THE VALUES OF SCIENCE

Science not only has great practical value, but it is interesting, exciting, and valuable for its own sake. For example—

by L. A. DuBridge

The modern technological society in which we live obviously owes most of its existence to the discoveries in science which have been made in the past 300 years, and to the imagination which has been used in putting those discoveries to practical use. If one pauses for a moment to reflect on the difference between the Western world of 1962 and the world of the time of Galileo and Newton, it is easy to see the enormous debt we owe to science. And when one realizes that changes in this world due to new scientific discoveries and their applications are taking place at a faster pace today than ever before in history, we have all the reasons we need for underlining the importance of public education in pure and applied science. A citizen who is illiterate in these matters can hardly be an intelligent citizen of modern America.

Yet there is another reason why it is important to give our people an opportunity to learn about science. That is because science not only has great practical value, but because it is interesting, exciting, and valuable for its own sake. Let me give you some examples of this belief which I have.

I can't at the moment foresee any practical inventions which will follow from the discovery made by the astronomers in recent years that the universe is probably more than 10 billion years old, and that the most distant galaxies that the Palomar telescope can see are so remote that the light which reaches us from them has been traveling on its way for over 6 billion years.

It may not improve your automobile or television set to have geologists discover that the most ancient rocks of the earth's surface are 4.5 billion years old, and that this is presumably the age of our earth and of the solar system. (Our solar system is thus a fairly recent arrival in a universe which is very much more ancient.)

Yet I think these are exciting things in themselves. The excitement began way back when Galileo turned his first telescope on the heavens, and observed that the planet Jupiter was possessed of moons which rotated about it – the first decisive evidence that not everything in the universe rotated about the earth . Then came Kepler, showing how the planets revolved about the sun; and Newton, with his brilliant and daring postulates of the universal laws of motion and of gravitation which brought, at last, law and order, precision, beauty, and predictability into the world.

It is precisely this feeling, this conviction, that there is law and order and beauty and predictability in the universe, which has been the guiding spirit of science ever since.

The modern concept of the universe is a majestic thing indeed. We do not yet fully understand it, of course; in fact, we become more aware of our ignorance every day. But we know now that ignorance is conquerable and that knowledge surely grows—slowly and painfully at times, often with many false leads, and often with the most obvious leads for a time unaccountably overlooked. But the picture gradually fills out. Today we see a universe stretching out billions of light years in all directions. It is composed of 100 billion or more galaxies, like our own Milky Way. Each galaxy is composed of 100 billion stars, more or less like our

Today we see a universe stretching out billions of light years in all directions. It is composed of over 100 billion galaxies like our own Milky Way, which is shown in the famous painting above. Our whole solar system is a tiny dot located somewhere about two-thirds of the way from the center of the Milky Way galaxy.

sun. And all of these galaxies are rushing madly away from each other with speeds up to half the velocity of light, as though they were the fragments of a colossal explosion which took place 10 or 15 or 20 or more billion years ago.

Yes, astronomy is an exciting subject – for its own sake.

And now, of course, the science of astronomy is about to take a new leap forward. Telescopes will someday be sent into space, free at last from the disturbing effects of the earth's atmosphere, which has impeded good observation throughout history. And what new things will be learned, how much farther we shall be able to see into space, what mysteries may be cleared up and what new puzzles discovered, we cannot begin to guess.

But now, lest you think astronomy is the only exciting field of science, let us look at the other end of the scale of size. Let us turn from the biggest thing man has looked at, the universe itself, to the smallest, the nucleus of the atom.

The discovery that nuclear energy could be converted to usable form created enormous popular interest in this subject, beginning in 1945. But physicists were excited about nuclei long before that. After Rutherford and Bohr did their great work before World War I, proving that the atom did indeed have a tiny but heavy nucleus at its center, surrounded by a cloud of electrons, a massive attack (massive at least by the standards of 1915) began on the atomic nucleus – to find out how big it was, what it was composed of, whether it could be broken up into yet smaller constituents, and what held such pieces together.

