scientists did not believe in the theory of spontaneous generation, but no one had ever proved the falsity of the notion. Pasteur set himself to the accomplishment of two great tasks: first, to prove that life did not develop out of nothing, and, second, that many diseases of plants, animals, and human beings are caused by germs carried from diseased bodies to those who are well, thus making them sick.

The common notions formerly held about sickness, even as late as the middle of the last century, seem very strange to us today. Many people believed that sickness was a visitation of Providence. They thought that when people did something that was wrong they were made sick as a punishment. It did not occur to these people that disease could be the result of their own careless living or the violation of health practices by someone else in the community. They, therefore, did not believe that disease could be controlled. One of the great contributions of Pasteur was his discovery of the method of the spread of disease, and, therefore, the basis of its control.


Photograph by Underwood and Underwood
Louis Pasteur

We must not get the notion that no progress had been made in the study of the origin of life before the time of Pasteur. Much had been done. For example, people had long believed that the maggots found in spoiled meat developed in the meat out of nothing. But an Italian scientist, Redi, who lived in the seventeenth century, disproved this. He did it by covering a piece of spoiled meat with gauze. Flies drawn by the smell of the meat laid their eggs on the gauze, and from the eggs worms hatched. None came from the meat itself. This demonstrated that the worms came from the eggs.

Pasteur set out to prove something more than this, however, for he had had a long experience in the study of fermentation. It was common knowledge that liquids, fruits, vegetables, and other things containing sugar, if left exposed long enough, would sour, but the men who had studied fermentation believed that it resulted from yeast. Justus von Liebig, a German chemist, had doubted that yeast was the only cause of fermentation and he raised the query: "Why should we think yeast so important when we see so many fermentations, that of milk for example, taking place without it?"

Pasteur began to study milk to see why it ferments. He saw that when milk sours, little gray patches are formed on the sides and the bottom of the vessel in which the milk is contained. He also saw, by use of the microscope, that this gray material was composed of tiny globules much smaller than those of yeast. When he placed these bits of gray material found in the milk into another liquid, properly prepared, fermentation was set up there also. Yeast he knew to be a plant, but he discovered that the gray material which also caused fermentation, though a plant, was not like the yeast plant. He found that it belonged to a group of plants which the scientists call bacteria. When Pasteur discovered these plants, or bacteria, and learned that they caused fermentation, he had made rapid progress toward the proof of the way in which life develops; that is, that it develops from other life.

Pasteur, through his study of fermentation, had discovered that there are many bacteria, and that each kind of fermentation is caused by its peculiar kind of ferment or bacteria. He then set out to prove that every form of life, no matter how small, springs from a seed, or germ, peculiar to itself.

If bacteria cause fermentation, what is the source of bacteria themselves? It appeared to Pasteur that bacteria must come from the air. To test the correctness of his theory, he drew air through a tube containing a plug of cotton wool and found that the wool was covered with black dust. This black dust, moreover, contained tiny bacteria which would multiply in milk or other solution of organic matter. This showed that life comes from bacteria, or germs, that are in the air and that it is not created out of nothing.

In order to demonstrate, still further, his theory of bacteria, he showed that if liquid capable of sustaining life is boiled and sealed in an air-tight container, as we seal fruits and vegetables in cans today, they remain pure indefinitely, just as our canned goods keep indefinitely at the present time. The sealed material keeps pure because all the germs, or bacteria, have been killed. Later it was discovered that liquids did not need to be boiled. If milk is kept at a temperature of 145 degrees Fahrenheit for one-half hour the germs, or bacteria, will be killed, and the milk will keep pure if protected from the air or other contact. We have given to this process the name Pasteurization.

It was only a short distance from this discovery to the one that proved bacteria to be the cause of disease. Pasteur reasoned that if bacteria are causes of diseases in wines and other organic substances, why may they not be responsible for diseases that can be communicated from one animal to another or from one person to another. He therefore advanced the theory that germs were the cause of disease, the theory that was to revolutionize the practice of medicine and surgery, as well as to provide the basis of individual and community health.

Fortunately, while Pasteur was in the midst of his study of the germ theory of disease, his old master, Dumas, invited him to make a study of the disease of silkworms that appeared to be rapidly destroying one of the most profitable industries of France. The population of Southern France depended upon the silkworm for a livelihood, and the income to the country from this source ran into the millions each year.

Beginning in 1849 disease had ravaged the silkworm nurseries. The disease attacked the egg, the chrysalis, and the worm, and every means was tried to stop its ravages. Worms were dusted with ashes, soot, charcoal, quinine, mustard, and sugar with no avail. The mulberry leaves upon which the silkworms feed were sprinkled with wine, rum, and absinthe. The worms were fumigated with chlorine gas and coal tar, but the disease still spread. It appeared in Spain, Italy, Greece, Turkey, the provinces of the Caucasus, and in China. It seemed that the silk industry might disappear from the face of the earth.

One of the signs of the disease was a little black or brown spot, which appeared on the sick worms. These spots looked somewhat like grains of pepper, and the French named the disease "pebrine," formed from the French word *pebre,* meaning pepper.

After long and careful study, Pasteur discovered that the disease was both contagious and hereditary. He found that he could cause the disease in worms by feeding them, or injecting them with, material containing corpuscles. "Corpuscle" was the name given to the tiny oval bodies which were found in the bodies of the sick worms. These were found in the worms by the use of a miscroscope. Pasteur also discovered that eggs laid by worms infected with pebrine contained corpuscles, and therefore concluded that the disease was also hereditary.

The outcome of this research of Pasteur was the discovery of the cause of the disease and the means of its prevention. This discovery was made only after six years of hard work, but it meant the saving of the silk industry to France, which provided the means for, among other things, the payment of the Franco-Prussian War debt. It also advanced Pasteur on the inevitable road toward the study of the diseases of man, which meant ultimately the saving of millions of human lives.

