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SCIENCE, TECHNOLOGY AND THE QUALITY OF LIFE

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October 31, 1979

Abstract

Science and technology are two quite different activities with different requirements but dependent on each other. Science has affected our view of ourselves and the world in which we live with the discovery of new ideas and concepts of how the world functions. Technology is subject to already known scientific principles.

The discussion of technology includes new developments in alternate energy sources which will use the sun's energy as a source of materials and fuels.

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SCIENCE, TECHNOLOGY AND THE QUALITY OF LIFE

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I'd like to take this opportunity to recall my first effort of this kind that represented for me a milestone in my career. The occasion resulted from the persuasiveness of a college president who had an excellent idea in arranging a symposium which he entitled "In Search of Significance". He, with his persuasiveness, trapped me into coming. You should understand why I say it that way. Prior to that occasion about fifteen years ago I had never undertaken to speak on a generally nontechnical subject. There I was, on the stage with many others, committed to speak on a nontechnical subject. I did, but they were not my words. My wife wrote the speech, and I read it. It was such a success that I have since undertaken a number of other such occasions, and each time she wrote the speech. The last few months she has been unable to do this, and so I am speaking at the moment with her help, but not from a manuscript written entirely by her. I am speaking on a nontechnical subject, SCIENCE, TECHNOLOGY AND THE QUALITY OF LIFE. I have divided it into two separate components: science (understanding) on the one hand, and technology (invention) on the other. They are two quite different endeavors, two quite different human activities with different requirements. They are dependent on each other, however. Science arises from technology and technology arises from science, but they have different social consequences.

Before going on into the discussion, I would like to digress a moment with a "toast to science". The words below are taken from those engraved in the Great Hall of the National Academy of Sciences in Washington, D.C. and, I think, sum up what science is and what it does for all of us.

To SCIENCE

Pilot of Industry
Conqueror of Disease
Multiplier of the Harvest
Explorer of the Universe
Revealer of Nature's Laws
Eternal Guide to Truth

* The preparation of this discussion was sponsored, in part, by the Office of Basic Energy Sciences and the Office of Energy Technology of the Department of Energy under Contract W-7405-ENG-48.

This discussion was presented, in a slightly shortened version, as the Marcus B. Finnegan Memorial Lecture of the Licensing Executives Society-USA in Vancouver, Canada, Sept. 18, 1979.

EFFECT OF SCIENCE ON WORLD CONCEPT

I will first discuss how science affects our view of ourselves and the world in which we live. This is really the basic question, the one that the college president was asking us to address some years ago when we talked about "In Search of Significance". Science contributes a primary input to our understanding of the meaning of our lives, and I would like to illustrate that with a series of historical illustrations, right up to and including today.

Copernicus, Kepler: Three or four hundred years ago our concept of the universe was rather circumscribed. The earth was its center and man was the important creature on earth and, therefore, in the universe. Copernicus and Kepler recognized that this was not so, that the earth was not the center of our universe, that the earth was near the edge and that the sun was the center of our local universe. That concept initiated an enormous change in our view of the world. The sun became the center and the earth one of several objects moving around the sun. This was not only a tremendous change in our view of the world, but it has had an enormous impact on human thinking. Galileo's telescope, of course, confirmed this idea by actually viewing and seeing the various planets that were moving around the sun, allowing precise calculation of the planetary orbits. This ultimately led to the equations which describe planetary motion, which had to be understood in more fundamental terms and this, in turn, gave rise to Newton and his law of gravity and motion.

Darwin: A second step in the impact of science on our view of the world--and all of these things affect the quality of our lives today--was taken a little later, a little over a hundred years ago, when Charles Darwin removed man from the center of things and moved him to the edge of the stream of life, to being a component in the stream of living things. In other words, man was removed from the center and made part of the evolutionary stream of all life, after Darwin. This was an even more profound change in our view of ourselves and the world in which we live than the discoveries of Copernicus, Kepler and Galileo. There is even today some slight argument about Darwin's ideas on evolution.

Einstein: In the twentieth century Albert Einstein, whose one hundredth birthday was celebrated on March 14, 1979, revised our view of the universe in a fundamental way. His classic ideas were developed while he was a patent examiner in Zurich and were published in 1905. He gave microscopic and macroscopic explanations for Newton's laws of gravity and motion and changed our whole view of how the universe is organized. Keep in mind that Einstein not only revised our view of the universe, he invented (he made real) the quantum of energy. Up until that time, the packet of energy, which we now call a "quantum", was a mathematical fiction used to help understand the distribution of energy emitted from a hot body.

