

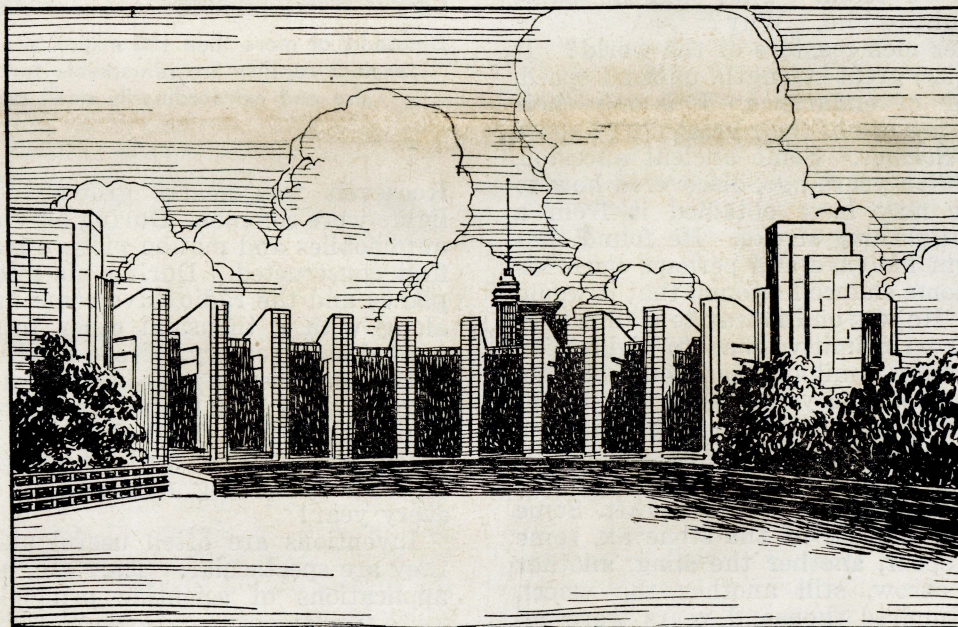
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# A CENTURY OF PROGRESS IN SCIENCE

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# A CENTURY OF PROGRESS IN SCIENCE

**M**ANY kinds of animals have lived that were fifty times as large and strong as men. With very few exceptions, these giant beasts have failed in the fight for existence and all are now dead. Their skeletons are in our museums.

Many kinds of animals now living can run faster than any sprinter. Many kinds can swim better than any boy. Many kinds can endure cold or heat or thirst or hunger better than the hardest man. Instead of tender feet, many kinds have hard hoofs. Instead of soft hands, many kinds have sharp claws. Instead of delicate skins, many kinds are protected by thick hides or heavy fur. Instead of frail teeth and sensitive stomachs, many kinds can crush bones or woody plants in their jaws and can digest coarse, uncooked food.

Yet a boy may go alone into the desert or the jungle and the animals will fear him. They will use their strength and speed to get away from him. They will use their hard hoofs to flee over stony ground. In his presence they will forget their tough skins, their sharp claws, and their great teeth. They will be panic stricken at sight of him. Why?

What makes men masters of the world? It is not huge size, great strength, unusual speed, or the power of endurance. It is only their brains. It is the use of their brains in what we broadly call *Science*. Some ancient ancestor, perhaps a million years ago, discovered how to use fire. He may have obtained it from a volcano or a lightning stroke. He found that it would warm his cave and perhaps burn his hands. By some chance he found that it would soften food. He was on his way to civilization.

The way from primitive man to civilization was long, possibly a million years long. Sometimes for ten thousand years there was no important discovery or invention. Until within a few thousand years progress was so slow it would seem to us disheartening. Eventually some one discovered how to paddle a raft. Some one discovered the use of the stone ax, some one else the spear, another the sling, another the bow and arrow, still another the wheel. Probably a hundred thousand years were required for these inventions. Four or five thousand years ago the Egyptians were piling up the pyramids. Two thousand years ago the Greek scientist Archimedes—in our histories we call him ancient—formulated the principles of levers.