The next study of Pasteur was devoted to the effort to determine the cause and means of prevention of anthrax, an infectious disease of animals. The disease of anthrax, or splenic fever, as it was called, was ruining the sheep industry. For the disease was widespread and twenty sheep out of each hundred infected died. There were farms and mountains in which sheep could not be pastured because of sure death. The animals would contract anthrax and usually die within a few hours. The disease infected horses, cows, and even men.

The background of knowledge that Pasteur had acquired from the study of fermentation and the silkworm led him to conclude that this disease must also be caused by bacteria, or germs. This conclusion was supported by the fact that certain fields were particularly hazardous to sheep that pastured there. He thought that there must be some source of infection in these fields. The farmers had allowed the sheep that died from the disease to decompose in the fields, and other sheep grazing there contracted the disease. He had the dead sheep burned, and this prevented the spread of infection.

But Pasteur was not satisfied with this method of controlling the disease. He had previously discovered, by accident, that he could inject cholera vaccine into chickens and render them immune to cholera, although chickens that had not been so treated would contract the disease. This discovery, together with the knowledge that vaccination against smallpox had proved successful, led him to try to discover a means of vaccination against anthrax. In this he was successful. As a result of all this work of Pasteur, we can now successfully inoculate people against many diseases, such as typhoid, colds, diphtheria, etc.

The crowning work of Pasteur, however, was the application of the principle of vaccination to the treatment of persons for the prevention of hydrophobia. This disease is caused by the bite of a mad dog, and it is one of the most dreadful of diseases, for death from it is always accompanied with great suffering. After long experimentation, Pasteur discovered that hydrophobia attacks the nervous system and that a vaccine made of the brain of an infected animal would render other animals immune. Dogs bitten by other mad dogs failed to develop rabies if they were given the series of injections shortly after they had been bitten.

And now comes the crowning achievement in the life of Pasteur. He knew that inoculation would prevent rabies in dogs. Would it prevent it in man? He had such reverence for the life of man that he felt that he could never forgive himself if this treatment should cause the disease. It had never been tried on man. One day the test came and he had no option in the matter. When little Joseph Meister came to him he felt that he must make the experiment.

Joseph Meister was an Alsatian boy of nine years. He had been attacked by a mad dog while on his way to school. Joseph was so small that he could not defend himself. The dog knocked him down and before he was rescued by a passing bricklayer, the dog had bitten him fourteen times.

Photograph by Underwood and Underwood

THE PASTEUR STATUE IN PARIS

The doctor who dressed the wounds advised Joseph's mother to take him to Pasteur, for the fame of the great scientist was then known throughout the country.

As was said before, Pasteur hesitated to give the inoculation for rabies, because he feared what might happen. He called two doctors in whom he had great confidence. One of them told him that it was his duty to use every means to save the boy and that he should take the risk. After the inoculation, which consisted of twelve injections, each stronger than the one before, Pasteur became uneasy. He remained awake and walked the floor the entire night. In the long dark hours of the night he feared that the boy might die. But he did not die. He was saved, and a means of preventing hydrophobia was discovered.

Pasteur's life was a struggle against ignorance and superstition, but today we honor him. In his discovery of the relation of germ to disease he laid the basis of modern surgery, of preventive medicine, and provided a means for the control of communicable disease through modern sanitation. Since 1885 the average length of life has been extended from thirty-five to fifty-eight years. This remarkable achievement in the prolongation of life has been largely the direct outcome of the life and work of Pasteur.

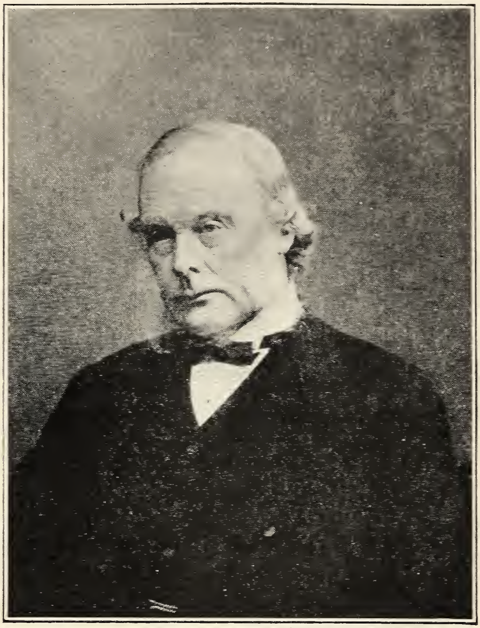
QUESTIONS AND TOPICS FOR DISCUSSION

1. What were some of the strange beliefs about life held in the past?
2. Who was Redi and what did he accomplish?
3. What did Pasteur discover from his studies of fermentation?
4. Write a composition about pasteurization.
5. In what way did the silkworm disease contribute to knowledge of disease germs?

6. How did Pasteur study anthrax and what results did he obtain?
7. What is meant by rabies and how is it now treated?
8. How was the life of Joseph Meister saved?
9. Make a list of Pasteur's benefits to mankind.

LORD LISTER, THE HERO OF MODERN SURGERY

The fifth of April, 1927, marked the one-hundredth anniversary of the birth of Joseph Lister, the hero of modern surgery. We usually think of heroes as legendary characters dating back to the days of Greece or Rome, or back to the days of the Middle Ages when the knights held sway, or to the days of Robin Hood, or even back in our own colonial period when our forefathers met the Indians in battle and marched to church with rifles which they stacked at the entrance of the meeting houses, ready to be seized in the midst of prayer or sermon when the Red Face appeared to make his attack.



Photograph by Brown Brothers
Lord Lister

However, we have a new kind of hero. We have men who have lived and worked and sacrificed to make the world a suitable place in which to live. These recent men are no less heroes than those of old, and the fact that we have so recently celebrated the one-hundredth anniversary of the birth of Lord Lister attests that fact. The recency of the achievement and life of Lord Lister may be made clear by the knowledge that there are people now living who were living when he was born. Many people now live who knew our hero, and hundreds of surgeons are now living who saw his gentle and unassuming face.