Nineteen hundred and five was a fantastic year for the scientific world: That was the year of special relativity when the equivalence of matter and energy was stated, with the famous equation--energy is mass times the square of the velocity of light, that is, the energy of a massive particle is equal to the mass times the square of the velocity of light. Also in 1905 there was the recognition of the way in which light ejects electrons out of metal. In describing quanta, the recognition came that light sometimes seems to be a stream of particles and sometimes behaves

as waves. Newton had struggled with that problem and concluded that light was a wave because it was diffracted into colors by a grating and formed interference patterns. Einstein, however, recognized the duality and he gave reality to the idea of a particle, a quantum, of light energy. This recognition gave rise to the quantum theory of matter, and the development of Einstein's special relativity realized the equivalence of matter and energy. Much later (in 1918 or thereabouts) Einstein devised the general theory of relativity, recognizing the equivalence of acceleration and gravity. This latter concept is easier to understand today because of our experience with space ships which did not exist in Einstein's time.

The equivalence of matter and energy and the equivalence of acceleration and apparent gravity are the two major theories which stem from Einstein's major inventions of the quantum theory and the relativity view of the universe.

Modern Chemistry and Molecular Biology: In recent years, life itself has been lifted out of its unique position and made part of the evolution of the physical universe. We begin now with matter itself in the collapsing stars which give rise to the planets which collect an atmosphere which gives rise to the organic molecules which, in turn, give rise to living things. There is a stream of evolution of the physical universe which ultimately gives rise to living things, and life itself has been moved from the unique place which it occupied until relatively recently.

All of these effects are very profound. Scientific understanding of the way in which our world works has modified our concepts of ourselves and our place in the universe and, in turn, this has changed what our beliefs are and what our rules of conduct are. All this comes from our view of ourselves and the physical world in which we live. Science in its MAIN function, UNDERSTANDING of how the universe works, has a profound effect on our behavioral standards.

TECHNOLOGY AND APPLIED SCIENCE

What has technology done for our lives in the past and what can we expect from it in the future? I can't project what we will discover in science, because it is in the nature of science to be unpredictable, that is, we can't specify what we haven't yet discovered. A scientist sets as his life goal the discovery of new ideas and concepts of how the world functions, but what the new principle may be is, by definition, impossible for him to predict ahead of time.

Technology (applied science) is subject to surmises of what it will do and predictions of what direction it will take because it depends on already known scientific principles. I have selected six different technological areas to discuss, three of them are old and three of them are new. One of them might even be considered as in the future.

Steam Engine/Internal Combustion Engine: These have had a profound effect on the form of our everyday lives in a physical sense. These two inventions actually reduced human dependence on physical labor and gave rise to what we have called the industrial revolution which began in Great Britain and later spread to Western Europe and the United States.

Maxwell's Electromagnetic Theory: The primary discovery by Faraday of electromagnetic induction gave rise to the electric motor and electric generator and all of the electrical industry which came out of this discovery. When Faraday was first demonstrating magnetic induction at the Royal Institution in London, he had a galvanometer connected to a coil of wire and when he moved a magnet past the coil the galvanometer deflected. When Faraday was making the demonstration with his magnet, one of the government ministers (finance, I believe) asked Faraday of what use his demonstration might ultimately be. There are two answers which are attributed to Faraday in response to that query. One was: "What good is a new born baby?" and the other answer that I have heard (and I don't know which one is true), "One day you will tax it". Both of these answers express the nature of the situation even today.

Electromagnetic induction is, of course, only one of the consequences of Maxwell's electromagnetic theory and Faraday's discovery of induction. The other consequence is the discovery of radio waves by Hertz which resulted in the development of the communication industry. The situation today with respect to knowledge of world events is so different today than it was fifty years ago that it is difficult to imagine. There is nothing that can happen anywhere in the world that we don't know about within hours, and actually, at times, we see it happening! This is a result of the discoveries I have just discussed. Now the world is a much smaller place which has given rise to political and social problems which have yet to be solved.

Synthetic Chemicals: This is the third major technological breakthrough, covering all synthetic materials (polymers, drugs, agricultural chemicals, etc.). In fact, probably a majority of the half a million or more known organic compounds are man-made synthetic materials. The most heavily used of these quantitatively are the polymers and synthetic fibers. All of us are in some way in touch with synthetic chemicals right now. Natural fibers (cotton, wool silk) have been displaced at this time for the most part by synthetic fibers. More importantly, other materials (wood, metal) have been replaced by plastics, particularly plastics made generally from petroleum raw materials. This shift to synthetic materials has created a revolution in western society and is beginning to effect the rest of the world as well.

Synthetic drugs, synthetic agricultural chemicals, synthetic materials have all made an enormous change in the way we live. Our daily activities are dependent on the existence of those synthetic materials.

