Science in Human Thought and Action

The following two articles—by Joel H. Hildebrand and Bart J. Bok—are based on papers given by the authors in the symposium on "Science in human thought and action," held in Berkeley, California, on 29 Dec. 1954, which comprised the third part of the general symposium on Science and Society. *The papers given in the session devoted to "Population problems" appeared in the 13 May issue; those in the session on "Natural resources: power, metals, food" will appear in a subsequent issue.*

interpretations, as listed by James C. Caldwell, of the University of California (*3*):

> If we glance at the variety of subjects and purposes deemed humanistic in times past, we see even more clearly the difficulty of the problem. For The Humanities have, for sundry humanists from Petrarch to the present, consisted in: discovering and editing Greek and Latin manuscripts; defining the nature of the courtier; developing liberal-minded citizens; a broad curriculum of study including agriculture, diet, exercise and moral teaching (Milton); knowing the achievements and aspirations of the spirit of man; narrow classical scholarship; broad classical scholarship; relating the results of science to man's need for conduct and for beauty (Arnold); discovering standards of value in the arts and religion; realizing the potential dignity of man as an autonomous being concerned with the efforts, including scientific ones, to increase the intellectual value of life; realizing the primacy of the higher will; studying great books in a grounding of Thomistic philosophy (the Chicago plan); the enlightened discovery of our larger cultural heritage; the effort to transform the chaotic variety of human records into a cosmos of culture; the identification and inculcation of the good, the true, and the beautiful; various "core" curricula.

In contemporary academic parlance, the term usually includes philosophy, language, literature, and history, but not even these without question. Douglas Bush (*4*), professor of English in Harvard University, has said:

> Negative terms, however, are not enough. The "humanities," in the original meaning of this and kindred words, embraced chiefly history, philosophy, and literature. These were the studies worthy of a free man, that ministered to *homo sapiens,* man the intellectual and moral being, and not to *homo faber,* the professional and technical expert. And these, with divinity, completed the central circle of human knowledge and understanding. Divinity went overboard long ago; history, which once was literature, is now a social science; and philosophy, though still grouped with the humanities, has become a branch of mathematics. Thus in common usage the humanities mean literature and the fine arts. That is an unfortunate narrowing—for Milton a humane curriculum included mathematics and science and even agriculture—but we may take things as we find them and may concentrate on literature, which is central and representative.

Social sciences, such as economics and sociology, are usually excluded, apparently because, although they are certainly concerned with man, they deal primarily with man as he is, instead of as some think he ought to be. They investigate money values but not moral values. Biology and physical science are not ordinarily included among "the humanities." If these distinctions are purely arbitrary, one should not quarrel with them; but if our concern is with humanity, then there is a good deal to be said. There is no assurance that a course offered by a department of chemistry or of zoology will be either more or less humanistic than one offered by a department of French or of philosophy. It is true that a course in chemistry may be merely "technical"—many of them are—but is a freshman course in a foreign language under a teaching assistant any less so? And where is the humanism in a philosophic disquisition on "the meaning of meaning"? Every academic field of study has its techniques; the question is, what do they yield?

In the case of science, they have yielded results of the utmost human significance. Most scientists, it is true, although there are exceptions, do not set out to prove by aid of their science their preconceived notions of right and wrong, but the results of scientific activity have far-reaching effects upon men's motives and conduct. The shrinking of time and space by the fruits of science have profoundly affected human relations. To see and hear a political candidate on television gives a very different sense of his value from that obtainable in my youth from his effigy on a banner in a torchlight parade.

Still more significant are the contributions that science has made to man's intellectual resources. As an example, let us compare Plato's statement of his method with modern scientific method. He said, in *Phaedo*:

> This was the method I adopted: I first assumed some principle, which I judged to be the strongest, and then I affirmed as true whatever seemed to agree with this . . . and that which disagreed I regarded as untrue.

No scientist today uses this kind of reasoning. No modern astronomer deduces the orbit of a celestial body from Plato's assumption that it must be a circle because a circle is the most perfect geometric figure. No physicist today teaches that "nature abhors a vacuum," and no mathematician defines an axiom as "a self-evident truth." No one who understands the distinction between the laws of science and those of the state would accept such an explanation of the recent high price of coffee as the one that it was "the natural result of the law of supply and demand."

