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Federal Science Policy

Roles of the President's Science Advisory Committee and the National Science Board.

Philip Handler

The question which has been posed, "Should the President's Science Advisory Committee (PSAC) or the National Science Board (NSB) be responsible for federal policy?" can have no categorical answer. However, since attempting an answer may serve as a useful exercise which might help to delineate the nature of the relevant problems, I shall so endeavor although, in doing this, there is a clear risk of seeming to be, at best, an amateur bureaucrat.

There are two major components in what is referred to as "federal science policy," namely, the utilization of science in federal policy generally on the one hand, and, on the other, policy for science itself. I shall suggest that, broadly speaking, the former should be the central concern of PSAC while the latter is the proper province of the NSB, while recognizing that these shade into each other so that, of necessity, there must be significant overlaps of interest and activity. I shall deliberately omit mention of other important sources of inputs into both policy- and decision-making, such as the Bureau of the Budget, the principal scientists and administrators of major agencies, the National Academy of Sciences, diverse advisory committees, as well as professional and scientific societies. Each of these has a proper and legitimate role in the policy-making endeavor, a process wherein ideas may be generated anywhere in the system and be reworked many times before consideration by the appropriate policy-making body.

Role of the President's Science Advisory Committee

The component of federal "science" activity which is most visible and which accounts for more than 90 percent of federal appropriations in this area is the utilization of science—and its derivative offspring, technology—in the implementation of federal policies. This is the applied research and development endeavor, an integral part of the mechanisms whereby diverse federal agencies further their missions—missions which include the security of our food supply, health, commerce, national defense, and our national prestige. The magnitude of the R&D programs of these agencies and, albeit to a lesser degree, the very nature of those programs, reflect national goals which are established not by scientists but by the Congress and the President. Establishment of these goals and authorization of the requisite R&D programs is, of itself, the paramount form of federal policy-making.

The programs required to attain these goals have sometimes fallen clearly within the purview of a single agency such as the Department of Defense, the Department of Health, Education, and Welfare, or the Department of Agriculture. In other instances a new agency has been required, such as the creation of the Atomic Energy Commission, to assure adequate exploitation and exploration of a new technology, or construction of the National Aeronautics and Space Administration to manage the huge effort inherent in the national space program. Patently, these prime affirmations of science policy were not made by scientists, neither by the President's Science Advisory Committee nor by the National Science Board. They were made by the duly elected representatives of the American people.

To achieve other recognized national goals such as exploration and exploitation of the oceans, improvement of the quality of our environment, control of our climate, and the development of a national system to manage the burgeoning mass of scientific and technological information, there have been initiated large programs of research and development which transcend established agency lines. Their conduct demands coordination of effort and continuing knowledge of the activities of each of the agencies so engaged. The mechanisms developed to achieve such coordination and communication include creation of the Federal Council of Science and Technology (FCST), formation of interagency committees responsible to FCST, and appointment of knowledgeable individuals to the staff of the Office of Science and Technology (OST).

It is against this backdrop that one must view the PSAC. This group of 17 was originally brought into being to provide the President with the most highly competent technical advice with respect to military technology. Accordingly, the prime qualification for membership has been—and continues to be—technical, scientific, and managerial competence. Military technology continues to be a major concern of the PSAC. Yet, this time- and effort-consuming activity has no public visibility since it relates entirely to highly secure problems.

With the passage of time, with the growing importance of the Office of the President's Science Adviser, with Congressional acquiescence to establish-

The author is chairman of the department of biochemistry at Duke University Medical Center, Durham, North Carolina and a member of the President's Science Advisory Committee and chairman of the National Science Board. This article is adapted from an address delivered to the Council of the AAAS on 30 December 1966 at Washington, D.C.

ment of the OST, the fields of interest of PSAC have broadened. Note that PSAC has no formal charter and has developed its own guidelines. With the assistance of highly knowledgeable panels, PSAC has made significant contributions to the formulation of national policy in many areas. In most instances, these have been concerned with the application of science or the development of new technology rather than with the growth of science per se. Some of these efforts have been visible as "white papers" such as those on the uses of computers in the life sciences, on pesticides, on toxicological information, on pollution of the environment, and on uses of the ocean, as well as a report, in preparation, on feeding an expanding world population. In other instances, no public statement may be issued, but a report may be sent to the President for his use or for transmittal to a single agency. These internal reports usually share the general character of those previously cited while also giving emphasis to the science which is to be made possible by the technological effort in question.