Three hundred years ago Huyghens and Galileo invented the pendulum clock. Less than 250 years ago Newton discovered the laws of mechanics and the law of gravitation. George Washington was 33 years old before Watt invented the steam engine. The first locomotive and the first steamboat were put into operation shortly before the birth of Lincoln. Lincoln

had grown to manhood before the first match was produced. Twelve years after his death and during President Roosevelt's childhood, one man spoke to another over a telephone for the first time in the history of the world. Mr.



Dinosaurs of more than 100 million years ago. These ancient reptiles are remarkable for their giant size and extraordinarily small brain-case

Roosevelt was nearly grown before electric lights were common. During his early manhood automobiles and motion picture machines were first constructed. During his middle life airplanes and the radio have come into existence, along with a thousand other things now regarded as necessary. More machines and new scientific processes have been developed and put into use since 1900 than were invented from the beginning of mankind down to the time of Washington. What an interesting age we live in, with something new and thrilling nearly every year!

Inventions are often useful and sometimes they are spectacular. They are, however, only applications of scientific principles that are more fundamental and even more interesting to those who like to know the reasons for things. The amazing inventions of the past century have been possible only because of the well-established scientific principles on which they have been based. Let us now turn from the applications of science to the fundamental developments in science during a hundred years.

In the discussions that follow we shall limit ourselves largely to describing the underlying principles of science. They are the foundations on which all scientific applications rest. They are also our deep understanding of the fundamentals of the universe. In formulating them

we have risen highest above the animals who fear us. For practical reasons we shall have to pass many scientific principles without mention and concentrate our attention on a few that have been most useful in applications or most interesting to inquiring minds. Only when we discuss man himself, in the last two sections, shall we depart from these limitations.

Nearly every fundamental of science has been the product of many minds and has been under development over a considerable period of time. Although the beginnings of some scientific principles date back more than a century, most of them belong entirely to the past hundred years. In fact, some of them are largely due to scientists still living. We shall briefly discuss each of the subjects contained in the following list. The few names and dates included in the parentheses mark important steps in the development of the respective scientific doctrines.

1. The Structure of Matter (John Dalton, 1803-1808; J. J. Thomson, 1897; Albert Einstein, 1907; Ernest Rutherford, 1911).
2. The Universe beyond the Earth (Isaac Newton, 1686; William Herschel, 1800; G. R. Kirchhoff, 1859; Harlow Shapley, 1915; Edwin Hubble, 1922).
3. The Conservation of Mass and Energy (A. L. Lavoisier, 1780; J. P. Joule, Robert Mayer, 1850; Albert Einstein, 1915).
4. Evolution (S. P. Laplace, 1796; Charles Lyell, 1830; Charles Darwin, 1859; T. C. Chamberlin, 1900-1928).
5. Microscopic Life (Louis Pasteur, 1850; Joseph Lister, 1865; Robert Koch, 1882).
6. The Coming of Man (Charles Darwin, 1871).
7. The Nature of Man (1871-1933).

## The Structure of Matter

No one knows how many different kinds of substances there are in the world. There are water and salt and sugar and sand and dozens of other common things which we readily recognize. There are thousands of others with which only scientists are familiar. There are even thousands of different substances in our own bodies, and on the earth there are probably hundreds of thousands.

At once we inquire whether all the varied materials we know are different through and through or whether they are made up of a relatively small number of fundamental kinds of units, just as all the words in our dictionaries are constructed by the use of only twenty-six letters. As chemists have found, the answer is that all the numerous substances we know are compounds of only ninety-two primary substances, or *elements*, as they are called. In fact, most familiar compounds are composed of only a few elements.

After an enormous amount of work by chemists, extending over several centuries, Dalton

in 1803 finally established the *atomic theory* of matter. Since that time this principle has been the corner stone of chemistry. The elements include such familiar substances as hydrogen, carbon, oxygen, nitrogen, sulphur, iron, nickel, copper, tin, zinc, silver, gold, etc. The compounds include water, salt, sugar, starch, etc., each of which contains two or more elements in chemical union. The individual particles of an element are called *atoms*; the smallest particles of compounds are called *molecules*. A molecule of water, for example, is composed of two atoms of hydrogen and one of oxygen joined in chemical union. The chemist writes the formula for water  $H_2O$ , meaning that two atoms of hydrogen and one of oxygen are chemically united. What could be simpler? An automobile exhaust gives off carbon monoxide,  $CO$ , a poisonous compound consisting of one atom of carbon and one of oxygen joined in chemical union. Most substances, however, are not so simple. Cane sugar, for example, is  $C_{12}H_{22}O_{11}$ , and morphine is  $C_{17}H_{19}NO_7 \cdot H_2O$ , in which N stands for nitrogen.

