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# The Future through Science

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As we consider the future of our country and of the world, we can perceive that our human resources of trained brainpower in all fields, including those of science and engineering, are foreordained to be of crucial importance to our destiny. It is my belief that we only dimly perceive the extent to which this is true, and that by no means are we taking the necessary steps to encourage the adequate development of this brainpower.

We, the people of the United States, are the most fortunate large group of people on the face of our planet in terms of our physical well-being, personal liberty, material comfort, and the opportunities open to us for social and intellectual development. We occupy only 7 percent of the world's total land area and number only 6 percent of the world's population, yet we are privileged to use 40 percent of the world's total electric power, to drive three-quarters of the world's automobiles, and to communicate through 60 percent of the world's telephones. We own 30 percent of the world's radio and television sets. In going about our daily business, we manage to use up two-thirds of the world's supply of newsprint, 60 percent of the world's annual production of aluminum, 40 percent of the world's annual supply of chromium, one-third of the world's annual supply of tin, and 50 percent of the world's annual supply of copper. Our gross national product of goods and services has soared from $56 billion in 1933 to $90 billion in 1939 to $375 billion in 1955.

Although we may think we enjoy this great prosperity simply because we richly deserve it, other more substantial reasons can be uncovered. We live in a land highly favored in climate and natural resources. Our shores have great natural harbors. We have extensive systems of rivers and lakes for internal transportation and irrigation. We possess extensive fertile range and farm lands situated in several climate zones, permitting the production of large yields of greatly varied grains, fruits, and vegetables. We have great forests, large amounts of water power, large deposits of coal, oil, copper, iron, uranium, mercury, zinc, phosphates, sulfur, and a host of other important metals.

We owe much to our democratic political system. We can be thankful to our tradition of religious toleration and the separation of church and state, which allows one man to pursue those goals and engage in those activities that could have been prohibited by the religious convictions of another. During the early decades of our history, the geographical isolation of the United States aided greatly in the evolution of our governmental and social system without serious molestation from without. Our particular system of capitalistic business enterprise, regulated in many important ways by government, provides, by-and-large, in an excellent way for the interests of the stockholder, the manager, the working man, and the consumer. The development of our public school system and the growth of our private and state institutions of higher learning have had an important role in all phases of our history in providing a literate and intelligent electorate, a group of skilled workers, and the core of leadership in the professions, business, religion, and public life.

## Debt to Science

To all these and other fundamental reasons for our present prosperity that are widely understood must be added another factor which has achieved its greatest importance only in the past two decades and is not so widely recognized. This factor is the firm establishment of scientific research and development as an important base element of our industrial system. The importance of the scientist and engineer in the development of the weapons of war is well recognized because of their impressive record in World War II, but the contribution of the scientist in times of peace is even more important.

The farmer of 1900 farmed with methods not greatly different from those of previous centuries except for the introduction of the horse-drawn steel plow, the reaper, and a few other simple machine tools. Our farmer of 1900 would not recognize the practice of farming as it is carried on in 1956. Indeed, most city people do not realize the extent of the revolution in farming methods that has occurred in the past 15 years. The introduction of more and more specialized motor-driven tools, of scientifically developed strains of crops and scientifically bred cattle, of new irrigation techniques, of weed-controlling chemicals, of insecticides, of new fertilizers and fertilization techniques, and of chemicals for the control of growth and disease in poultry and cattle has allowed great expansion in productivity in the face of a sharply declining farm population.

In medicine, we have seen the development of the sulfa drugs, the antibiotics such as penicillin, streptomycin, aureomycin, erythromycin, and the sterol derivations such as cortisone; the introduction of new operative techniques, a better understanding of viruses, and polio vaccine; the development of new drugs for the treatment of mental disease; and other developments too numerous or too technical to mention.

Every household is familiar with the miracle fabrics nylon, Dacron, and Orlon. Soap, which remained for cen-

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turies mankind's principle cleansing agent, now runs second best to its tersely labeled synthetic successors, Dreft, Treet, Trend, Tide, Surf, All, Add, Fab, Dash, Vel, Joy, and Cheer.