Many of the present members of the English Royal Society, of which Lord Lister was a member, were no doubt present when the American Ambassador in London, Mr. Bayard, at a dinner of the society in 1902, arose and proposed a toast to this modern miracle man of science. The ambassador said: "My Lord, it is not a profession, it is not a nation, it is humanity itself which, with uncovered head, salutes you." This was not an extravagant statement, for the work and achievements of our hero have saved more lives than all the wars of the nineteenth century have destroyed. We rightly celebrate his birth and revere his memory.

It is well known that the great work in preventive medicine, community sanitation, and public health has been accomplished within the last seventy-five years. We accept modern health practices as a matter of course at the present time. We enjoy the fruits of the developments of modern science as a right, without remembering that our forefathers, only two generations ago, suffered and toiled without the benefits we enjoy, and that many men have worked and sacrificed to make the world a safe as well as a beautiful place in which to live.

It is well to remember that modern interest in health is a part of a great social movement, the scientific movement of the nineteenth century, in which we have come to view life from a new angle. This scientific movement had as the center of interest the study of human life and its development. Scientists had begun to regard life as a process of growth. They pointed to the fact that at one time all men were barbarians, and that from the barbaric tribes of centuries ago we had developed the nineteenth century civilization. They also pointed out that if we should study how this life had developed, and learn something of its secrets, we could promote more effective living in the future. The work of the pioneer in science began, and we have the new type of hero who has become characteristic of recent times.

We need to look a bit into the medical practices of the early nineteenth century in order to appreciate the favorable conditions under which we live today. A view of that time will also show us the meaning of the achievements of men like Lord Lister. When Lewis and Clark, back in 1804–1806, made their expedition into the far West, the practice of medicine consisted mainly of bleeding and sweating. Captain Clark of that expedition was a typical medical practitioner of the time. He tells of a man taken violently ill with pleurisy. He bled the man and the next day gave him a sweat. The preparation for the sweat was made by digging a hole in the ground, building a fire in it, and making it thoroughly hot. Then the fire was removed and the man placed in the excavation and covered. Clark says of the bleeding operation: "I had no other instrument with which to perform this operation, but a penknife, however, it answered very well."

This method of operation was the common practice. Little was known of germs at this time, and any knife that would cut served the purpose in an operation. There was no treatment for the wounds to prevent infection, and "surgical fever," or infection, usually resulted from an operation. One-third of all the patients who were operated upon died as a result of the operations. It is no wonder that surgeons hesitated to operate and did so only when it was the last hope of saving the life of the patient, and then with the expectation that fatal results would probably follow. Today infection seldom follows an operation, and when it does it is usually because of the neglect of the patient, and not through lack of skill on the part of the surgeon. The results of aseptic surgery are well nigh perfect.

We have already become familiar with Pasteur and his experiments with germs in relation to diseases of plants and animals. Lister had been inspired by the work of Pasteur and had come to believe that the germs that Pasteur had learned so much about were perhaps responsible for the infection in cases of operations. Bacteriology was then unknown, and it was assumed that Pasteur's germs were everywhere suspended in the air. Lister believed that these germs in the air of the sickroom infected the wound of the patient and caused the surgical fever and death. Lister was a Bachelor of Medicine of the University of London and a member of the surgical staff at the Royal Infirmary.

After extensive experience and study as a surgeon of the Royal Infirmary, and after becoming interested in the study of germs, Lister went to Edinburgh. Here, he married the daughter of the celebrated surgeon, Professor Syme, and remained eight years. In 1860 he moved to Glasgow and began to study the fearful mortality of surgical operations.

The Royal Infirmary of Glasgow was no better nor worse than other foreign hospitals of the time, which were little, if any, worse than the hospitals in the United States then and later, when there were few trained nurses, and when untrained people ministered to the needs of the sick. The first principles of sanitation were scarcely known. Lister wrote concerning his own ward: "My patients suffered from the evils alluded to in such a way that was sickening and often heart-rending, so as to make me sometimes feel it a questionable privilege to be connected with the institution."

Lister was fully alive to the seriousness of the situation. He was fully convinced from the studies of Pasteur that

Photograph by Wide World Photos

NURSES PREPARING FOR AN OPERATION

germs were the cause of infection in surgical wounds. His first effort then was to kill any germs that had already been admitted to the wounds of his patients. After considerable study he chose carbolic acid as his germicide, and cotton wool in variously medicated forms as his protective covering against the admission of more germs. In March of the year 1865, Lister tried a German creosote, a crude form of carbolic acid, for the first time. In May of the next year he achieved his first unmistakable success with it.

We may say then that antiseptic treatment in surgical operations was originated in 1866. This seems too simple to be true. What do we mean by antiseptic treatment? Dirt in the surgical sense means putrefactive bacteria, or germs, and antiseptic treatment is the means of obtaining surgical cleanliness, that is, freedom from these bacteria. It seems impossible that this simple procedure should not have been discovered and followed before, but it was not; and so to Lister is accredited antiseptic surgery. It is furthermore true that the result of this first effort of Lister in 1866, followed carefully since, has revolutionized surgery.

The care of the surgical wound was merely the beginning of the experiments of Lister in the development of antiseptic surgery. As was pointed out before, bacteriology was unknown and physicians who knew of the work of Pasteur believed that his germs were suspended in the air. Lister produced a carbolic spray with which to kill these bacteria which he supposed to be suspended in the air of the operating room. This may be regarded then as the second step in the experiments.

