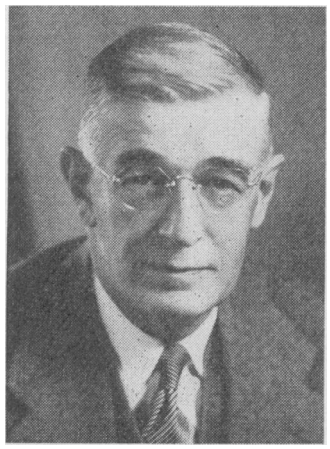

"We are in danger of building a Tower of Babel"

By VANNEVAR BUSH, D.Eng., Sc.D.

An eminent scientist speaks of overspecialization and the volume of publication . . . *and proposes concrete action*

EVERY SCIENTIST feels acutely today the effects of overspecialization. The volume of publication is so vast that it is impossible to keep abreast of it, even as the field of interest is narrowed. Whole new sciences and branches of engineering appear, with their specialized societies and journals. Intensely progressive gatherings of research workers develop their own jargon, unintelligible except to the initiated, heightening the barriers which separate their works from the main stream of progress.

Dr. Bush is president of the Carnegie Institution of Washington. As wartime director of the Office of Scientific Research and Development he was intimately associated with developments in nuclear fission and with the work of the Committee on Medical Research. Dr. Bush's address to the 23d annual Scientific Assembly of the Medical Society of the District of Columbia appeared in full in the January 1953 issue of the Medical Annals published by the Society. These excerpts are presented with permission of the editors and the author.

We are told that, long ago, there was a strange sort of real estate development. My memory of what I learned about it in my youth is somewhat hazy. But it seems that there was a project to construct some sort of Empire State Building, only much larger and more grandiose, reaching up toward the sky and mingling with the clouds. It was called the Tower of Babel. As the story goes, it was never completed, for the plans ended in confusion. The workmen suddenly found that each one was speaking a special language and that no man understood what the other was saying. So the minor construction went on piece by piece, but none of the pieces fitted; and the general plan of construction was completely lost. We are in danger, in science, of building a Tower of Babel.

The Complexity of Man

This is especially true in the science that deals with man. For man is complex, with a complexity far exceeding that which was assumed in the early days when the practice of medicine was a simple matter of applying empirical experience

and the science of medicine was nonexistent. As we have learned more, so have we learned that there is vastly more to learn before any comprehensive over-all understanding can emerge. A unitary organism has been found to involve the widest possible range of science, in the interconnected phenomena by which it functions to maintain existence in its environment.

Very subtle organic chemistry appears in connection with its hormonic system, its enzymes and vitamins, its antibodies, the nucleic acids of its genetic apparatus, and the metabolism of its proteins. A mysterious process by which a substance molds its surrounding medium into its own image transcends all that classic chemistry has to teach. In the chemistry of muscle, that process, unused by man in his artificial engines, whereby the energy of chemical combination is transformed directly into mechanical work without the intervention of any other forms, leads us into thermodynamic and chemical considerations beyond our present comprehension. The electrochemistry of nerve action introduces relationships far more bizarre than those simple effects which man utilizes in his batteries or his electrometallurgy.

And all this is affected, in completely ungrasped ways, by the functioning of a brain, which in its mere complexity reaches far beyond the relatively feeble electronic computing devices of which man is currently so proud, and which undoubtedly also involves phenomena the mere nature of which we cannot now specify or define, much less examine. The human system is unbelievably complex, and its examination by research calls for all the science that man has yet learned and for much which is still a closed book.

All this gives zest to our endeavor. It makes the study of man by man the most challenging problem that man can conceive. There will be many researches, many papers, many lives lived, before there can emerge that integrated, complete understanding which alone can form a sound and adequate scientific base for the profession of medicine. And in the meantime we pursue individual paths, which continually diverge, which become daily more specialized; and there is danger that the pioneers on the boundary of knowledge will completely lose touch with one another, that we shall learn more and more about less and less, and that the grand design may be completely obscured by the inconsequential detail which we pile up before it.

I can give you no solution for the quandary in which we find ourselves. There is probably no single solution. But there are a number of things which would help.

Versatility and Understanding

For one thing, I feel that it is obvious that the present day calls for more versatility and breadth of understanding. The difficulty is to acquire these virtues without at the same time becoming superficial. I feel that in our education, not merely in the field of medicine but in all the professions, we need more emphasis on the ability to grasp, on learning to learn, with the sacrifice of a great deal of practical, detailed, factual knowledge; more dependence on ability to find and evaluate, and less on memory. For the facts presented to memory are today overwhelming in any profession, and the attempt to carry them all, even for a narrow field of practice, can lead only to mental indigestion and a stultifying of those qualities which distinguish a human brain from a book or an adding machine.

This leads to the thought that we need to give attention to the means by which our accumulated knowledge becomes stored and transmitted. The printed page, the library, the spoken word, the lecture—in the forms in which they have operated for centuries—are no longer adequate for the purpose. And we seem to be doing little to improve the means for gaining access to our accumulated knowledge, which is growing at a prodigious rate. The holdings of prominent university libraries have been doubling every 16 years for some time. The number of journals publishing results of original research runs into many thousands. The pace is now increased and especially marked in science. How many of you, for example, have time to keep up with the literature written in the various fields of medicine?