Space allows only a brief recitation of important industrial products and accomplishments: synthetic rubber, plywood, plastics, foamed plastics, television, high-fidelity sound reproduction, synthetic adhesives, paints and corrosion-resistant coatings, new methods of printing and reproduction, color photography, titanium, tantalum and zirconium metal, transistors, magnetic tape, solar batteries, electronic computers, nuclear reactors, jet aircraft, atomic-powered submarines, and so forth.

Each phase of our everyday life, whether it concerns food production, heavy industry, transportation, communication, commerce, entertainment, public health, medicine, home life, or our social behavior, depends very directly on the development of these new products. It is hard to establish in cold dollars and cents what part of our gross national product depends directly or indirectly on the scientific applications that have been developed to commercial usefulness only within the past decade, but it certainly is a substantial percentage. Two of our largest concerns, Dow Chemical Corporation and Monsanto Chemical Corporation, trace 30 to 40 percent of their 1956 sales to products that have been developed in the last 10 years. The new agricultural chemicals alone—the fungicides, herbicides and insecticides—constitute a $400 million-a-year business. Eighty thousand employees of the General Electric Company work on products that did not exist before the end of World War II. A spokesman for the National Science Foundation estimates that United States industry as a whole gains back $20 to $50 for each $1 that has been spent on research during the past 25 years.

Now, while it is true that a rather large proportion of our population is involved in the manufacture, distribution, and sale of these products, it is also true that the original conception and development of the ideas upon which these products are based were carried out by a comparatively miniscule fraction of the total population. In this age of specialization we all find it possible to enjoy the benefits that stem from the ideas of the few without understanding what those ideas are. We find it sufficient for our purposes that some among us are able to synthesize penicillin, design an atomic reactor, solve a system of simultaneous equations on an electronic computer, trace the course of photosynthesis, or take a photomicrograph of a living virus. To enjoy the advantages of our complex industrial society, we recognize the necessity for this interdependence and give up the greater self-reliance we possessed in an earlier age. We give thanks that the specialists somehow seem to appear to solve the problems we cannot solve ourselves.

In our situation, when so many of us owe so much to the few, we would suppose that one of our chief national concerns would be for the conservation of our most important natural resource—trained brainpower. However, there are many signs that this is not the case. Let us consider some of the tasks of the future for which we shall require all the assistance we can get from trained brainpower—from the scientist, the engineer, the lawyer, the industrial executive, the economist, the social scientist, the statesman, and many others.

First of all, merely to maintain our present economy we shall have to carry out scientific research and industrial development on an accelerated pace. Basic science will have to be given strong support, and the intellectual geniuses among us must be discovered, trained, encouraged, and rewarded. A large body of trained workers and technicians must be raised to fill many new types of industrial positions.

Second, we must face squarely the implications of an expanding population. The present population of the United States in 168 million, increasing at the rate of 1.5 percent annually. This means a 35-percent increase in 20 years and an increase of almost 100 percent by the year 2000—only 43 years hence. Our power consumption will go up at a much greater rate. The total installed capacity for power generation in this country is roughly 100 million kilowatts. The Federal Power Commission estimates that we shall need three times as much by 1980. We are rich in coal, oil, and water power, but not nearly so rich that we could meet this staggering increase with these sources of power alone. Hence we may expect to see a great development in nuclear power generating capacity. In a few decades, atomic power will be for us an absolute necessity. In several other major industrial countries, such as England and Japan, which are even now running out of reserves of fossil fuels, atomic power is a necessity within the coming 20 years. There is also hope that solar power or the use of controlled thermonuclear reactions will add eventually to our supply of energy from other sources.

