The Program in the Natural Sciences

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THE PROGRAM IN THE NATURAL SCIENCES

A Statement by Warren Weaver

"The physical sciences have placed vast stores of energy and a multitude of new materials and devices in our hands. Yet we must be on the eve of a still mightier challenge. He that ruleth himself is greater than he that taketh a city. A society that has the measure of itself is greater than one which chains the lightnings and harnesses the seas. It may be that we shall presently begin to use science in a new and worthier way, to give us our bearings, to help us understand the ecology of our own species." From Charles Darwin, by Paul B. Sears.

The program of the Natural Sciences division of The Rockefeller Foundation is somewhat complex, taking different emphases in different parts of the world, changing as new opportunities emerge, utilizing widely varying kinds of activities. But all the variety and technical detail fall into a recognizable pattern if one has in mind the underlying strategy. Let us therefore start by examining the philosophy which motivates the program.

The Philosophy of the Program

With the understanding that each statement deserves a considerable expansion, here is the credo of the present Natural Sciences program:

During roughly the past century, science has made tremendous progress in studying the physical universe, bringing its electro-mechanical forces under analysis and control.

This has involved the development - largely in pure physics and chemistry - of exquisitely precise and powerful methods of studying inanimate nature.

This penetration of the mysteries of physical nature will, and should, go on.

But research in physics and chemistry receives large support from governments, from industries, and from many other sources.

For this reason, if for no others, we need not be concerned with supporting research in the physical sciences.

The analysis and control of the physical universe has made possible technological advances which have contributed to our safety and our comfort; but it is also true that some frightening secrets have been unlocked.

Whether man has the wisdom to utilize properly his increased knowledge of physical nature is not as yet clear.

To prevent becoming degraded by gadgetry or destroyed by physical force, it will be necessary to solve a variety of problems; and behind most if not all of these personal, social, and international problems there is a more basic set of problems - the problems involved in understanding individual human behavior.

We have made some useful progress in recognizing and treating certain pathological aspects of behavior and in understanding why normal people act the way they do; but broadly speaking, this field remains a mystery, and ignorance concerning it constitutes a great handicap to man's attaining a rational life.

Before we can hope to be very wise about so complex a subject as the behavior of a man, we obviously have to gain a tremendous amount of information and insight about living organisms in general, necessarily starting with simpler forms of life.

Indeed, in viewing the development of science and its influence on man, it is a partially unfair but nevertheless clarifying simplification to say that physics (plus parts of chemistry, mathematics, geology, etc.) tends to lead to technological advance - to gadgetry, to improvements in the mechanisms of existence, to control of the forces of inanimate nature; while biology leads to an understanding of life - and hence furnishes the basis necessary for progress in the sequence of problems which begin with the strictly biological, but then move through the mental to the social.

At this point in the argument one reverts to the opening statements about the physical universe. Why has physics so far outrun biology? Why do we seem to know so much more about atoms than we do about men?

The answer, of course, is that life is so subtle and complex an affair. Inanimate nature can be broken up into bits and analyzed piece by piece. A living organism, on the contrary, loses its essential character of being alive if it is dissected. Furthermore, man had to learn a great deal of the chemistry and physics of inanimate nature before he was prepared to take on the problems of living things.

There is, nevertheless, a large and a rapidly growing body of evidence that the biological sciences are now coming of age; and it is amply clear that the physical sciences have, in technique and experimental procedures, a great deal to contribute to the study of biological problems.

It is important to note, incidentally, that the biological sciences, having less extensive or less immediate connections with technological developments and with military preparedness, receive relatively little support as compared with, say, physics.

But support for the biological sciences - greatly increased support, imaginative and flexible support, sustained support - is necessary if we are to gain, for the animate universe, an understanding and a capacity to guide and control which is comparable to what we have gained for the physical universe.

It would be ridiculously naive to expect that basic research in biology will promptly and completely furnish an understanding of human behavior, or that it will quickly close the gap between the natural and the social sciences.

But research in basic biological problems is research in the right direction. And it is surprising and gratifying how rapidly results do break through. The biochemical genetics of five years ago has led to a new kind of attack on the problem of alcoholism in man. The painstaking research of the protein chemist has led to the development of antihistamines which promise to control the common cold. Studies of absorption spectra of steroids, begun under Rockefeller Foundation auspices only twelve years ago, now constitute one of the most promising attacks on the cancer problem. Studies of the physiologists and the biochemists have revealed substances, totally unknown a few years ago but which the organic chemists have now synthesized, which permit the treatment of various disordered mental states.

Thus the next hundred years - perhaps even the next fifty years - can well be the great period of accomplishment for the biological sciences, the period in which man acquires a real insight into the essential nature of living things, leading eventually to a real understanding of his own self.