These are rational, appropriate roles for the PSAC, recognizable in retrospect and established by evolution rather than by fiat. First, PSAC should serve as critical adversary of agency planners, to be convinced by them, so that it may provide, to the President, objective, unbiased advice with respect to the quality and magnitude of ongoing programs and the plans of the science-using agencies and of interagency arrangements. It is inherent in this role that no small part of PSAC's effort must be devoted to "brushfires," crises in the various federal programs which require the urgent attention of the President's Science Adviser or even of the President himself.

Second, PSAC should engage in a continuing appraisal of our society with respect to the manner in which our national goals may be furthered by technological means. When, hopefully, a politically stable and peaceful world permits a reduction in the effort to perfect our arsenal, this second and already prominent activity should become the dominant responsibility of the PSAC. To be sure, as a group of scientists, the PSAC cannot help but also be concerned with the advancement of science, per se. And since so large a fraction of basic research is conducted in the laboratories of such agencies as DOD, AEC, NASA, and NIH, or under their sponsorship, as the leading edge of a program with ultimate applied goals, the PSAC must be concerned with the nature and quality of this effort. Nevertheless, the health of the total science endeavor, per se, need not be the major responsibility of the PSAC whereas it is the proper central concern of the NSB and a major responsibility of the OST. If the latter function well, PSAC input in this regard should diminish.

Role of the National Science Board

In addition to the types of national goals which we have already enumerated, there is another group of goals which need to be stated. For most of us gathered here, it is an article of faith that the attainment of an ever more complete and penetrating understanding of man and the universe in which he finds himself is, of itself, one of mankind's highest goals. Even though this sometimes is disparaged as "science for its own sake," the intellectual edifice thus constructed may well be the most enduring expression of our civilization, fully comparable, in this sense, to the cathedrals of the Middle Ages or the art of the Renaissance. As such, this endeavor fully warrants ample public support. Moreover, it is a second article of faith among us that some of the knowledge so gained will be translated into the technology which, tomorrow, will serve as the means by which man will raise himself from his animal estate, loosen him from his inherent biological limitations, and thus free him for whatever spiritual goals may lie ahead. Surely our nation can, and must, pursue these goals in parallel with those other aspirations which have been more explicitly stated and more generally accepted within overall federal policy.

In any case, among the latter aspirations is the thought that every American should have the opportunity to enjoy the highest level of education by which he can profit. Underlying acceptance of this goal is the historical truth that America's fortunes have prospered as our citizenry, generally, first became literate and, later, were offered primary, secondary, and collegiate educations. In our time, this process is being extended to include graduate and professional education. Clearly, if our aspirations for science and society are to be realized, it is imperative that the science component of education—at all levels—be the very best we can manage. Only if we are successful in that effort may a maximum number of potential scientists find opportunity to contribute to the progress of science as, concurrently, as many nonscientists as possible are prepared to live in the new world created by the scientific revolution. These, broadly taken, are our goals for science. Formulation of decisions concerning the rate, magnitude, and mechanisms whereby these goals shall be approached constitutes the formulation of policy for science.

Implicit in such policy-making are various subsets of decisions. Among the very many that we might note, only as examples, are such questions as, "By what criteria shall one allocate resources to the various scientific disciplines? Should the concept of 'principal federal agent' for given scientific disciplines be extended? What are the most appropriate mechanisms for support of research? Of research training? How, where, and when shall one fund major, expensive new tools of research? How shall we reckon future requirements for scientific manpower? How shall we manage scientific information? How shall one optimize the interface between the natural and social sciences; how can we blend their inputs so as to alleviate the major ills of American society? And so on, and so on."

Importantly associated with this genre of questions are the parallel problems of institutional forms, most particularly the changing relationship between government and academic institutions. What is the most appropriate quality of this relationship? What are the responsibilities of the two parties? What should be the position of the individual investigator in an ideal system? What is the relationship between the size and quality of the science program of a university and the economic vitality of the geographical region in which it finds itself? By what means and at what rate can or should we foster the development of new major academic centers of science? What is the role of the federal government in this regard? What is the optimal mechanism for integrating the large national laboratories into the total fabric of the science effort?

In my view, all of these are proper questions for the NSB. The act which created NSF clearly indicated that the Board should serve not only as the "Board of the National Science Foundation" but as the "National Science Board" in the full sense of that term. But because the budget of NSF constituted so small a fraction not only of total federally supported research and development but also of academic science, and because of the embarrassment inherent in the fact that the other science-supporting agencies are at the same hierarchical level in the government as is NSF, the Board of the Foundation considered that it must eschew its role as the "National Science Board."

