THE ROLE OF SCIENCE IN HUMAN WELFARE

By L. A. DuBRIDGE

THE TRAGEDY of the modern "scientific age" is that so many people do not know what science is.

If you turn to the so-called science section of a daily newspaper or weekly magazine, what kind of things do you read about? Jet airplanes, atomic bombs, radar, television, rockets to the moon.

Well, whatever science is, it is *not* these things. The relation between these things and science is somewhat like the relation between an automobile and the factory that produced it.

Radar, atomic bombs, and television are *products* of science. The automobile is the product of the factory, but we don't confuse the factory with the automobile. We call them by different names. What then *is* science?

Science is that great body of knowledge about nature which man has accumulated over the ages. With this knowledge man has found it possible to develop useful things—for his comfort or happiness, for peace or for war.

Similarly, the scientist is not the man who develops radar, the atomic bomb, or television sets; the scientist is a man who is seeking knowledge. He is trying to find out about nature, about the facts and principles which govern the physical world, including the men who live in the physical world.

Who is it then who takes this knowledge and uses it to make things? There is no single term to describe such men. I like to use the term "technologists" for them. The technologist is a person who uses the knowledge of science to develop or design or to bring into being things that men want at a particular time—whether it's a new industrial product, a weapon of war, or a new medical technique.

An engineer, for example, is one type of technologist. His job, in general, is not to discover new knowledge, but to take the knowledge which has been discovered in past ages and use it to design better structures, better bridges, better automobiles, better radio sets. An engineer has the additional job of putting a dollar sign on his work, because the things he designs must not only work, they must also be relatively cheap. Somebody has defined an engineer as a fellow who knows a thing will work before he builds it, because any fool can tell afterwards.

Now, it's quite easy to get scientists and technologists confused with each other, because the training they have is much the same, they are much the same sort of people, they have to have somewhat the same background of knowledge, and, as a matter of fact, one often converts himself into the other.

For example, when a war comes along, a lot of scientists leave their science, and turn their attention to military technology, and they may develop radar, atomic bombs, or penicillin.

Similarly, some technologists start searching for more background knowledge to help them in designing the things they're interested in, and they turn into scientists seeking new knowledge.

I think this contrast between science and technology is most important to keep in mind. Science and scientists have to do with the pursuit of knowledge, and usually with the pursuit of knowledge for its own sake. Their goal is the understanding, the comprehension of the physical world. The technologist has as his aim the meeting of some of the practical needs of men, by using the knowledge which the scientists have produced for him.

In general, it's a long road from scientific discovery to practical application. Many people seem to think that the scientific discovery of one day is the device you buy at the store on the day following. Well, it doesn't happen to be that simple.

It is a long, painful road from discovery to practical realization. Usually it is not a single road, but a road of trial and error; a road of backing and filling; of discoveries coming together, and being related to each other, and leading to new discoveries; of discovery leading to a new technology, and that technology reflecting back and aiding new discoveries.

One could go through the history of science and trace out case after case in which this long and difficult trail has been followed. There are some who think that the atomic bomb was something of a special case—that here a discovery was made one week and a bomb was ready the next. But even here the beginnings of nuclear physics date back at the very least to the time of Becquerel in the 1890's, and to the Curies and Rutherford in the early 1900's. For 40 years scientists worked

Excerpts from a speech delivered at the Pasadena City College Tuesday Evening Forum, September 30, 1952 in this field of nuclear physics, on the nature of the atom and the atomic nucleus—its size, its weight, its behavior, its energy—learning a great deal that would enable them to predict and understand nuclear experiments. The bomb could not have been made without all this accumulation of knowledge.

I remember how industrial companies used to chide us in the universities in the days before the war. "All the graduate students that you train come out well versed in nuclear physics," they said, "but nuclear physics is obviously a field that will never be of any use to anybody. We wish you would train these people in optics and mechanics and chemistry and a few things that have some industrial practicality."