However, it soon appeared that bacteria in the air of the operating room were much less dangerous than those found on the skin of the patient, on the surgeon's hand, on the instruments used in operating, and on the sponges used in cleansing the wounds after operation. This discovery led to the abandonment of the carbolic spray and subjected Lister to the cynical comments of fellow physicians, who condemned him because of his efforts to promote science and human welfare. In the history of the past the leaders of great movements have usually been subjected to the cruel comments and vigorous opposition of persons of even the greatest respectability, who ought to be leaders in scientific advance. These opposers were ignorant, and, because of their ignorance, fought scientific advance.

Bacteriology, however, had made sufficient advance to discover that bacteria could best be destroyed by heat. Heat, then, became the means of sterilization, and the emphasis shifted from the destruction of putrefactive bacteria in a wound, and the destruction of bacteria in the air with a spray to the exclusion of the germs from the wound. This meant the complete sterilization of everything that came in contact with the wound of the patient. The time had now come in the civilized countries when festering in a surgical wound no longer caused the surgeon to ask himself whether he had omitted one of the Listerian precautions, but to ask himself instead which one of the precautions he had omitted.

What has been the result of the work of Lister? In 1858 there were published the results of 679 amputations of the leg in English hospitals, and of these cases 205 died, almost one-third of the number. Furthermore, this does not tell the whole story. In many cases these amputations would not now be necessary, for aseptic methods would prevent the infection in case of a compound fracture that had to be reckoned with in the era before Lister had made his remarkable contribution. In 679 cases today, such as those reported in 1858, perhaps five deaths would be a high estimate, and this better showing may be attributed to the achievements of our hero of surgery.

There is no wonder then that we honor Lord Lister. It is not surprising that we designate him as the hero of surgery. The date of his birth should be appropriately observed in every school in the land in order to keep alive the memory of the deeds performed in the face of the ridicule of his compeers. Lister lived for science and humanity, and the results of his labors are that all men may live better and be happier. Hail to Lord Lister, the hero of modern surgery!

QUESTIONS AND TOPICS FOR DISCUSSION

1. In what manner does the new kind of hero differ from the old?
2. Why is Lister known as the hero of modern surgery?
3. How do modern ideas of medical practice differ from old ideas?
4. What was Lister's theory of infection?
5. What is meant by antiseptic dressing?
6. What is sterilization? How is it used to advantage in modern surgery?
7. Name some of the important results of Lister's work.
8. Write a composition telling why Lister's birthday should be observed by schools.

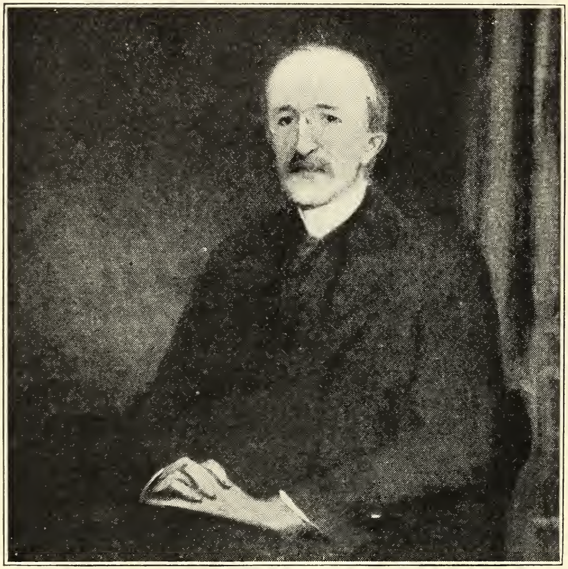
TRUDEAU AND THE WHITE PLAGUE

With the spread of health knowledge and the control of communicable diseases through sanitary measures in the twentieth century, it seems hardly possible that such crude ideas could have prevailed as were characteristic of even scientific men in the nineteenth century. But interest in the improvement of health is comparatively new. In the middle nineteenth century, we must remember, we did not know how diseases were communicated from one person to another, and it was generally believed that germ life, the real cause of disease, was spontaneously created. We have already learned the part that Pasteur took in eradicating that idea.

If we recall the notions that prevailed regarding disease and the method of its spread before the time of Pasteur, we shall then be prepared to understand some notions that were common about tuberculosis, the dreaded white plague. There were several curious notions about this disease. People generally believed, and this belief was shared by physicians and scientists generally, that if parents had tuberculosis their children would probably have it. They believed that the disease was transmitted by birth from parents to children.

Another belief, quite as common, was that if one contracted tuberculosis there was no chance for his recovery, that nothing was left for him to do but to wait for the end of life. There was no hope of cure. You can perhaps picture the hopelessness of the person who once contracted the disease, and the fear of persons who had a trace of it in any of their ancestors.

Edward Livingston Trudeau, our hero, was a member of a tubercular family. He grew up with the notion implanted in his mind that he would probably contract the disease. He also had the notion that if he should contract it he would not recover. Like people generally, he did not imagine that he could take the disease from some one else who was sick with it. He did not know that disease was infectious.



Photograph by Wide World Photos

Dr. Edward Livingston Trudeau

Trudeau, like all young people, was full of hope. He decided that he would like to enter the Naval Academy, and he was about to enter this institution to train for his career when his brother became ill. He loved his brother dearly and at once gave up his appointment to the Naval Academy to take care of him. It was discovered that his brother had the dreaded tuberculosis.

The statement of Trudeau shows how completely unaware he was of the nature of the disease. He says: "We occupied the same room and sometimes the same bed. I bathed him and brought his meals to him, and when he felt well enough to go downstairs I carried him up and down on my back, and I tried to amuse and cheer him through the long days of fever and sickness. . . . Not only did the doctor never advise any precautions to protect me against the infection, but he told me repeatedly never to open the windows, as it would aggravate the cough; and I never did till toward the end my brother was so short of breath that he asked for fresh air."

As was to be expected, the brother died and Trudeau was left in sorrow. Having given up his appointment to the Naval Academy, he had to choose some other profession in which he could earn a living. He finally decided to be a physician and in the fall of 1868 entered a medical college in New York City. This was at the time when Pasteur was arduously working in France upon his contributions which were to revolutionize modern health practice.