Year by year the picture evolved. All nuclei, it turned out, were composed of protons and neutrons. The forces between these particles, the energies involved in packing them together or tearing them apart, were slowly unraveled. New nuclei could be created almost at will by shooting high-speed protons or neutrons into an existing nucleus. These might stick, or they might knock out other protons or neutrons, or whole groups of them. The stage was then set for the surprising discovery in 1939 that a nucleus of uranium could be completely torn apart on collision with a rather slow neutron, the phenomenon of fission.

One of the greatest of all scientific mysteries, of course, is the mystery of life itself. Living things are so complicated! There are as many atoms in a tiny living cell as there are stars in a galaxy. They are grouped into large molecules which are also bewildering in their complexity. And this tiny cell grows, multiplies itself, can cause other types of cells to form – and a human being may be the ultimate result.

The molecular basis of life

Only in the last few years has it become possible to learn something of the molecular basis of life. We know that the original egg cell from which a complex creature will eventually grow contains all the information required to produce that creature. This information is enclosed within a group of structures in the nucleus of each cell, called the chromosomes. These chromosomes are, in turn, made up of chains of tinier particles called genes. Each individual gene, it turns out, governs the building of a particular type of molecule which performs an essential role in the cell's function. These genes are themselves giant molecules built of submolecular groups, each of which has been analyzed and identified. Their essential feature is a molecule of a chemical substance known as DNA, which is a particular nucleic acid. The DNA molecule, it turns out, is the ultimate coding element which contains the information necessary to build new molecules. The DNA molecule also has the property of reproducing itself, and thus the whole basis for the hereditary process is contained in this molecule.

Does this discovery have any practical results? As yet it would be hard to answer yes to this question. But, surely, the fact that human beings can understand and interpret some of these basic mysteries of life is one of the great achievements of science.

Let me touch on just one more field of science in which there have been important advances in our understanding in recent years – the field of geology, the study of the earth. A geologist was once visualized as a husky, outdoors-type man, clad in high boots and equipped with a hand pick, who trudged out through the wild country examining chunks of rock and noting the structure of the landscape. The groundwork for knowledge of the earth's surface was indeed laid in this way, Today, however, a typical geologist remains in his laboratory, surrounded by a bewildering array of elaborate scientific instruments. The tools for studying the nature of the earth's surface and the structure of the earth's interior have multiplied with astonishing rapidity in recent years, and our knowledge of the earth has grown accordingly.

The measurements of radioactivity and of isotopic constitution of the heavy elements gives us our best information about the age of the earth. It is from such measurements that it has been determined that the earth must be around 4.5 billion years old. Here the geologists join hands with the astronomers in tying the history of the earth and the solar system to the history of the rest of the universe.

But the geologists are interested also in probing into the earth's interior. They discovered many years ago that the tiny little tremors registered by a sensitive seismograph are caused by elastic waves which are generated by earthquakes in the earth's crust, or by storms at sea, or by other disturbances. These elastic waves travel not only in the crust of the earth, but through the crust into the next layer, known as the mantle, and even through the mantle into the hot dense core of the earth. As these waves travel, they are reflected from various layers or discontinuities in the earth's structure, and they are refracted, or bent, as they pass from one kind of material into another and the velocity of the waves is changed. Thus, by analyzing these records one can tell the depth of the various major discontinuities; one can deduce the elastic properties of the materials in the crust, the mantle, and the core.

The geologists, however, are not wholly satisfied with what they can learn from seismographs, and they are now embarked, with the help of the National Science Foundation, on one of the daring scientific projects of modern times; namely, to drill a hole clear through the earth's crust, penetrating into the mantle which lies beneath. Spectacular new knowledge about the nature of the earth's crust and the underlying mantle is sure to result from this project.