That 15-year old decision, which was completely sound when it was made, no longer seems appropriate to me. To be sure, NSF now supports only 15 percent of the total of federally-sponsored academic project research—but this is approximately $200 million in this fiscal year, a large sum in absolute terms. More importantly, perhaps, NSF has learned to discharge its unique function—assurance of the vitality of American science—by a diversity of means which, in sum, account for the other 60 percent of the NSF budget. Among these we may note fellowships, training grants, course content improvement activities at almost all educational levels, institutes for high school and college teachers, science information activities, and provision of major research tools such as large optical telescopes, oceanographic vessels, phytotrons, and Van de Graaff machines. Further, to assure access of the national scientific community to the largest and most expensive facilities, NSF fully funds the Kitt Peak National Observatory, the Greenbank National Radio Astronomy Observatory, the National Center for Atmospheric Research, and the Cerro-Tololo Observatory in Chile as well as the continuing scientific program in Antarctica. The International Geophysical Year and the Indian Ocean Expedition have been joined by the International Biological Program as national programs fully supported by NSF. At the same time, the Foundation provides funds, albeit on a woefully insufficient scale, for construction of research facilities for graduate education. Most recently, the Foundation has embarked upon a series of programs designed to assist universities and colleges to upgrade the quality of their efforts in science. Thus, although we could wish that the NSF appropriation were twice or thrice its current level, this agency has carefully and skillfully developed a broad panoply of programs by means of which we may hope to secure the strength of American science.

The Board of the Foundation fully participated and cooperated with Waterman and Haworth and their staff in the development and inauguration of these diverse programs and it is from the experience so gathered that the Board may now speak. Moreover, the very composition of the Board—a mixture of working scientists and of academic and industrial administrators from all regions of the nation, who were originally trained in some area of the natural or social sciences—renders it a most appropriate body to develop broad policy for science and science education.

Several instruments of policy are available to the Board. First, the form and content of the programs of NSF itself are, of course, the major means. Second, the Board may submit memoranda to the President. This is particularly appropriate with respect to recommendations concerning government-wide practices and policies. Third, if the bill introduced by Congressman Daddario is passed at this session of Congress, the Board will be expected to submit an annual report on the state of science for transmission by the President to the Congress. This would not be an annual report on the activities of the NSF, or the accomplishments of the scientists whose work is supported by the Foundation; that is already available in the annual report of the Foundation. The annual Board report will be an analysis of one or more major aspects of science policy together with the Board's recommendations. This should develop into a major instrument for the formulation and expression of federal policy for science by the Board.

Be it said that I see no reason for a mass transfer of support for academic science from the mission-oriented agencies to NSF. The various reasons for current practice remain as valid as ever, although I hope to see the NSF budget rise to 25 to 30 percent of the total. But I do consider it appropriate that the Board, conscious of the "balance wheel" function of the NSF, and hence necessarily knowledgeable with respect to the totality of federal science support, should develop recommendations intended to coordinate and render more uniform agency practices and administrative policies, as well as recommendations designed to achieve whatever may appear, from time to time, to be an appropriate balance of national effort both by discipline and by opportunity. Although this means development and statement of recommendations concerning activities of sister agencies at the same hierarchical level as NSF, these other agencies support science only because this is required for accomplishment of their categorical missions. DOD, NASA, AEC, and HEW, unlike NSF, have no explicit charge to guard the welfare of science or of the universities. To be sure, NSB recommendations cannot be binding upon these agencies. As the Board assumes this role, its policy recommendations can be considered for the other agencies at the level of the FCST, or be given the force of a Presidential Executive Order or the force of law by the Congress.

Another significant area of potential overlap between the purviews of PSAC and of NSB should be recognized. The Daddario bill authorizes NSF to support, for the first time, *applied* research. This provision is interpreted by the Board as permission to support research which is seeking generalized solutions to generic problems rather than specific solutions to unique or narrow problems. Presumably, these would generally lie outside the specific interests of the more vigorous, better funded science-using agencies. Inauguration of some such support programs at NSF may well be preceded by appointment, by the Board, of commissions which will be requested to examine various aspects of the American economy, society, and government, noting opportunities for pronounced upgrading by adequate and appropriate research programs.

Indeed, there is need for intensive study of the very process whereby the findings of fundamental research are translated into useful goods and services. Such a study should complement the findings of "Project Hindsight" which highlighted the *immediate* inputs which made possible new developments in weapons technology. By tracing the dependence of applied research and development upon the growth of fundamental understanding, and clarifying the linkages between basic and applied research, the reports of these commissions, as well as such programs of applied research as the Foundation may inaugurate, should strengthen the case for federal support of fundamental research. I know that I speak for the Board and the Director in stating that, when the Foundation does embark upon the program of applied research authorized—and hence, directed—by the Daddario bill, the Foundation will nevertheless remain acutely aware that its primary concern is the strength of our national effort in fundamental research and science education and that a program of applied research supported by this agency should complement and strengthen the basic research program and not be undertaken at the expense of the latter.