After the completion of the medical course, Trudeau married and settled down in New York City for the practice of his profession. Not long after that he began to feel tired, and was advised to have his lungs examined. The examination took place and he was told that his left lung was infected, that he had tuberculosis. Can you imagine the darkness and gloom that came over him? He had the picture of his brother in his mind. He also had the conviction that was commonly held, namely, that if a person contracted tuberculosis he could not recover. The world had lost the last vestige of hope for him.

Trudeau had always loved the mountains and the wilderness. He thought that if he had only a short time to live he would spend that time as he liked most. He would spend the remainder of his life in the great out-of-doors, in the fresh air, sunlight, and among the objects of nature that he adored. In 1873 he started for the Adirondacks, and after a long and tiresome journey reached the hunting lodge of Paul Smith, a friend. He was so happy to be in the forests that he forgot the tedium of his long journey.

Picture the situation of Trudeau at this time. A bright promising young doctor with a happy family, a wife and child whom he dearly loved, retiring into the mountains to die. But he did not die. The mountain life had a wonderful effect upon him. He began to eat heartily, sleep well, and he soon lost his fever. He had gone to the Adirondacks in May, and by September he was feeling much better and had gained fifteen pounds. He decided to return to the city and resume his practice. Again in the city, he lost ground. He had had a taste of the mountains and the consciousness of health improvement there and the next year he decided to go back where he had gained his health before. He now had two children. Knowing the results of his return to the city previously, after careful consideration with his wife they decided to remain in the Adirondacks for the winter.

Most people thought it was foolhardy to remain in the rigorous climate of the Adirondacks for the winter as no guests had ever remained with Paul Smith at his lodge for that season. Physicians recommended a warm climate for tubercular patients, but Trudeau wanted to stay where he had regained his health, and his wife and children joined him for the winter.

The family, after a visit to New York, returned to the Adirondacks and were met by Trudeau and Smith at Malone. They traveled from there forty-eight hours to reach the lodge in the mountains. This trip was made through the heavy snow, which was so severe at one time that the children had to be sheltered in a cave dug out of the snowdrift to keep them from freezing to death. In spite of the rigors of the climate Trudeau spent a well winter, scarcely ever having a fever. He violated all the rules for the treatment of tubercular patients and it appeared that he was recovering from the disease, instead of dying as was expected

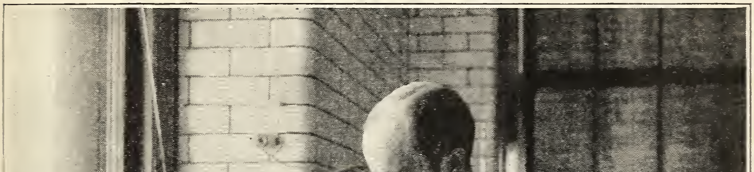
Trudeau decided not to return to the city, and began to practice his profession among the guests that spent the summer at the lodge. When the winter came again, Trudeau found that he could not stay at the lodge for Paul Smith had chosen to run a hotel somewhere else during the winter. He therefore had to look elsewhere and finally decided to move to Saranac Lake, which was later to become famous because of the work of Trudeau in the study and prevention of tuberculosis.

Saranac Lake, the center of so much interest later on, was at this time a little village consisting of a small hotel for guides and lumbermen, a schoolhouse, and probably a dozen houses inhabited by guides. In addition, there was a country store where the people could get flour, sugar, and a few groceries, tobacco, and some patent medicines. It was a dreary place for Trudeau to take up life after the bright prospects of the successful practice of his profession in the city. But he was then seeking health and not the success of a profession. He gained both.

The recovery of Trudeau you can well imagine made an enormous impression upon him and also upon the medical profession. The theories about tuberculosis had all been upset. Physicians began to send patients to Saranac in the hope that the experiences of Trudeau might be repeated in them. Trudeau decided to build a place where those who came suffering from the disease from which he had recovered might have the best conditions for recovery. He thought of a sanatorium. Although it was still not known that tuberculosis was infectious, Trudeau thought that it would be better to have patients by themselves, so he decided to build small cottages. This was the beginning of the "cottage plan" for the treatment of tubercular patients.

The experiences of Trudeau created in him the desire to discover the real causes of tuberculosis and if possible to discover the methods of its prevention, as well as to determine how it might be cured. In 1882, a German scientist, Koch, had announced the discovery of the tuberculosis bacillus, or germ. Trudeau had read of this and also knew of the experiments of Pasteur, who believed that all infectious diseases come from living germs. He also had read of the discoveries of Lister, an English surgeon, who had learned that wounds would not become infected if treated with antiseptics, such as carbolic acid. He felt that if he could, following the lead of Pasteur, grow the tubercle bacillus outside of the body, and then produce tuberculosis with it in animals, he might be able to discover something or some way in which he could destroy the germ in human beings.

Trudeau began his experiments by setting up a laboratory, eight by twelve feet, in a frame cottage with crude equipment. He took three lots of five rabbits each. The first lot he inoculated with tuberculous germs and put them in a favorable environment. He turned them loose in the air and sunlight and provided them with food. They all recovered from the infection. A second lot of five was also inoculated and placed in a damp, dark place. Four of them died within three months and an analysis of the organs showed extensive tuberculosis. The third lot of five was not inoculated, but they



Courtesy National Tuberculosis Association

DR. TRUDEAU IN HIS LABORATORY

were kept under the same conditions as the second lot. They were poorly fed, kept in a dark, damp place with foul air. They became thin, but they did not die, and they did not contract tuberculosis.

These experiments showed several things. They showed that tuberculosis is caused by germs, that it is infectious, and may be communicated from one person to another. They also showed that under proper treatment in its early stages tuberculosis may be cured by proper feeding, sunlight, and fresh air. This discovery of Trudeau represents one of the greatest achievements of mankind.