Coming to still lower levels of thought, no person with a modicum of scientific education would be impressed by the pseudo-science that bulks large in advertising. He knows, also, that "the law of averages" does not cause a coin to strive, on the next throw, to even the score, and he knows that only a loaded roulette wheel has "lucky numbers." He knows that an analogy, however suggestive, is in no sense a proof, and he has a wholesome skepticism about extremely simple explanations for complex phenomena, for such a "model" as "the economic man," or "the typical Englishman." He distinguishes between the predictability of a statistical event, such as the rate of decay of radium, and the utter unpredictability of the time when a single atom of radium will decompose, and the parallel difference between predicing the death rate in a large population and the death of an individual. He should know that the "business cycle" cannot be analyzed, like a complex musical tone, into regular subcycles that can serve for prediction, and that a rigid extrapolation of history into the future by a "historicist," that "some sort or other of totalitarianism is inevitable," is arrant nonsense. Contributions to clear thinking such as these, with their indirect influence upon men's attitudes and conduct, are surely a valuable element of humanism.

The "integration" and "synthesis" of knowledge called for by educators has no more striking instances than those achieved in modern genetics, thermodynamics, quantum theory, and the relationships between atomic structure and physicochemical behavior. These and others are among the finest products of the mind, comparable to great works of art and literature. Surely they are part of humanism.

Many persons differentiate the sciences from the humanities on the assumption that the latter alone are able to impart sense of values. But hear what a philosopher, William R. Dennes, dean of the graduate division of the University of California, has said on this subject (*5*).

> Science is not the enemy of morality. But neither science nor metaphysics nor theology can yield a theoretical demonstration of moral norms or a theoretical establishment of moral ends. These are the objects and the goals, not of knowledge, but of love. Yet of all the servants of morality, science is the greatest; for it is the one serious way we have to discover what means are likeliest to lead to the realization of the ends we cherish.

In thus asserting the claim of science to a place among "the humanities," I do not wish to be interpreted as minimizing the contributions that the more traditional "humanities" can make to liberal education. We scientists are not arrayed against these subjects. Most of us read at least a little good literature; some paint; many have discriminating taste in music. Few of us are "narrow specialists." My contention is, first, that humanism is not an exclusive attribute of courses in certain nonsciences; and, second, that neither in a science nor in a nonscience is humanistic content and treatment guaranteed merely by the name of the department, but that it depends upon the humanism of the teacher. I shall return to this subject.

In academic circles today many are understandably concerned with the possibility that one may explore a limited area without appreciating its position on the larger map. In order to prevent this, some institutions take their students at the very beginning on a large-scale survey ride at high altitude, which, it is hoped, will excite curiosity sufficient to impel them subsequently to explore intensively some limited portion of the terrain. Now this is one way to attack the problem, but it is not the only way; nor is it, I think, the best way for every student. For those students so unfortunate as to have attended a "child-centered" school, where "subjects" are not presented by teachers capable of arousing intellectual curiosity in them, such a plan is probably appropriate, but I have not known many students to be stimulated by such a general view to seek more intimate acquaintance with the terrain. Many students, especially the mentally most alert, have had their curiosity awakened by their own reading or by a teacher who had a contagious enthusiasm for a subject. Any intellectual interest that has been aroused is so precious that it should be carefully nurtured and used as a basis for expansion, not thwarted by the requirements of a rigid curriculum designed by persons who do not appreciate individual variability. If a student is eager to delve deeply, by all means let him do it; later on his interests can be broadened gradually and naturally. A lad whose interest has been awakened in chemistry soon learns, if he is in a good environment, that mathematics and physics belong with chemistry, and if he finds that the men who teach these subjects are not ignorant of history and have some taste in literature, music, or art, his range of interest is easily expanded to include such subjects.