The interests of scientists

Thus, we see that the interests of scientists range from the interior of the earth to the most distant galaxies, from the structure of the atomic nucleus to the structure of living cells, through the nature of all the chemical materials of which the universe is composed.

A few years ago, all of these different branches of science – geology, physics, biology, chemistry, astronomy – were somewhat compartmentalized, and each subject built up its own techniques and its own knowledge somewhat independently of all the others.

Today this is no longer true. Chemists, physicists, and biologists join in studying the molecular basis of life. They are joined by the astronomers in studying the structure and history of the earth and the solar system. The electrical engineers developed elaborate computers which contribute to the more rapid interpretation of knowledge in all fields.

Possibly the most spectacular enterprise in which all the sciences come together is that of space exploration.

To the American public it may appear that the primary purpose of the U. S. space ventures is simply to get a man on the moon and bring him back. But it goes far deeper than that; our space program is a vast program of scientific research. Every space capsule which has been launched is actually a miniature scientific laboratory. It is equipped with instruments to measure magnetic fields, cosmic rays, radiation from the sun or from other parts of the universe, instruments to get a better look at the moon or the planets, and, eventually, instruments to determine whether any forms of life are to be found on the moon, or Mars, or Venus.

Mariner II

Right now (December 7) a space capsule known as Mariner II is on its long journey toward the planet Venus. Ever since the launching on August 27, all of the scientific equipment on the Mariner has been in operation, and the measurements have been relayed back to receiving stations on the earth by radio. Only three watts of radio power are actually being transmitted from the Mariner radio antenna, yet, with the huge receiving antennas here on earth, this will be sufficient to allow transmissions until the capsule has receded more than 35 million miles from the earth and has passed well beyond the planet Venus into a permanent orbit around the sun.

A magnetometer is measuring the magnetic fields in space – principally, now, the magnetic field of the sun, which has never before been accurately and directly measured. And it has also been learned that there are fluctuations in the field caused by clouds of charged particles which the sun frequently ejects into space, and which travel out for a billion miles or so, carrying their own magnetic disturbances with them. Magnetic storms which disrupt radio communication here on the earth may be caused by similar clouds—the results of giant, and so far mysterious, eruptions on the surface of the sun.

As Mariner II nears Venus on December 14, four radiation-measuring devices will be turned on to scan the surface of the planet. Two of these will operate in the infrared, giving some idea of the temperature within the Venus atmosphere. Two will operate at short radio wave-lengths, which hopefully will see through the atmosphere to the surface and report temperature conditions there.

Any practical value to this? I don't know. Is it nevertheless exciting? You must agree that it is. And now the Russians have launched a similar, and larger, capsule to perform a similar mission on a journey to Mars.

Even more exciting space ventures lie ahead. There will be more capsules to encircle the earth and measure the ion clouds trapped there. Capsules will land on the moon, and measure moonquakes and how seismic waves travel through the moon's interior. Devices will sample the stuff on the moon's surface and analyze it chemically, and probe beneath the surface to find out how hard or how soft it is – whether it is mostly made up of dust, or whether it is dirt, or solid rock. Television cameras will take close-in pictures of the moon's surface, and show the small features forever hidden from earth-bound telescopes. And then men will go, too, acting as still more versatile scientific instruments to look and see and test and photograph and measure many things.

Apollo project

A joy ride to the moon would interest me very little – spectacular though it might be, as a stunt. A scientific expedition to the moon, however, is one of the greatest enterprises in human history. That is what the Apollo project should mean to the American people. It is a project where all the sciences and all the techniques join together to extend man's knowledge just a little further into the unknown.

You will see, then, why I say that science is exciting and worth while in itself. The study of science enlarges a student's horizon, gives him a finer and more adequate concept of the nature of the world and of the universe in which he lives, and brings him in touch with some of the greatest achievements of the minds of men. In these respects the study of science has much in common with the study of literature, of history, of philosophy, and even of art and music.