Much has been done since the time of Trudeau. Thousands of lives have been saved. In Framingham, Massachusetts, the rate of tuberculosis was decreased 69 per cent in a period of ten years by the application of the principles discovered by the experiments of Trudeau. What is more important, we have discovered that by correct living with proper food, fresh air, and sunlight we may keep our bodies in a condition that will ward off the dreaded white plague. We might well call the beloved Trudeau, the hero of tuberculosis.

QUESTIONS AND TOPICS FOR DISCUSSION

1. What are some of the common beliefs once held concerning the white plague?
2. What were the early beliefs of Edward Trudeau concerning it?
3. Tell the story of Trudeau's entering the medical school.
4. Give the details of Trudeau's experience in the mountains.
5. Describe the "cottage plan" for the treatment of tuberculosis.
6. Explain Trudeau's method of experimentation to find the cause and prevention of tuberculosis.
7. What were the results of these experiments?

WALTER REED AND YELLOW FEVER

Photograph by Wide World Photos

Major Walter Reed

We have become somewhat familiar with the achievements of the men of science in the control of disease. We have learned how Jenner provided a remedy for the control of smallpox, how Pasteur discovered the disease germ and explained its relation to disease, how Lord Lister, following the lead of Pasteur, developed antiseptic surgery, and, finally, how Trudeau, familiar with the achievements of all these men, provided a means for the control of the white plague. We are therefore prepared to study the history and achievements of Walter Reed, the conqueror of yellow fever.

What is yellow fever? This disease was, at one time, one of the scourges of the earth, and, therefore, we should know something of it. Yellow fever was a dangerous, infectious disease. It received its name from the fact that it causes the skin of the patient to assume a yellow tint. The disease develops in from three to five days after infection, and in severe cases the patient sometimes dies in a few hours after becoming ill. The sickness is usually fatal, and therefore yellow fever, in the warm countries, has been one of the most dreaded diseases in the history of mankind.

The earliest records of yellow fever go back to the sixteenth or seventeenth century. Some authorities say that it was known in Central America in 1596. Others say that it was first recognized as a definite disease in 1647 in the West Indies, and since that time it has been known as an epidemic in West Africa, South America, Spain, Portugal, and in some of the southern parts of the United States. Though a warm-climate malady, it has appeared as far north as Boston.

Yellow fever is thought to have been known among the Indians in New England as early as 1618. It is said to have appeared on the island of St. Lucia, one of the Bahamas, in 1664, where it is said to have been responsible for the death of more than 1,400 of a population of 1,500 soldiers. In the next year, in the same place, 200 out of 500 sailors died of the disease. As has already been indicated, it is known to have visited some of the northern settlements in the early days of our colonial history. New York was visited by the scourge for the first time in 1668, Boston in 1691, and Philadelphia in 1695. There have been, in all, 208 invasions of the United States by this scourge, and more than 100,000 deaths can be traced to it.

This history indicates something of the seriousness of this disease, and explains why we rightly call it a scourge, or a plague. But the cold facts hardly present an adequate picture of the terror that an epidemic of yellow fever struck in the hearts of the people of a community when the disease appeared. When the epidemic appeared in Philadelphia, in 1793, all the streets and roads leading from the city were crowded with families flying to the country for safety. Most of the doctors were ill with the disease, and there were few to relieve the sick and suffering, while people were leaving their homes from fright.

The most hopeless aspect of the malady, however, was that no one knew either its cause or its cure. In all the history of the disease for more than two hundred years, no progress had been made in its control. Though the most capable men of science of the times had searched for the clue by which control might be assured, the scourge was repeated year after year, and a heavy toll of life followed in its path.

The Spanish-American War of 1898 had left upon our hands the administration of Cuba as well as of other islands in the West Indies. The disease of yellow fever was never absent from Cuba or from the city of Havana. Our administration of the island, until it could be given a stable government and left to self-administration, subjected not only our citizens who were called upon to administer the islands to the menace, but the increased intercourse between the island and the United States created increased dangers for all our people.

Obviously, something must be done. The selection of the man best suited to study this problem was not an easy task. Finally, in 1900, a board of medical officers was appointed to investigate acute infectious diseases, and especially questions relating to yellow fever on the island of Cuba. This board was composed of Major Walter Reed, Dr. James Carroll, Dr. A. Agramonte, and Dr. Jesse W. Lazear.

Major Reed was well equipped for this task. He not only had had a brilliant career as a student in the Bellevue Medical College of New York City, now the Medical College of New York University, but after graduating from this institution he had followed a career which particularly fitted him for his great work. He became an army surgeon. This gave him large opportunity for the study of disease. During the Spanish-American War he had studied the cause of typhoid in the army camps and had come to the conclusion that the house fly carried the germs of typhoid.

From this experience of Major Reed, it is not surprising that when the commission reached Cuba, it decided to sift all the evidence that seemed to point to an insect-carrier of the disease. Insects had already been discovered as carriers of disease. Pasteur had laid the basis for such investigations, and several others had made studies along this line. We have already mentioned the fact that Walter Reed had himself discovered that the fly was a carrier of typhoid bacteria. Dr. Ross, an English army surgeon, had discovered that the parasite of malaria gets into the blood of a human being through the bite of a mosquito, the Anopheles, and that this germ can be carried in no other way. Major Reed was already of the belief that a species of the mosquito was responsible for yellow fever. He started out to determine whether his theory was correct.

There were several reasons for suspecting the mosquito as the culprit for the ravages of yellow fever. Among the important reasons were the following:

1. In almost all of the accounts of yellow fever epidemics that had been recorded, large numbers of mosquitoes were alleged to have been present in the vicinity where the outbreak occurred.