Our population growth of the next 50 years poses other problems of no mean magnitude. Our present farm surpluses will disappear, and we shall require all the skill of our soil scientists, agronomists, and agricultural experts to raise productivity to the required levels. New methods of processing food to secure greater utilization of our plant and animal crops and to reduce waste and spoilage will have to be devised. We shall be faced with increasing difficulties in obtaining sufficient forest and mineral products. The adoption of adequate conservation policies and the development of substitute materials will assume great importance. Our normal sources of fresh water will have to be supplemented on a large scale by fresh water obtained from the sea. Congestion in our cities will intensify our present problems and create new ones in transportation, utilities, water supply, waste disposal, public health and recreation, and mental health and social behavior. We may be forced to reduce drastically the waste of resources entailed in the unlimited production of consumer goods that is symbolized best by the American automobile. The automobile is a peculiarly fertile species that reproduces freely and appears to have no natural enemies sufficiently powerful to hold its growth in check. Furthermore, its reproduction has the peculiar feature that the offspring is always 6 inches longer, 3 inches wider, 10 percent more powerful, and 20 percent shinier than its parent. It will be interesting indeed to note the breeding habits of the automobile 50 years hence.

## School Crisis

These are but a few of the internal problems that we must face and that will have to be solved largely by the young men and women whom we are training in our schools today for intellectual leadership. If my analysis means anything at all, we need to insure that a high percentage of our most gifted young people be trained to a very high degree in intellectual and professional fields. The graduates of the near future must exceed those of the past generation not only in numbers but in quality. Unfortunately, the alarming crisis in our school system makes it certain that we shall fall far short of this goal. Without strong emergency measures, the results may be extremely serious.

We have a school crisis because we have an almost explosive increase in the numbers of students at the same time that the social and economic position of the teacher relative to the rest of society has fallen so precipitously that only a small fraction of the needed qualified teachers can be found. The birth rate was abnormally low during the depression of the 1930's, but it has risen steadily since. In 1956 the number of children born was more than 4 million, or twice that of 1935. The tidal wave of new students has reached the primary schools and is reaching the high schools, resulting in the overcrowding and split sessions so common in most communities. Six

million children were in secondary schools in 1946, 8 million are there today, and in 1966 there will be 12 million with the peak still not reached.

Our colleges are just now feeling the upswing after the downturn following the expiration of the GI Bill. Not only is the college-age population growing, but the percentage of that population seeking a college education is also increasing. Our present college enrollment of about 3 million will increase to at least 4.5 million by 1966 and could well climb to 5.5 million. Certain areas such as my home state of California will be particularly affected. In California the population will increase 30 percent in the next 10 years. The school population at all levels will increase by as much or more. If we were prepared to maintain educational standards for such an expanded school population, these statistics would be very heartening, for universal education has always been one of our cherished dreams. Considering the great deficiencies in our preparation to meet these phenomenal increases, our dream will have some nightmarish aspects.

The physical space simply does not exist to accommodate these students. We need something like 700,000 new classrooms for the next few years, not to mention laboratories, libraries, and recreational and other facilities. Finding the teachers to staff these classrooms is an even more difficult problem. We shall need 600,000 new teachers by the end of this decade. At the college level we shall need 25,000 new faculty members per year. To supply these totals over the next few years would require that one half of the recipients of college degrees accept jobs as teachers. At the present time, only 20 percent do so, and the percentage is likely to decrease rather than increase, particularly among graduates with training in the sciences. Hence the quality of teaching, particularly at the high-school and grade-school levels, is certain to decrease. Even if teachers were well rewarded, we could not hire enough highly qualified teachers because the potential supply is so much less than the total demands of industry, government, and education.

But teaching, far from being a well-paying profession, is one of the most poorly rewarded occupations. The starting salaries are substantially less than those available in industry for college graduates and after many years of service will not increase substantially, whereas a college graduate in industry will typically double his salary in 5 years. Electricians, plumbers, auto workers, and railroad conductors and engineers earn more than teachers. Considering the depreciation of the dollar, the real income of the teachers has actually fallen since 1940. Every year thousands of capable, effective teachers who love the work they are doing leave the profession because they simply cannot support their families in any decent standard of living on the pay that they receive. It is pure fantasy to believe we can bring about any real change in our school systems without a drastic change for the better in the economic incentives for teachers.