## How the Chemist Works

Certain rules apply in combining letters to form words. Similarly, the chemical elements combine in conformity to certain principles that have been discovered through experimentation. It is the knowledge of these principles that enables the chemist to produce, almost at will, such marvelous substances as the beautiful aniline dyes and the chemical medicines. As the chemist's knowledge of chemical principles increases, his amazing powers increase. Already he has far surpassed all the magic ascribed to the fairies of childhood's fancy.

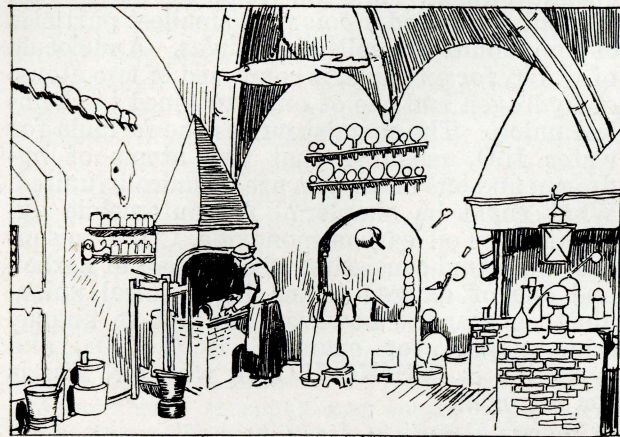
A particle of dust floating in the air appears to us to be very small. It is, however, as much greater than a molecule as Lake Michigan is greater than a tiny grain of sand lying on its shore. In a drop of water, for example, there are about  $3 \times 10^{21}$  ( $10^{21}$  equals 1 followed by 21 zeros) molecules. If the molecules in a drop of water were divided equally among the 2,000,000,000 inhabitants of the earth, each individual would have more than a million times a million of them. Even if he could count continuously at the enormous rate of 1,000 molecules per second, it would take him 50 years to determine whether he had his share.

Since atoms are only parts of molecules, it follows that in general atoms are much smaller than the minute units of water we have just considered. One naturally inquires whether the atoms are final, indivisible units beyond which there is nothing smaller. Until the year 1900 approached such was generally thought to be the case. At any rate, it seemed hopeless to prove the existence of anything smaller than atoms. But new methods of investigation have led to amazing results. The atoms themselves have been found to be complicated structures of positive and negative charges. An atom appears to consist of a very small positive *nucleus*,

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containing most of the atomic mass (Ernest Rutherford, 1911), and of negative charges (J. J. Thomson, 1897), called *electrons*, circulating about the nucleus. The lightest atom, that of hydrogen, is about 1845 times greater in mass than one of these negative electrons.

Are the electrons structureless and indivisible



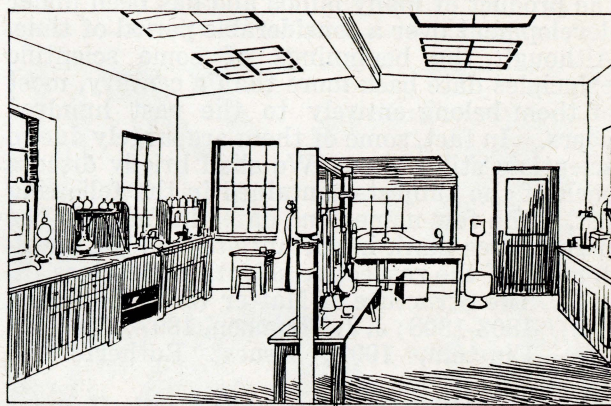
The poorly-finished laboratory of the alchemist of the Middle Ages