2. It had been noted that epidemics of yellow fever broke out in low marshy regions, where stagnant water was common. It is well known that stagnant water is a breeding place for mosquitoes. Therefore stagnant water, the source of mosquitoes, suggested that mosquitoes were the cause of the fever.

3. The supposition had been that yellow fever was carried from one person to another, or was spread by contagion. Major Reed doubted this, for, in the case of an epidemic, the disease was not contagious in the high and dry places in the city. In the outbreaks, the people fled from the low lands to the high places. Although some persons became ill, the disease did not spread in these areas. This suggested that it was caused by something in the air in the low regions.

4. The belief that yellow fever was air borne and not contagious was strengthened by the fact that the epidemic spread in the direction of the prevailing winds. If there were no winds the disease spread only in the neighborhood of its source. This was later interpreted to mean that the mosquitoes were blown by the wind to new areas and thus spread the infection.

5. It was also well known that yellow fever occurred only in warm countries or in the warm season of temperate climates. People always looked forward to the fall frosts, when the disease was stamped out. Mosquitoes also disappeared with the early frosts. Naturally there appeared to be a relation between the disappearance of mosquitoes and the dying out of yellow fever.

For the reasons given it appeared that the mosquito was the criminal, and the commission decided to begin its investigation with this insect. But since animals do not contract yellow fever, it was necessary to experiment upon human beings. In other words, it was necessary to have mosquitoes bite well persons after the same mosquitoes had bitten persons ill with the yellow fever. This was an enormous responsibility. When Major Reed invited someone to submit himself to the test he already had sufficient evidence to be fairly certain that the volunteer would have the disease and probably die. Could he ask people to submit themselves for the experiment? The members of the commission agreed to experiment on themselves as well as on those who volunteered for the experiment.

The first experiments were made in August, 1900. Eleven persons were allowed to be bitten by mosquitoes after the mosquitoes had bitten persons with well-marked cases of yellow fever. Two out of the eleven developed yellow fever and both recovered. One of these cases was Dr. Carroll of the commission. On September 13, Dr. Jesse W. Lazear was bitten while visiting a yellow fever hospital. He noticed the insect light upon his hand but he did not brush it off. He waited patiently until it had completed its task. He contracted the disease and died, a true martyr to science.

Major Reed and his companions selected a site six miles from Havana and there built a camp which they called Camp Lazear in honor of their dead comrade. They put the camp in the best of condition for living, with proper sunlight and fresh air.

As a part of the equipment of Camp Lazear were two specially built rooms. Room No. One contained the bedding formerly used, and even the clothing worn, by yellow fever patients who had died. Nor had any of these articles been disinfected. Precautions were taken, however, to exclude mosquitoes from this room. Room No. Two was a model of hygienic system, containing nothing suggestive of yellow fever. But into this room mosquitoes that had bitten yellow fever sufferers were freely admitted.

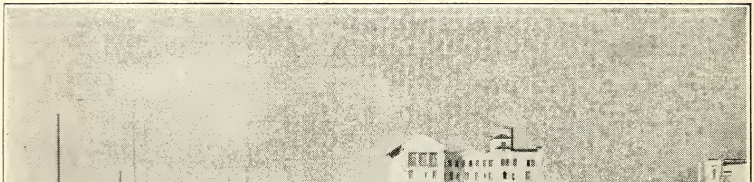
The experiment consisted of two parts. The object of the first was to see whether or not yellow fever is contagious. The object of the second was to determine if it is caused by the bite of the suspected mosquito. To answer the first question, room No. One was used, to answer the second, room No. Two.

Since it takes at least six days for yellow fever to develop after a person is bitten by a mosquito, they kept the patients in quarantine for two weeks. This would guarantee that they had not been infected before entering.

To find out whether yellow fever is contagious, seven patients, who had been in quarantine for two weeks, were put into room No. One. This was the room, you remember, containing the clothing that had been worn and the bedding that had been used by men who had died of yellow fever. From this room the mosquitoes were carefully kept out. Though the new patients wore the clothing and used the bedding of the yellow fever victims, none of them caught the disease. Thus it was proved that yellow fever is not contagious.

To determine the guilt or innocence of the mosquito, room No. Two was used. This room, you know, was a model of hygienic cleanliness, except that mosquitoes already known to have bitten yellow fever patients were admitted. Seven of the patients who had been in careful quarantine for two weeks were entered. Six of them contracted the disease. This proved quite conclusively that the mosquito was guilty as charged.

The first effect of this discovery of method of the spread of yellow fever was an effort to get rid of this particular mosquito in Cuba. They began to clean up the breeding places and to cover them with oil. Since the larvae, developing into the mosquito, has to come to the top of the water in which it is bred in order to breathe, and since this oil prevented contact with the air, these young died. Yellow fever was thus banished from Cuba, and it has since been banished from many other



Photograph by Publishers Photo Service

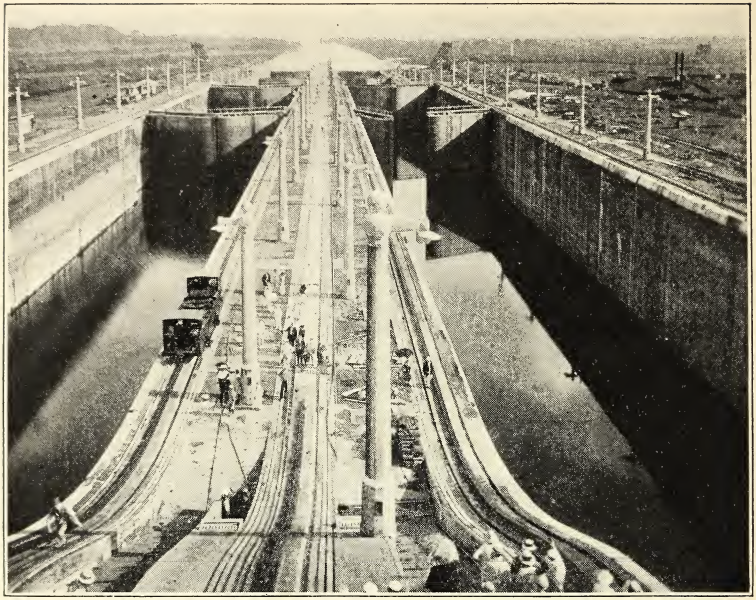
Havana, Cuba. View of the Prado

parts of the civilized world. This world achievement was accomplished only through the use of science and the sacrifice of the men who offered themselves to science.