This coming of age of biology will be seriously impeded unless the circumstances of encouragement and support are favorable for the breaking down of old orthodox compartments in science, unless all the tools and the techniques of the physicist, the chemist, and the mathematician can be brought effectively to bear.

The gap between our sciences and our morals is primarily a gap between the capacity with which we control the physical forces of nature and the wisdom with which we control ourselves. Research in the physical sciences does not contribute toward closing this gap, and is in fact likely to widen this gap. Research which lays the foundations for a better understanding of the functioning of living organisms, and hence an ultimately better understanding of human behavior, tends to help close this gap.

If it is objected that this seems a long, slow approach to the problem of human behavior, one can only agree and ask if there is any safe way of proceeding without knowledge of the biological facts which condition behavior. If it is objected that morals make a more direct approach to the problem of increasing the wisdom of our control of ourselves, one agrees again, but adds that this does not in the least reduce the desirability that science contribute to the problem as positively and as effectively as possible.

Conclusions

All of the foregoing argument culminates in a few conclusions:

Do not, at least for the present, be generally concerned with supporting research in the physical sciences.

Place dominant emphasis on studies which are aimed at increasing our knowledge of basic biological problems.

Particularly stress fields that promise to increase man's understanding of himself.

Encourage the application to biological problems of all the methods developed in physics, chemistry, and mathematics.

The Experimental Biology Program

The considerations just sketched led to the adoption, in 1932 and 1933, of a program for the Natural Sciences in which the primary emphasis is upon experimental biology.

Expressed in the most general terms, it is intended that the activities of the division be aimed toward the life sciences, rather than the physical sciences. Within the classical fields of biology, there is a strong preference for the more modern experimental studies (such as genetics and cellular physiology, for example) as contrasted with the older collecting and descriptive studies.

In addition to the more orthodox biological subjects, the program has had a special concern to develop the connections between the biological

and the physical sciences (biochemistry, biophysics, chemical genetics, molecular biology, etc.).

Condensed to one sentence, the program in experimental biology is broadly concerned with the constitution, structure, and functioning of living organisms and their component parts, including a special interest in the application to basic biological problems of the analytical and experimental techniques of chemistry, physics, and mathematics.

In terms of more specific detail, the experimental biology program may be outlined as follows:

Biology - including cytology, ecology, embryology (developmental mechanics), genetics, histology (tissue culture), microbiology, molecular biology, physiology.

Chemistry and Biology - including biochemistry, organic chemistry and biology, physical chemistry and biology.

Physics and Biology - including radiation biology, structure analysis, biophysical instrumentation.

Mathematics and Biology - including mathematical biophysics, statistics.

Importance of the Human Element

Planning is necessary, and there is such a thing as a good plan or a bad plan. A stimulating and stable institutional setting is also important. But the really important thing is men.

The way to advance work in any field whatsoever is to seek out the well-trained men of capacity and character, men who are imaginative and energetic - and then back them. If one is giving broad and sustained support to an area, he must also be concerned to help create a future flow of such persons - that is, he must help create attractive circumstances for the recruitment and training of younger personnel.

There are variants to this principle of backing men, and the variants are not always obvious. One must not expect that backing men will always involve grants to individuals, or grants for salaries. Sometimes one is fortunate enough to find a considerable group which deserves backing. Thus at the California Institute of Technology we are giving broad support to the combination of chemistry and biology. But even in these large groups, the leadership of Pauling, Beadle, and others, is an absolutely essential matter. And it is the combined quality of all of the personnel involved that, in the last analysis, justifies the support. Once in a while one finds a situation where the traditions are so high and so well maintained that support is justified even if it is support for future men not at the moment known and specified. But in all such variant cases there is - or should be - no real departure from the guiding principle that what counts is men.

Subjects of Present Special Interest

It is neither possible nor desirable to give support to all phases of modern biology. As an illustrative rather than inclusive list, some of the subjects which now appear to be of special interest and promise are the following:

Biochemical Genetics - A study of the chemical mechanisms of inheritance, leading to the concept that the presence of a single inherited gene gives the organism the capacity to carry out some one chemical process, whereas the organism cannot carry out that process if the gene in question is not inherited.

Enzyme Chemistry - A study of the chemical substances, protein in character, which even in very small concentrations and without themselves being used up in the process, exert an essential control over the chemical processes in a living organism.

Cytochemistry - The study of the detailed chemical happenings within individual cells. Modern micro-cytochemistry involves highly advanced instrumentation, chiefly furnished by the physicist, which makes possible chemical investigation of even a very small portion of a single cell.

Protein Structure - The study of the architecture of protein molecules. These huge and complicated molecular structures, containing thousands or hundreds of thousands of atoms each, are the basic units out of which living stuff is formed.