units of matter, or are they composed of smaller units? There is evidence that they have structure, perhaps very complicated, but their composition is as yet unknown. It may be that they will never be analyzed into components, as atoms have been. At any rate, the opinion is now widely held that in some way matter is transformed into light and radiated away. If this theory, which finds support in Einstein's Relativity (1907, 1915), is correct, such radiating bodies as the sun continually decrease in mass. Unfortunately the theoretical loss of mass with radiation is far too small to be detected by any known means. The energy equivalent of an ounce of matter, for example, is sufficient to melt 4,000,000 tons of iron. Hence it is evident that such rates of radiation as can be controlled in our laboratories are accompanied by losses in mass too small to be detected.

As we have just seen, the innumerable substances of which the world is composed have been found to be made up of molecules, so small as to be far below the reach of microscopes. Each of these molecules is a chemical compound of a few or of many atoms from among the 92 elements. The atoms in turn are composed of positive and negative electrons. It is believed by many men of science that these electrons under certain conditions are transformed into light and other radiant energy. Starting with objects of every day experience, we have analyzed them by successive steps into the infinitesimal electrons, where for the present the sequence terminates. Let us now turn our attention in the opposite direction to successively larger things.

## The Universe Beyond the Earth

No one can realize how vast the earth is unless he has crossed a continent or an ocean. Even then one will fail to comprehend its immense size. Yet the earth is relatively only a particle revolving around the sun, which is more than a million times larger. Sometimes we see



A modern chemical laboratory

the sun apparently among or just beyond the clouds. The thunder from a flash of lightning in the clouds comes to us in a few seconds. But if thunder, traveling at the same speed (a mile in 5 seconds), could come to us from the terrific storms that rage on the sun, it would require about 15 years to cross the 93,000,000 miles that separate us from this great body.

Besides the earth, seven other bodies of comparable size revolve around the sun at different distances and with different periods. The nearest to the sun and the smallest (Mercury) completes its circuit in about three of our months; the period of revolution of the most remote (Pluto, discovered in 1930) is about 250 years. These *planets*, as they are called, are dark bodies except as they are lighted by the sun, and in comparison with the sun they are all insignificant.

As has been stated, the sun in volume is more than a million times greater than the earth. Instead of being dark and cold, it is brighter than an electric arc and hotter than liquid iron. It pours out heat and light at such an enormous rate that its total radiated energy would melt a globe of ice as large as the earth in 17 minutes.

When we turn our eyes to the sky on a clear night, we may see the moon, an insignificant dead little body 2,000 miles in diameter, revolving around the earth. We may see two or three planets, looking like stars but actually somewhat similar to the earth, shining by reflected sunlight. But the stars that sprinkle the sky are suns, many of them larger and more brilliant than our own. Without a telescope we can see about 5,000 stars; with telescopes, hundreds of millions. They appear small and faint only because they are very far away. If the

earth were as near some of them as it is to the sun, its surface would be burned to cinders.

The hundreds of millions of stars of our system form a *galaxy*, having about the shape of a watch. It is so enormous in size that it is useless to express its dimensions in miles. We use as a unit instead the distance light travels in a year, the *light-year*. Since light travels 186,284 miles per second (A. A. Michelson, 1928), the light-year is about 6,000,000,000,000 miles. The thickness of our galaxy of stars (suns) is something like 10,000 light-years, while its greater diameter is something like 100,000 light-years (Harlow Shapley, 1915-1932; R. J. Trumpler, 1930). What a range of magnitudes we cover in going from electrons to a galaxy!

Every inquiring mind asks what is beyond our galaxy of suns. During the last decade it has been found that there are hundreds of thousands of other galaxies within the reach of the greatest telescopes. The nearest are about 1,000,000 light-years away; the farthest so far observed something like 100,000,000 light-years (Edwin Hubble, 1922). In some cases these galaxies appear to be grouped into super-galaxies (Harlow Shapley, 1930), just as stars are grouped into galaxies.

If we ask what is beyond the super-galaxies, there is no answer except the echo of our question. In the direction of increasing magnitudes we are baffled by the unknown. But what an excursion we have made!