Microprocessor: This is a technology whose day has just begun. There has been an explosion in the use of the microprocessors, solid state devices that are the basis for the computers, watches, tape recorders and other such devices which are so prevalent in our country and whose use is expanding throughout the world. That revolution in the collection, storage and recovery of energy is just beginning. Information will become accessible with these "gadgets" by telephone, home consoles and various other devices. This revolution will have many social consequences. The increase in the ease and availability of these microprocessor devices for storing, transforming and recalling information will change the way we behave. First of all, the whole question of individual personal privacy will arise. The "bytes" of information which will be accessible to almost anybody will be very important information that will reduce our privacy. Everybody

will be able to look into your life, punch a button and see everything you have done since the day you were born, if they want to. Perhaps the device could be coded so the information won't be accessible, but that is very difficult.

You take for granted today that you have your privacy. In the future, you won't have your privacy unless you buy it. Your bank accounts, telephone calls, etc. will be recorded on a computer and people will have access to this information unless you fix it so they cannot. Privacy is one thing we would like to retain, and this microprocessor revolution is already beginning to show how difficult it may be.

Nevertheless, access to information of all kinds (scientific, political, economic) will be available so decisions will not have to be made on incomplete knowledge as they are today. We make decisions with only a fraction of the information we actually need and must use our "human" judgment for decision making. To make a decision when enough information is not available seems to be called "judgment". The time is coming when this will not be necessary. I believe this microprocessor "revolution" will change our behavior significantly. Our "judgment" may be better but our human interactions will change, which will lead to problems of another sort.

Applied Relativity (Nuclear Energy) refers to Einstein's equation $e = mc^2$, that is, nuclear energy. We must learn to deal with nuclear energy and use it in the proper way. We are trying to do this, sometimes successfully and sometimes no, but the method of operation is still in flux. We have not really evolved methodology for dealing with nuclear energy. There are some who believe that the only form of nuclear energy that we can use safely is fusion energy, with the fusion reactor, i.e., the sun, located about 93 million miles from the earth.

Applied Molecular Biology (Biological Information Transfer, Genetic Engineering and Biological Energy Transfer): There are a number of ways in which we may be able to usefully capture solar energy. Two of the most interesting, and perhaps accessible, ways stem from our growing knowledge of the molecular basis of photosynthesis. The first of these applied molecular biology activities involves genetic engineering--how do you modify the genetic behavior of a cell, invent a new crop that does not exist today, for example.

(1) Petroleum plantations: In the past four years we have been growing two species of *Euphorbia* plants for the purpose of harvesting the latex they produce and extracting the oil from it. This work was undertaken as an extension of our knowledge of the basic process of photosynthesis with a specific application, i.e., development of renewable resources from plants as alternate sources of energy. We have used in this work two species of *Euphorbia*, *Euphorbia lathyris* (Figure 1), which is an annual and *Euphorbia tirucalli*, a perennial. Both of these plants are shown in Figure 2 which shows the "plantation" in Southern California about one year ago; the *E. tirucalli* are in the foreground and the *E. lathyris* in the background. The *Euphorbias* exude a white latex, which is an emulsion of oil in water and we separate the emulsion to obtain black oil. The latex is a complex mixture of hydrocarbon-like materials. The overall yield of hydrocarbon is roughly 8% by weight of the dry *Euphorbias*. Since we can grow some of these species to maturity in one season (six months

or thereabouts) the amount of dry weight corresponds to 6 barrels of oil per acre per growing season. This yield is using wild seed, without selection and without plant breeding.

Furthermore, we have not yet had enough material to develop a true commercial extraction process. Therefore, it is a bit premature to make economic estimates. Nevertheless, this has been done at the request and demand of the Department of Energy, in spite of the fact that the data upon which these estimates were based was our own, and I am aware of how "flimsy" it is. The data does provide estimates of the order of \$20 per barrel for processing costs and another \$40 per barrel for capital costs for the actual processing plant, based only on a bench-top extraction plant. The cracking pattern of the material from the Euphorbias, by the way, is very similar to that obtained from the naphtha; the latter product sells for more than \$40 per barrel in the United States and \$50 per barrel in Europe. The preliminary economic estimates for the Euphorbia process are shown in Table 1.

Table 1

Comparison of Independent Evaluations of Oil from Euphorbia

	<u>Chevron</u>	<u>Stanford Research</u> <u>Institute</u>
	(1000 bbl/day)	(1600 bbl/day)
Feedstock		
Cost from farm	11	30
Credit for bagasse	--	19
Net feedstock cost	11	11
Other operating costs	10	14
Capital cost	46	41
(Amortization, 15% return, etc.)		
Total production cost	67	66

Obviously an improvement either in the oil yield or the oil composition from Euphorbias will greatly reduce the crudely estimated costs. IN the first instance, improvements can be achieved by simply selecting proper seed and plants. However, ultimately we want to reduce these plants to single cell tissue cultures. By selecting the cells for their oil productivity, both in terms of amount and in terms of composition, we could recover whole plants with the agronomic characteristics of oil production and composition that we want from the single cells separated out of the culture. It is conceivable that we might be able to introduce into these cells the genetic mechanism of the enzymes which would produce precisely the kinds of materials we desire with control mechanisms responsible to the climatic and agronomic conditions which we have available. We are, of course, limited to the use of land which is today not agriculturally productive, and that means "inventing" a new crop, which is where this discussion began. There is at this point the possibility of genetic engineering to solve our major energy problem.