There can be no better liberal arts course of study than one with a backbone of a basic science enriched by good courses in literature, history, philosophy, or the fine arts, during the junior and senior years, or, vice versa, one beginning with nonsciences and expanding in later years to include science. To require every student to follow the same sequence is to disregard the wide variations in human beings. Certain sequences are natural; the elementary must precede the advanced; but prescribed, rigid curriculums in "general education" often include some that are purely arbitrary. Do professors really know what is best for every student? I suggest that a higher institution might do well to offer only nutritious fare and then leave choices largely to students, with more attention to providing inviting opportunities and less to compulsions.

No curriculum should be filled to the brim with required courses all from one area. Curriculums in sciences and engineering are in this often the worst offenders. Those who construct them hate the thought that a student may graduate with gaps in his education. But the vast and ever-growing body of knowledge makes this inevitable; hence, the pretense should be

abandoned in favor of a kind of education designed to produce men with the impulse and equipment to go on growing. No one whose education ceased at age 25 is an educated person at age 50. The test is not what the institution pours into the student but what it succeeds in planting to continue to grow. This, in my view, is what can make an education liberal.

It is ideas that enable us not only to find our way among the myriad facts of any one area but even, now and then, to take excursions into neighboring territory. In any branch of science it is the conceptual framework which, like the steel frame of a building, determines its form and structure. Isolated facts are as far from constituting a science as piles of building materials are from being a building. The dictionary definition of science as "classified knowledge" is far less than the truth. It corresponds only to an orderly arrangement on the ground of the various building materials. It applies to a science only in its early stages. The materials must be put together according to a design appropriate to their nature and to the function intended for the structure. Thus the biological sciences, beginning with natural history and taxonomy, gathered scientific significance by advancing to ecology, physiology, and genetics. Chemistry has progressed far beyond the mere description of substances and their properties and now incorporates the comprehensive ideas of kinetics, thermodynamics, inter- and intramolecular forces, and the relationship of atomic and molecular structure to physical and chemical behavior. It is ideas such as these that save us from being overwhelmed by the mere description of the half-million known chemical compounds and make of chemistry a manageable and predictive subject. They indeed "synthesize" and "integrate."

A student asked me recently to define chemistry. I answered with the best definition I can construct, "Chemistry is what chemists do and how they do it." It is essentially an enterprise, not a defined content. The most important element in the education of a chemist—I mean a scientist, not a technician—is association and apprenticeship with chemists at work and thinking. The graduate students in the department to which I belong are trained mainly by doing research and participating in seminars on live, controversial topics, with only a bare minimum of courses, and even these emphasize the powerful methods now available, not material to be memorized.

I am using a similar approach in a course for junior and senior students with a wide variety of nonscience majors, called "Methods and concepts in physical science." I advised the students, at the beginning, not to take notes, saying that I would not expect them to memorize and recite anything I would say; I would deal rather with the ways in which scientists work and think, ways which I hoped they would find suggestive for work and thought in other fields. A pleasing result was that I looked into faces instead of at the tops of heads. One student expressed what was evidently the general opinion, saying: "This is a think course, I have never had anything like it." That all did a good deal of thinking was evident from term papers and final examination.

By way of summary and in conclusion, the sciences should not play two distinct roles: one for the technicians, the other to give a smattering of scientific facts to future "philosopher-kings" who are supposed to guide society. The scientist should not be a "mere technician," he must be a wise member of society; nor can society be well guided by men who are ignorant of those criteria for reaching sound conclusions that are the essence of science. There is no more important task ahead for scientists than to teach the science to both groups, not merely as information, but as science.

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Science in International Cooperation

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THE International Scientific Unions are the backbone of all scientific collaboration of an international character, and it is important that all scientists, young and old, should be acquainted with the over-all structure of the International Council of Scientific Unions, known among the initiated as the I.C.S.U. The United States adheres to the I.C.S.U. through the National Academy of Sciences and the National Research Council, with the principal liaison being provided, and very effectively so, by the Office of International Relations of these two organizations under the direction of Wallace W. Atwood, Jr. The I.C.S.U. represents the central office and, in a sense, the parliament for the adhering scientific unions, 11 of them at the present. The scientists of the United States participate in the activities of their unions either as members-at-large or as members of specific commissions of the various unions.