## The Conservation of Mass and Energy

When coal is burned the matter it contains does not cease to exist. The carbon of which it is largely composed unites with the oxygen in the air and passes into the atmosphere as carbon dioxide (CO<sub>2</sub>). Instead of being destroyed, the carbon simply unites with oxygen and becomes a gas. When the two gases, oxygen and hydrogen, unite, the product at ordinary temperatures is the liquid, water. When iron rusts, the oxygen of the air unites with iron in the presence of water to form a red solid compound of iron, oxygen, and hydrogen. Thus chemical changes involve such radical transformations of matter that it is not easy to follow the individual elements. Yet it has been found by elaborate experiments that however great the changes may be the total mass of hydrogen, oxygen and all the other elements involved remains precisely the same (A. L. Lavoisier, 1780). Matter is not created nor is it ever destroyed—it is only transformed. This is the *principle of the conservation of mass*.

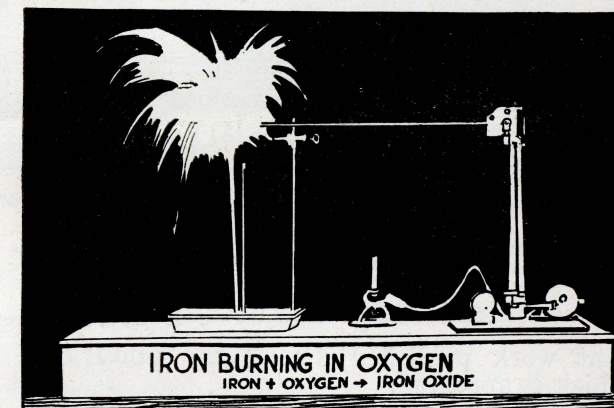
Another principle, fully as important as the conservation of mass, was established and accepted by scientists about 1850 (J. P. Joule, Robert Mayer). It is that *energy may be transformed but not created or destroyed*.

Energy has various forms. Perhaps the simplest is that possessed by a body in motion, the kind that is called *kinetic energy*. A moving body, such as a hammer, will do work when it strikes. Perhaps it will generate heat, another

form of energy. If the moving mass is the armature of an electric generator, it will generate electricity, still another form of energy. A moving body may slide up an incline, after which it will have *potential energy* because of its elevated position. If two suitable elements are properly separated, as in a storage battery, they have *chemical energy*.

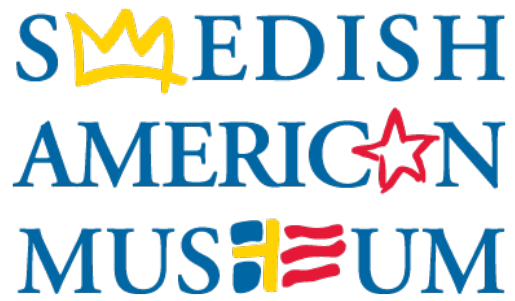
All the various forms of energy may be transformed into one another. For example, the chemical energy in coal and the oxygen of the air is transformed into heat energy in a furnace. The heat generates steam under pressure which possesses potential energy. The steam moves a turbine and produces kinetic energy. The turbine rotates a generator and generates an electric current. The electric current produces a light or turns a motor or causes such a chemical reaction as that of electro-plating. In all these changes no new energy is created and no energy is destroyed, though at every transformation some is dissipated, usually in the form of heat.

Scientists have found through experimentation the numerical equivalents of various forms of energy. For example, the heat required to raise the temperature of a pound of water one



Illustrating the union of two elements to form a third substance different from either

degree Fahrenheit is equivalent to the energy required to raise one pound 777 feet above the surface of the earth. Or if a body should fall 777 feet in a vacuum at the surface of the earth, it would generate enough heat on striking to raise the temperature of an equal mass of water one degree Fahrenheit. There is potential energy in our food which in the cells of our bodies is changed into heat and other forms of energy, enabling us to do work. If we assimilate (digest and store up) fewer *calories* (the unit usually used in diet) than we use up, our weight decreases; if more, it increases. Every question of efficiency, whether of a machine or a man, is one expressible in terms of the conservation of energy. Since energy cannot be created and since there are at least small losses of energy in the operation of every machine, we know that



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