Microbiology - The study of single-celled living organisms, such as bacteria, bacteriophage, fungi, yeasts, and viruses. These simpler forms not only teach us a great deal about more complex forms of life; they are also in direct practical relation with men (antibiotics, synthesis of fats and proteins by microorganisms, etc.).

Human Ecology - The study of men in relationship with their total environment. This subject involves all divisions of The Rockefeller Foundation, as is made clear by merely mentioning that the population problem is included within human ecology. The natural science aspects of human ecology involve genetics, biochemistry of nutrition, certain phases of conservation, our interests in agriculture, etc.

Agriculture

Agriculture is, in large part, applied biology, and hence it is not a surprising nor anomalous part of a program which stresses biology.

The Natural Sciences division has two sorts of activities in agriculture. On the one hand, it has responsibility for administering the interests of The Rockefeller Foundation in cooperating with certain governments in conducting research in agriculture. The only presently active instance is the Mexican Agricultural Program, although a smaller but similar undertaking has recently been approved for Colombia, and is just in the process of being initiated.

On the other hand, the division's normal (i.e., non-operating, involving only grants to other agencies) program of work in Latin America involves an increasing emphasis on agricultural science, including advanced

training of personnel and grants for scientific equipment. We treat this non-operating interest in South American agriculture as a part of our central emphasis on biology - a part which is specially adapted for the region in question.

The Record

Over the past seventeen years, the recommendations of the division have led the Trustees to devote to the main interest in experimental biology something like 80 per cent of the total funds charged to the Natural Sciences.

Of the remaining 20 per cent, just about half has been given to so-called "Special Projects" and the other half to "General Program." Special Projects is our new name for what used to be called "Exceptions to Program." They are projects, not in biology at all, which seem so specially promising and so unique in character that they deserve consideration, quite apart from any definition of program. "General Program," on the other hand, involves projects which concern the whole range of the natural sciences. The best and by far the largest example of General Program is the support of the National Research Council Fellowships in mathematics, chemistry, physics, biology, psychology, anthropology, forestry, etc.

The real record of this program is not to be found in any tabulation of moneys spent. It is to be found in the record of the men aided; in the existence of an enlarged number of well-trained individuals who are determined to go on working on basic biological problems; in a new spirit of cooperation between the physical and the biological sciences; in such official and professional recognition of this cooperation as is shown by the

establishment in England of the first professorship in "molecular biology"; in a changing orientation of effort and emphasis within biology itself.

To sense the full flavor of these statements, and to observe directly the evidence for them would require a large and extended effort. A visit to the biology department of the Massachusetts Institute of Technology fifteen years ago and another visit now would tell a good part of the story. An examination of a year's output of articles in the Scientific Monthly fifteen years ago, and in the Scientific American now, would also tell a good part of the story.

Out of the great variety of proposals for research projects submitted by institutions and individual scientists for consideration by UNESCO, the Secretary General made an evaluation of the urgency of the problems involved and set up a list of fifteen projects in the order in which they should be considered. Top priority was given to an institute for the study of self-reproducing substances (cells in living bodies, microorganisms, and viruses); second on the list was a chain of laboratories in nutritional science and food technology; third was an institute to study life and resources in humid equatorial zones; and of the remaining twelve, only one project deals exclusively with physical science (astronomy), five deal with studies which combine physical and biological interests, four more concern subjects specifically within present Natural Sciences program, and two are medical.

Thus this world-wide canvass of the most urgent present problems of all the sciences gives highest priority to three projects which fairly well define the present Natural Sciences program, and gives the Natural Sciences program a total score of something like twelve out of fifteen.

Recently, with both German and American participation, a conference of biologists was held in Germany to consider the re-establishment of biological research and instruction in German universities. In formulating its conclusions, the conference began with a statement of principles, from which the following are quoted:

"1. The importance of biology for human welfare is steadily increasing. Biology forms the essential foundation for a large number of other disciplines.

"2. Therefore, biological research must receive more active promotion than hitherto, and biological instruction must be adapted to the present and anticipated expansion of knowledge.

"3. In biological research and instruction, the emphasis is shifting markedly from the forms of life to the phenomena of life. Therefore, phenomena common to all forms, such as structure and function of the cell, heredity, development, growth, environmental effects, etc., should be given, wherever possible, unitary presentation.

"4. A well-proportioned program of biology requires the inclusion of many central and borderline areas which have previously not been treated adequately, or not in the proper context, e.g., biophysics, biochemistry, microbiology, applied biology, etc."

Thus, today's biologists state the matter in terms almost identical with those which were used in first presenting the Natural Sciences program to the Trustees eighteen years ago.