It is strange that we seem to be so baffled by this problem in these days of intense mechanization. Machinery, control devices, and instruments, have entered many a field to make it pos-

sible to contend with growing intricacy of operation. A modern bank, a modern factory or refinery could not operate without this mechanization. Sorting machines, automatic controls, applied power, and machines which make machines have enabled us to build our civilization to its present point of high individual productiveness, interrelationship, and standard of living. But these things have hardly touched as yet the ways in which we store and communicate our findings and our thoughts.

New Methods of Publishing

Books and journals published for a limited group such as yours are bound to be expensive; they cannot be produced by conventional means at prices that are easy to bear. This fact tends to reduce further the size of the group that can have easy access to them, however essential to your profession may be the information they contain. True, there are devices being built which will greatly decrease the cost of printing on paper. The day of metal type, which has served so long, may be nearing an end. New electronic photocomposition machines are beginning to produce books, and this is by no means the final step in a revolution of methods of printing.

We also have microfilm. With some of the refined types of film developed during the war it is no exaggeration to state that the *Encyclopaedia Britannica* could be compressed to the size of a matchbox. There are all sorts of useful but not revolutionary card sorting processes and the cards can carry microfilm. There is a little used machine in existence—the rapid selector—which can review items on a strip of microfilm at the rate of 1,000 items a second and print those which are selected in accordance with a code set on a keyboard. It could, for example, review the case histories of half a million hospital patients in 10 minutes and present for aid in diagnosis printed copies of the few cases which corresponded to an unusual set of symptoms and complications. I say it could, but as yet it does not.

We might profitably give some attention to our methods of indexing and cataloging scientific literature. In an era of chemical physicists, physical chemists, biophysicists, biochemists, neurologists, neuropathologists, neurosurgeons, clinical psychiatrists, and so on, it is difficult to know how our knowledge ought to be classified and how to thread our way through the classifications, once they are temporarily established, to find the information that we need.

The rapid selector mentioned above will select according to an established code, but the code must be developed on a rational principle so that it can be effectively operated. No system of coding or of indexing under established subject heads can efficiently serve to guide us through the written thoughts or findings of scientists when the very science in which they work will not submit to definition. We can only wish—the optimists among us may hope—that a way will be found for converting into some form of mechanism the kind of fluid indexing and cataloging that takes place in our minds. There is here a feature which man has not yet introduced into his machinery, a feature of great power, the pursuit of paths through a complex record by means of association of ideas. Modern electronics can do for us almost anything we ask in the way of rapid, involved operations upon masses of data. But we still tell our research findings to one another in much the same old way, and we record our research results in a mass of paper from which their extraction becomes increasingly laborious.

Two Lines of Practical Action

There are two very concrete things that we can do in the present situation that can help enormously.

In the first place, we can be intelligible. We can school ourselves—all of us—to express ourselves so that what we have to communicate can be quickly and easily apprehended by others within our profession and in the nearly related professions. There is, as has recently been said, a moral obligation upon all of us to be intelligible.

In the second place, we can gather, integrate, interpret. We can take measures to encourage a few at least within our professions who have the native skill to gather, summarize, and interpret the information developed by many workers—who can make great masses of seem-

ingly confused data clear, intelligible, and useful to their fellows. Men possessing this kind of skill are rare and need to be encouraged. In these hurried days their efforts in explaining where we are, where we are going, and what recent developments really mean, is utterly invaluable.

I said before that the most helpful thing that can be done to advance fundamental science is to find the truly gifted scientist and support him to the utmost. Let me repeat this for the individual who can integrate the current stream of emerging knowledge. Only too often his work does not receive the recognition it deserves, and his labors are performed at the sacrifice, not only of his own career in strictly novel research, but also of his scale of living, for the direct rewards of this sort of publication are not large. I wish there were more generous support for labor of this sort and more recognition for this type of attainment. Had I invented a new dynamite and reaped a fortune from it, I should be inclined to establish a Nobel Prize for the integrator and interpreter of science, who can in these days often serve his fellows far more than the individual who merely adds one morsel to the growing, and often indigestible, pile of accumulated factual knowledge.

The dangers and difficulties which attend us as the pace of scientific research is quickened and the field of knowledge expands into many new paths . . . are real, and we would do well to devote deep thought to their avoidance and to finding solutions for the problems they present. Still, the most significant aspect of the present day in science is that we are going ahead energetically and accomplishing much. . . . It is far better that we should be embarrassed by the consequences of our rapid progress than that we should be bogged down to a snail's pace. Our problems of integration and interchange are solvable if we will devote enough of our energy to grappling with them. . . .

These are invigorating days in science and its applications. And if we can only avoid the disaster of another world war, I am convinced that we are on the threshold of great things, full of hope for a better future and a more healthy, happy race of men.

Five Reports on Psychosocial Aspects of Cancer

During the National Conference of Social Work sessions at Chicago in May 1952, the American Cancer Society sponsored discussions of the psychosomatic and psychosocial aspects of cancer under the general title, "Living With Cancer." *Public Health Reports* is publishing in this issue the fifth and final paper selected from these discussions—"The Aggregate Community Picture," by Edna Nicholson (see facing page 169). The four previously published papers are:

Professional attitudes and terminal care, by Charles S. Cameron, October 1952, pp. 955–959.

Typical patient and family attitudes, by Addie Thomas, October 1952, pp. 960–962.

Psychological impact of cancer surgery, by Arthur Sutherland, November 1952, pp. 1139–1143.

The sequence of emotional reactions in radical mastectomy patients, by Morton Bard, November 1952, pp. 1144–1148.