Today, these same companies are covering the country with their recruiting teams, looking for more nuclear physicists. And today physicists are in search of knowledge in other fields. Soon, of course, the industries again will be complaining that physicists are impractical—but in another ten or twenty years the impractical experiments of the physicists of today will become the engineering necessity of the industry of tomorrow.

Why then is science valuable? First, because it is better to know than to be ignorant—because knowledge is desirable for its own sake. Secondly, because knowledge helps men attain things they want—cures for disease, machines to relieve them of the necessity of human slavery, houses to protect them better, better places in which to work, better agricultural techniques, and a thousand things which have advanced human welfare.

Is the end in sight? As I've already suggested, we've hardly begun this process of learning about nature, and using the facts that we've learned from nature to devise and develop things which we can use. We're still in a really primitive state in certain fields.

Consider, for example, the problem of food. In many parts of the world, human hunger is still a present danger, astonishing though it may seem. This is partly because modern agricultural techniques have not as yet been adopted in certain parts of the world; often their adoption is prevented by social, economic, political or even religious reasons. A vast educational program may be necessary before modern technology can solve the problems of hunger in over-populated portions of the world.

But, though many of the technical problems have largely been solved, agriculture is still a very primitive art—hardly even a science. It was developed through the centuries by trial and error—by observing what kinds of foods would grow in what climates, in what kinds of places. Only in recent years have men really begun to study plants as a scientific project, to understand the chemistry and physics of plant life, and to get a few hints of the nature of those complex processes through which soil, air, water, and sunshine all come together to produce usable and edible food.

In recent months, for example, at Caltech, workers have discovered for the first time the chemical reaction which accompanies the ripening of fruit. It is now quite possible that, by injecting a particular chemical into a partially ripened fruit, one might cause it suddenly to ripen. Or, one might delay the ripening by an inhibiting chemical.

Possibly, by further knowledge of chemistry, one can adapt fruits to climates where they do not now have a long enough growing season.

Only in recent years also have we come to understand the complex process which we call photosynthesis—the process by which solar energy is converted into chemical energy, the energy of food. It has been known for a long time that this was the essential process in plant life and plant growth, but the chemistry and physics of this photosynthetic process has just begun to be unravelled.

Someday, I suspect, as our supplies of coal and oil and other fuels get scarcer or more expensive, and as our demands for additional sources of energy increase, we may become more dependent on solar energy. The energy of the sun is almost unlimited. It is also something we can depend on—for the next few billion years, at least. If we could only find ways of converting it more efficiently into more useful forms, it would be an enormous boon to mankind.

Photosynthesis may be the key to this, because in this process solar energy is converted into chemical energy. We may be able to develop methods whereby this process takes place more efficiently and on a larger scale, so that we can use the products of photosynthesis for fuel as well as for food.

In any case, it's certain that in coming years our knowledge about plant life, plant physiology, and plant chemistry, will continue to grow; and, as a result, agricultural technology will make giant strides forward. There should be no reason, in a few years, why hunger should any longer exist on the face of the earth. If it does, it will be solely for social, religious, or political reasons, and not for technological ones.

Medical technology

There are many ways in which medical technology is still an art rather than a science. Only in the last 50 years has medical practice really been revolutionized by new discoveries in physics and chemistry and biology. The X-ray, which was discovered in a physics laboratory by a physicist who hadn't the slightest thought of making any contribution to medicine, has helped to revolutionize medical practice. Discoveries in chemistry and in other branches of physics have been equally important. Yet, today, we understand very little about the complex physical and chemical processes that really go on in living matter. Some of the simplest processes are the most mysterious to us.

For example, I suppose the simplest form of life—or what we can call life—is the virus. Viruses are, under certain conditions, just ordinary chemicals—complex organic chemicals. They can be crystallized, dissolved, filtered, and stored away, just like ordinary table salt.

Under proper conditions, these viruses suddenly acquire the property—which is characteristic of living things—of reproducing themselves. They can multiply with astonishing rapidity. They can multiply through many generations in a few minutes.