These factors have led to a severe decline in the quality of our secondary-school education. Half the American public high schools offer no foreign language at all, and one-quarter teach no physics or chemistry or geometry. Students get less and less contact with basic fields of science. In too many schools the inspiration of a gifted, inspiring science teacher has disappeared completely. Students of unusual intellectual endowment are not encouraged or are actually repelled, and if later they do develop an interest in science they find that their high-school preparation is inadequate to permit them to elect a science or professional major field of study in college.

These school problems are of such proportions that they cannot and will not be solved for many many years, but determined steps can be taken to check a complete breakdown in the quality of the education of our youth while we rebuild for the future. Limited space does not permit me to review the many recent actions of local communities, of private foundations and corporations, of scientific societies and other social and political groups which indicate an awareness of this problem and the initiation of steps to alleviate the evils. I should like to add a few personal comments on possible solutions.

First, a great many more of us are going to have to realize how important it is to our continued national well-being and progress to maintain and expand our public school system. Our forebears had no sooner set foot on the soil of New England or entered the forests of Pennsylvania or Kentucky than they entered upon the construction of schools and procured a schoolmaster so that their sons should achieve the elementary literary skills so necessary and prized even in a pioneer community. Our own sacrifices to this ideal are small by comparison, and surely there is room for additional support on our part in the form of taxes and effort. Surely a nation that can efford $5 billion annually for tobacco, $1.7 billion for newspapers and magazines, $10 billion for hard liquor, $2 billion for television sets, $1.3 billion for movie tickets, and $1.2 billion for foreign travel will not be brought to its knees by some billions of additional expenditures for education.

We must immediately put out sizable funds for classroom construction and for drastic increases in the pay scales of our teachers. I do not see how we can avoid the conclusion that a large part of the money for this purpose must come from the Federal Government. I see no fundamental reason why methods for the dispersal of such funds cannot be worked out without endangering local control of our schools. We need to establish the principle that it is in the national interest that every student above a certain level of ability, regardless of his origin and the status of his family's finances, is privileged to carry his education as far as his personal motivation and his scholastic ability will carry him. This principle requires that a system of scholarships paying a major fraction of tuition, book, and living expenses be established. These scholarships should give the student wide limits in his choice of school and choice of field of study.

We need to explore new teaching techniques. We are not quite sure of the most effective role of television, audiovisual aids, and other methods in and outside of our modern classrooms, but certainly their role is important and should be explored thoroughly at once so that our limited numbers of teachers can be used more effectively. We need to relieve our present teachers of the clerical and menial tasks that take up one to two-thirds of their time. For the gifted student, we should explore techniques of self-teaching and individual study with much less detailed guidance from the teacher. We must reexamine our licensing procedures, which now contain much nonsense. We need to do a much better job of counseling the young and instilling a better attitude or motivation toward intellectual pursuits in general. In this regard, it is not enough to emphasize the importance of advanced intellectual training; we must also present a clearer picture of what a scientist actually does and try to convey some appreciation of the fun, the thrill, and the inner satisfaction which a scientist usually experiences in his career. Professional men within each community can assist greatly in this problem of counseling, and indeed I am fully aware that many member organizations of the AAAS have active programs in this area.

Many reforms are also necessary in the university science departments to maintain the high position of university research as a fountainhead of new ideas. I believe we need to establish more research professorships so that outstanding research scientists who may not be needed or suited for formal teaching are able to assist in the training of graduate students. We need to set up new central campus facilities for electronics development and service, radioactivity measurements, computing equipment, and so forth, so that the research man can spend

his time on new experimental ideas rather than on the menial tasks of equipment building better done by technicians. My space does not permit me to expand here on the many ways in which we can foster the work of the creative thinker on the campus.

## World Situation

I have indicated that the serious educational problems we presently face are of considerable concern because of our internal situation arising from an expanding population. Our concern is greater when we consider also the problems of foreign policy. The problems raised by rising population in our country are minor compared with those in many nonindustrial areas of the world. We are in an era of rising nationalism, an era of what Chester Bowles has called rising expectations, among the backward and colonial peoples of the world. The transition of these peoples to stable democratic self-government and to the status of modern industrial states which most of them aspire to become would be a herculean task, even if it were approached in a completely rational manner by all parties concerned. We know only too well that confused, emotional, and irrational steps leading frequently to bitter and ugly armed strife have too frequently marred the attempted transition to a better way of life.