(2) Diesel trees: On a recent trip to Brazil, my wife and I encountered another possibility for hydrocarbon production, a tree (Copaifera langsdorfii). We were told that if a hole were drilled in this tree, oil would come out. (We had heard of this tree on a previous visit and did not believe the stories about the production of oil after tapping.) We went to the Ducke Forest in the Amazonian jungle to observe one of these trees and watch the production of oil after tapping. The tree itself is shown in Figure 3 and it is possible to see the bung stuck in the hole from which the oil flowed in Figure 4. The tree we observed was one meter in diameter and about thirty meters high, a mature tree obviously. The amount of oil from one hole in the tree is about 20 liters in two hours, which means about five gallons of oil in about two hours. The material that comes from the tree can be used as a diesel fuel directly. There is no processing, no companies just nature--from the tree immediately into the diesel tank.

Can these trees grow in the United States. I have been in communication with the U.S. Department of Agriculture, and we hope that we will be able to obtain some seeds, or seedlings, of this particular tree for experimental purposes. The plan is to try to cultivate this species in Southern Florida and near the Gulf Coast of Texas. The reason we feel that these trees will be successful in these environments is that the USDA does have an experimental planting near Miami which contains Hevea rubber trees which grow under the same conditions as the "diesel tree" we saw in the Amazon jungle.

How long it will take to grow a tree of tapping age is a moot question. Keep in mind, however, that the original giant rubber trees that were tapped in Brazil for wild and they were tapped for almost seventy years. The Hevea seeds were eventually taken from Brazil to London, germinated there and then transferred to Malaysia where they were planted. Now all rubber is plantation rubber, taking eight years from germination to tapping for the rubber tree. Perhaps a similar pattern will evolve for the Copaifera tree, i.e., a relatively short period from germination to tapping.

(3) Synthetic chloroplasts: We are using our knowledge of how the plant takes sunshine and carbon dioxide from the air to synthesize fuel. We are able to predict how the green part of the plant captures the quantum and uses the quantum to make the fuel from the carbon dioxide of the air. We are just on the edge of being able to reproduce that process, not with biological materials but with totally synthetic materials.

Our understanding of the basic process of quantum conversion now permits us to create a solar capturing device which will make gaseous fuel. By an understanding of biological energy capture, conversion and transfer we can produce synthetically the functions of the energy-capturing system which are the most useful. We believe that the process consists of two quantum steps involving electron transfer across a phase boundary. If this premise is correct, it should be possible to construct that double layer with the photosensitive material residing on both sides of that double layer. We are now almost able to construct "synthetic" chloroplasts, these green particles of the plant that have the same function as the biological material.

CONCLUSION

Each of the problems I have discussed is not only a problem but an opportunity. It is an opportunity for us to grasp and solve that problem in a humanly acceptable way. Hard problems make life worthwhile and the solution of hard problems gives real pleasures in living.

I cannot refrain from a quote by a biologist of broad experience (Lewis Thomas, 1978): "We need science, more and better science, not just for its technology, not for leisure, not even for health and longevity, but for the hope of wisdom which our kind of culture must acquire for its survival".¹

I would like to close with a quotation by Albert Einstein written in September 1937: "...Our time is distinguished by wonderful achievements in the fields of scientific understanding and the technical applications of these insights. Who would not be cheered by this? But let us not forget that knowledge and skills alone cannot lead humanity to a happy and dignified life. Humanity has every reason to place the proclaimer of high moral standards and values above the discoverers of objective truth. What humanity owes to personalities like Buddha, Moses and Jesus ranks, for me, higher than all the achievements of the inquiring and constructive mind".²

1. Lewis Thomas. THE MEDUSA AND THE SNAIL: MORE NOTES OF A BIOLOGY WATCHER. Viking Press, New York (1979), p. 175.

2. Helen Dukas and Banesh Hoffman (ed). ALBERT EINSTEIN: THE HUMAN SIDE. Princeton University Press (1979), p. 70.

Figure 1
Calvin.
"Plantation", Santa Ana, CA
E. tirucalli (front)
E. lathyris (rear)

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CBB780-15635

Figure 2
Calvin
"Plantation", Santa Ana, CA
Euphorbia lathyris

Figure 3
Calvin
Copaifera langsdorffii,
Ducke Forest, Manaus, Brazil

CBB799-11783

Figure 4
Calvin
Copaifera langsdorfii,
Ducke Forest, Manaus, Brazil,
showing bung in tree trunk

CBB799-11785