The second step in the control of yellow fever was carried out by Colonel Gorgas in Panama. The United States had secured the right to build the canal across the Isthmus of Panama, but it dared not undertake its construction until sanitary conditions were improved. The French had attempted to build a canal and had failed in the attempt. They had abandoned the project. The greatest difficulty the French had to contend with in their attempt at its construction was the mysterious fever which carried off their workmen by the thousands.

When the Americans went to Panama to prepare for the building of the canal they found it one of the wettest, hottest, and worst fever-infected regions in the world. They proceeded to clear up the region for the purpose of eliminating among other things the yellow fever mosquito. In order to do this, in the first years they cut down five square miles of swamp brush, drained one-third of a square mile of swamp, cut ten square miles of grass, maintained 550 miles of ditches, emptied 1,300,000 cans of garbage, and fumigated 11,000,000 cubic feet of residential space. All this was done for the purpose of stamping out the mosquito. The application of these methods under the leadership of Colonel Gorgas and his staff practically eliminated the yellow fever from the country. Their efforts represent the greatest fight against the mosquito that has been waged in the whole history of mankind.

It is fair to say then that if it had not been for the destruc-



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THE GATUN LOCKS IN THE PANAMA CANAL

tion of the mosquito as a disease carrier, it is doubtful whether the gigantic project of digging the Panama Canal could ever have been carried through. When the United States took over the task, the first thing the authorities put their hands to was sanitary work. Their first efforts were directed toward making the canal zone a place in which men could live and work. The accomplishment of this task by Colonel Gorgas and his men required two years of unremitting labor. The result of their labors was that the mosquito and yellow fever were eliminated and the canal zone became virtually a health resort with a lower rate of mortality than that of our best cities in the United States.

The effectiveness of this experiment in the elimination of the dreaded scourge of yellow fever may be shown by the situation in the tropical countries today. Yellow fever has been practically eliminated from the Western Hemisphere. There were only two deaths from the disease in the year 1926 in both North and South America. The whole credit of this achievement, however, cannot be given entirely to the army physicians and engineers. Theirs is a full meed of glory and credit because they risked their lives and sacrificed their conveniences to the work of eliminating this disease which was a dreaded scourge of mankind. But we must also give credit to the army privates who offered themselves to the experiment with almost sure death facing them in order that science might be advanced and lives saved.

The story of Dr. Lazear has already been briefly told. He gave his life in the cause. He was a hero, even a martyr. But there were others equally brave. One of these is John R. Kissinger, a private in the United States Army, now living in the town of Andrews, Huntington County, Indiana.

When Major Reed had decided upon the experiment we have already described, Kissinger accidentally overheard a conversation between him and others. He heard that experimentation could be made only on human beings and that it was going to be difficult to find anyone willing to undergo the great risk. Kissinger thought the matter over and talked it over with his pals among the privates in the army, and finally offered himself as a subject for the experiment.

Kissinger was told of the great danger to which he was exposing himself. It was explained to him that, in all probability, he would lose his life as yellow fever was nearly always fatal. After a full understanding of the danger, he insisted that he be permitted to offer himself for the experiment in the interest of science and human life. Dr. Walter Reed, the United States Army Major, saluted Mr. John Kissinger, the private. Later in his report to General Sternburg he declared that this exhibition of moral courage had never been surpassed in the annals of the army.

Kissinger was one of the patients in the experiment. He contracted the disease but did not die. The effects of the attack, however, left him a permanent invalid. The successive illnesses attendant on his infection left him broken in mind and body. While the Government of the United States has provided Kissinger with annuity, it has not been sufficient to take care of him including the necessary expenses for medical and nursing services. He has become an object of public charity.

The action of the American Association for the Advancement of Science shows how completely true this statement is. At its December meeting in 1926 the Council of the Association adopted the following resolution: "Resolved, that the Council of the American Association for the Advancement of Science asks that the Congress of the United States take suitable action with regard to cases in which persons in government service meet with serious incapacity or death on account of dangers incurred in carrying out experiments in the interest of the nation and science."

The citizens of America, like people of other countries, are inclined to laud the successful man or woman, but often forget those who have rendered untold service to the nation and to mankind through heroic sacrifices to the cause of science and humanity. We cannot forget the meaning to science and life of such heroic sacrifices. We cannot fail to laud our achievements as a nation building and controlling the Panama Canal. We can never fail to remember the value to commerce and industry of this wonderful achievement, but let us not forget the hero, John J. Kissinger, and the noble sacrifices he made that we might live and enjoy the fruits of his heroic endeavors.

QUESTIONS AND TOPICS FOR DISCUSSION

1. What is yellow fever and why is it so named?
2. Give the history of yellow fever.
3. What problem did our government face when Cuba came under its control?
4. Why was Major Reed well equipped by training and disposition to study yellow fever?
5. Name several reasons for suspecting the mosquito of being a yellow fever carrier?
6. Describe the experiment of Major Reed upon human beings.
7. What definite results followed the experiment?
8. What steps were taken by Major Reed to rid Cuba of yellow fever?
9. To what degree were the methods used by Major Reed successful?
10. Describe conditions in Panama when the American Government started work on the canal.
11. How did Colonel Gorgas combat yellow fever?
12. Tell the story of Dr. Lazear.
13. Tell the story of John Kissinger.

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