These problems would certainly have been with us even without an ideological conflict with the Soviet Union. This conflict of course adds greatly to the problem of the emergence of the former colonial and backward nations. It also adds greatly to our own insecurity. For the first time in our history we are faced with the certainty of extensive damage to our own cities and civilian population in the event of a major war. In quantitative terms, this change is almost the most extreme that could be imagined. During and at the end of World War II no nation had the power to inflict serious physical destruction on continental United States. Today or in the near future, the Soviet Union has, or will have, the bombers and the atomic and thermonuclear bombs to lay waste the centers of all of our major cities, within a very short period of time, and to annihilate a sizable fraction of our population. We have defenses against such an attack, but our defense is only partial. Within a few years—perhaps 5, perhaps 20—both the United States and the Soviet Union will have perfected the intercontinental ballistic missile with a thermonuclear-bomb warhead. Against this ultimate weapon an effective defense is extremely unlikely.

Our main program at the present time is the grim and uncomforting reliance on the mutual deterrent power of annihilation, the threat of counter blows so completely damaging that no rational government would initiate a large-scale war. In lieu of any real agreement with Russia and with other nations on arms limitation and inspection, this is our chief national policy. Plausible arguments can be given for believing that peace can be maintained on this basis of more and bigger bombs and surer means for their delivery. I regard this policy as somewhat disturbing, and as several more nations are added to the present three in possession of nuclear weapons, I shall regard the policy with even greater uneasiness. Countries such as France, Sweden, Belgium, Germany, and Japan clearly have it within their scientific and industrial resources to develop atomic bombs within a few years.

I am not at all sure that nuclear disarmament with adequate safeguards against treachery can be achieved, but it is vital that we maintain a continuing evaluation of every possible approach. I see no fundamental reason why we of the West and our ideological opponents behind the iron curtain cannot ultimately adjust our differences sufficiently to live side by side in mutual trust. The appalling waste of the nuclear arms race and its threat of potential utter disaster are two of the central problems that face us in the next few decades.

## The Future

This problem and the others I have all too briefly sketched will not be solved by scientists alone or by an educated elite alone. But no solution will be successful which ignores the scientific and intellectual basis of modern civilization. We need highly skilled specialists to attack the agricultural, industrial, social, and governmental problems not only of our own country but of every part of the globe. We need many new specialists in fields to which we have paid scant attention on a national scale in the past. We need to understand the language and customs, the history, the hopes and fears of other nations so that our technical skill can be effectively applied to the problems of development in other lands. The solution of these problems is vital to our own security and to the emergence of a more satisfactory world order.

We need great leadership in all fields by men who are cognizant of the values of our civilization and the factors which influence it. The liberal education that prepares men for such leadership must include science as an integral part, for science is too central a part of our modern culture to be ignored.

We may look forward to many wonders in the coming 50 years. Large earth satellites will continuously circle the earth and monitor the weather, making weather prediction a much more certain matter. We may even effect large-scale control of the weather itself in some areas. Manned satellites may be possible, and space travel to the moon may be achieved. Large ships will be propelled almost exclusively by nuclear power plants. Air travel to any part of the world will be a matter of a few hours. We shall have TV phone communication. Our knowledge of photosynthesis and the processes of the living cell and bodily functions will be enormously more complete, giving us greater control of disease. We shall exercise greater control over human fertility. Problems of mental health, delinquency, and crime should yield to better understanding of biology and of mental processes and social behavior.

We cannot take it for granted that these things will come to pass, that our country will continue to prosper, that the continuing international crises can be overcome without disaster. We must recognize the hazards and prepare ourselves to meet them. The last 25 years have emphasized to any discerning person the importance of trained brainpower to our future—to our scientific future in which our economic prosperity and military security are by no means assured. It would be perilous indeed to neglect the discovery, training, and encouragement of the intellectual leaders of this generation and of the generations of the future.