In the general area of applied research, NSB and PSAC would seem to hold essentially equivalent hunting licenses. But there is so much to be done, I fail to see this as a problem as long as the communication channels remain open. In any case, prediction becomes difficult because, in this area, NSB-NSF and PSAC-OST will be attempting to fill a vacuum which presently exists by virtue of the inadequacy of the efforts of those federal agencies which should have been responsible for fostering innovation in the civilian sector of our economy, that is, the Departments of Commerce, Justice, Interior, Labor, and the Post Office. We have yet to observe the approaches of the Departments of Transportation and Housing and Urban Development. As all of these learn to be effective science-using agencies, the need for much of the activity presently contemplated by PSAC and NSB may well subside.

This, then, is the pattern I foresee for the next several years: PSAC-OST will be largely concerned with policy and technological problems related to specific agency and interagency missions and affecting all phases of American life while NSB-NSF will be mainly concerned with the progress of science and science deucation including the problems of scientific manpower, science information, provision of research resources and the welfare and development of the institutions in which science and science education are conducted. Both bodies will continue to seek means by which science and technology may improve the human condition, but these opportunities are so diverse, unlimited, and challenging that we can only hope that this combination will prove equal to the total task.

Note

These opinions do not necessarily represent those of other members of NSB or PSAC. No official position in these regards has been taken by NSB, PSAC, NSF, or OST.

Metabolic Aspects of Acid-Base Change

Interrelated biochemical responses, in the kidney and other organs, are associated with metabolic acidosis.

William D. Lotspeich

During normal metabolism certain animals, including man, produce large quantities of acid. Carbon dioxide, hydrated to volatile carbonic acid, is excreted mainly by the lungs. However, there are also produced considerable amounts of nonvolatile strong acids, particularly sulfuric and phosphoric, from the breakdown of phosphorous and sulfur-containing amino acids; these must be excreted by the kidneys. During some disease states in man, large quantities of either weak or strong acid accumulate in the body; during certain chronic lung diseases, for instance, carbon dioxide cannot diffuse rapidly out of the blood into the lung's air sacs, and the concentration of carbonic acid rises in the tissues; this condition is referred to as respiratory acidosis. During uncontrolled diabetes, when utilization of sugar is faulty, strong acids of intermediary fat metabolism accumulate in the body; this condition is called metabolic acidosis. For these reasons, the buffering of acid in the tissues and body fluids, its carriage in the bloodstream, and its excretion by lungs and kidneys represent important physiological and clinical problems.

Transport of strong acid in the bloodstream requires its neutralization with fixed cations, mainly sodium. In addition, it is apparent that not much of this acid can be excreted in the free form within the observed limits of urinary *p*H; thus most of it must be excreted, with its full complement of cation, in the form of an acid salt. It is apparent that if the cations implicated were those in limited supply, such as Na^+, K^+, Ca^{++}, or Mg^{++}, excretion of even the normal daily load of acid—not to mention the increased amounts during metabolic acidosis—would put an intolerable drain on these fixed reserves of cations. Therefore other means of excreting the acid must exist, and we now know that they do.

The kidney-tubule cells secrete hydrogen ions derived from metabolically produced carbonic acid, and ammonia derived from glutamine and amino acids. The secreted hydrogen ions, which represent the ultimate loss of the strong acid originally produced, are buffered either by phosphate or bicarbonate appearing in the glomerular filtrate from the blood, or by the ammonia made in the kidney cells and secreted into the filtrate as it passes down the tubules. Thus the strong acid is really excreted as the salt of a weak buffer acid or as the ammonium salt. For every mole of hydrogen so excreted, 1 mole of fixed cation is retained by the body, and to this extent the fixed cation reserves are protected. Our present concept of these mechanisms is portrayed in Fig. 1 (from *1*).

My purpose is to discuss some of the changes in kidney metabolism associated with excretion of acid, and the condition of metabolic acidosis. I also wish to point out some related changes in the biochemistry of other organs during metabolic acidosis, changes that illustrate the fact that the biochemical response to a metabolic acid-base change is a complex process involving the whole body in a way we are just now beginning to glimpse.

The author is professor and chairman of the department of physiology at the University of Rochester School of Medicine and Dentistry, Rochester, N.Y. 14620.