For example if a single virus of the proper kind attacks a bacterium (a bacterium being much larger than a virus), it will multiply so rapidly that within about 15 minutes that bacterium will literally explode.

This is a very nice property which some kinds of viruses have—that of destroying bacteria. Those particular viruses which destroy harmful bacteria are great friends of man. But there are other viruses which are not such good friends, because they, in their multiplication processes, cause diseases such as pneumonia, tuberculosis, polio, and the common cold.

We don't know how to conquer these viruses yet, or how to find something which will destroy them. But work is now proceeding. Only last spring a really new and revolutionary technique for studying the viruses was developed by a scientist at Caltech.

Monkeys were used in early virus studies. Dozens of them would be injected with viruses. Then would come weeks or months of waiting to see if they got sick, and, if so, what was the matter with them. It was a terribly expensive and time-consuming process.

Then somebody found that you could infect the embryos of chickens, and so, instead of cages of monkeys, you had cases of eggs. But even this was a slow and difficult process.

Now it's been found that ordinary animal tissue can be made to grow in a little dish, and the virus can be made to infect that tissue. Almost immediately, spots will arise where individual virus particles have attacked that tissue. So, within minutes or hours, one can do experiments which formerly took weeks or months.

Furthermore, these dishes can be stacked up by the thousands in a small laboratory and experiments can be done in parallel, under controlled conditions, at an enormously increased rate over what was possible just a year ago. This will accelerate the accumulation of our knowledge as to what these virus particles are, how they behave, what chemicals stimulate or retard their growth, cause them to die or to become inactive.

This is one of the most important problems in the field of medicine. And it will be solved by studies in chemistry and biology, in laboratories and universities where people are working, trying, for the sake of knowledge itself, to learn more about these mysterious particles—not only because they're dangerous and important to human beings, but because, by their very simplicity, they take us down to the basic elements of life and give us a little better inkling as to the nature of life itself.

What must be done if we are to make continued progress in the field of science, and if we are to use science to the maximum to advance human welfare? Well, I sometimes get worried because so many people still think that jet airplanes and atomic bombs are synonymous with science. When Congress appropriates money for government laboratories to develop better bombs, better airplanes, better weapons of war, or when industry spends money for developing better television sets, better automobiles, and better airplanes, people conclude that "science" is being handsomely supported.

This has nothing to do with the support of science. This is the support of technology—the activities which make use of the knowledge which science is supposed to discover, and apply it to things which are useful. But if there is no science going on, where will come the knowledge which the technologists will apply?

Funds for science

In this country, in spite of the fact that we're somewhat better off than 25 years ago, the exploration and the support of science for its own sake is not being adequately—certainly not generously— supported. It is extremely difficult to get adequate funds and even adequate people, because of salary competition, to carry on investigations in the field of science.

It is primarily in the universities that the search for knowledge has always flourished. And do universities find it easy to secure money for this scientific exploration? Well, you all know that the problem of financing universities is difficult. It is difficult both for state and private institutions.

We do not complain about the difficulties. It's all right to have to sell one's ideas and to have to seek money for them. But the thing that disturbs scientists is to be told that they are already too rich—that there are billions of dollars now being spent on science in this country.

There are billions of dollars being spent on military and industrial technology. But the amount being spent on science can be measured in a small number of millions of dollars per year—a small percentage of the amount we're putting into technology.

And so I think that some of the lessons which we as laymen and citizens ought to learn, is that science and technology are handmaidens. Science comes first and lays the foundation. Technology builds upon it a superstructure which you see and which is useful. But without the solid foundation of science, the superstructure couldn't be built; or, if built, could not long last.

I think one could say that this scientific exploration, the search for knowledge, has proved over the generations to be useful for its own sake. It has yielded to man a satisfaction in replacing ignorance with knowledge, and has given him the practical results of being able to shield himself against the calamities of nature and the calamities imposed by other men. And this knowledge and this ability will expand and give rise to increased welfare of men in future years.