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Strengthening the Behavioral Sciences

The Behavioral Sciences Subpanel of the President's Science Advisory Committee surveys the underlying needs and recommends action to meet them.

The support and use of modern science in the national interest is recognized today as an important obligation of the federal government. The success of this policy has more than justified the expenditures entailed. Behavioral science has profited from general interest in scientific progress and has received modest but increasing support in recent years. This support, however, has not yet been as effective as it might be, mainly because it has not met certain underlying needs. Yet the general issues studied by behavioral scientists are critically important to our national welfare and security. Ways must be found to strengthen these disciplines and improve their use.

What is the current status of behavioral science? Are there promising developments that need support, or established facts that should be put to work? Are any special measures needed to facilitate the growth of behavioral science or to make its skills and knowledge better known to those who could best exploit them? Such questions are entered into, but not exhausted, in this report, and some key recommendations are made.

The scientific study of behavior has been a relatively recent development. Matter and energy are the domain of the physical sciences. The element of life introduces those complex, transitory features so sensitive to experimental interference that make the biological sciences challenging. When the boundaries of science are pushed back still further to include human behavior and human culture, all the processes of symbolization and self-direction of which the human mind is capable are introduced. The main effort to study behavioral processes scientifically is less than a century old, and most of the work is much more recent. The boundaries are expanding each year to include new behavioral phenomena.

The behavioral sciences have both a fundamental and an applied aspect. As fundamental sciences they are concerned with the careful, dispassionate discovery and analysis of the basic facts of human behavior, individual and social, and with the construction, testing, and revision of theories to explain observed regularities. As applied sciences, they are concerned with the application of facts, tested theories, and developed insight to questions of practice in such areas as education, mental health, personnel utilization, city planning, communications, and the problems of emerging countries. Behavioral scientists use methods common to all sciences: observation, instrumentation, field and laboratory experiments, statistical analysis of data, construction of models and theories, and good, hard thinking.

Perhaps the first impression one has of behavioral science is the enormous scope and variety of its problems and its methods. At one extreme, some psychologists combine biochemical and behavioral techniques to study the brain. At the other, sociologists and anthropologists deal with institutions and cultures. Social psychology studies the relation of the individual to his social and cultural experience. The domain of the behavioral sciences is vast and heterogeneous. The current division into academic fields—psychology, anthropology, sociology, economics, political science, linguistics—is subject to continual revision and amendment.

The general aims and criteria of evidence of the behavioral sciences are the same as they are in other sciences; however, it has so far frequently been necessary to settle for more approximate answers—errors of measurement may be large, and often, where experiments are not yet possible, correlations still substitute for cause-effect relations. The number of variables apparently needed to understand many kinds of human behavior, when combined with random or uncontrolled variations familiar in most of the life sciences, account for imprecision of results. Nevertheless, behavioral scientists are finding ways to develop and test meaningful theories; they have managed to amass a considerable store of tested and useful information.

The impact of the behavioral sciences on our society is far greater than most people realize. At one level they are providing technical solutions for important human problems. But at a deeper level they are changing the con-

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ception of human nature—our fundamental ideas about human desires and human possibilities. When such conceptions change, society changes.

In the past few generations, many beliefs about such diverse matters as intelligence, child rearing, delinquency, sex, public opinion, and the management of organizations have been greatly modified by the results of filtering scientific fact and theory through numerous layers of popularizing translation. The casual way in which unproved behavioral hypotheses often find widespread acceptance underscores the importance of strengthening and deepening the behavioral sciences and of securing better public understanding of what they are and what they are not.

The continued progress of the behavioral sciences—and particularly of basic research in these fields—is best assured by applying to them the same policy guidelines that promote growth in any science, and by associating them closely with other sciences. In this connection we note two encouraging steps forward: The National Institutes of Health, a major source of support for basic research in neurophysiology and psychology, are strengthening their programs in sociology, anthropology, and other behavioral sciences; and the National Science Foundation recently established a Division of Social Science.

Development and Present State of Behavioral Science

Many areas of behavioral science have grown rapidly but quite unobtrusively. As a result, it is hard for anyone to get a complete picture of their present scope and depth. This portion of the report offers a sequence of strategically located examples, illustrating, in active areas of behavioral-science research, both successes already attained and challenging problems that can be attacked now or in the near future. These concrete examples may help to suggest the scope and nature of certain of the behavioral sciences, where they stand today, and something of how they got there. Thus, they provide a background for our more general discussion and recommendations.

We have tried to keep this illustrative material as brief as possible. Consequently, many substantial and significant topics, such as mental testing, group behavior, studies of demography, bargaining, and descriptive linguistics, to name but a few, are only mentioned.

Effective experimentation in behavioral science was once thought to be confined to experiments on animals, to the simplest interaction of people with physical stimuli, and to some aspects of human problem solving. One of the advances of recent years has been in our ability to carry out experiments to analyze interactions between people, both in pairs and in groups. As with any experimental technique, an adequate description of what has to be done to make such experiments effective would involve us deeply in detail. So this area, too, is only mentioned.

The study of communication. Early studies of "mass communications" were very simply conceived. The "mass media" were thought to provide stimuli to which all the separate individuals in the audience responded in much the same way. This conception had to be discarded, however, once survey techniques were available to measure the impact of such communications on a sample of individuals. It became clear that individuals engage in selective exposure and selective perception. Those least predisposed to change are least likely to allow themselves to be exposed to a persuasive communication, and if they are exposed, are most likely to engage in misperception, a kind of motivated missing-the-point. If a new piece of information would weaken the existing structure of their ideas and emotions, it will be shunned, rejected, or quickly forgotten; if it reinforces the structure, it will be sought out, quickly accepted, and remembered.

This new understanding was soon followed by another development. As evidence accumulated of the strong effects of interpersonal relationships on the acceptance and diffusion of communications, the unit of analysis shifted from the individual to the social network itself. Studies attempted to trace the flow of a new development as it passed through a social network. Thus, a series of researches that began with the study of the impact of mass communication on separate individuals developed into a study of interpersonal networks and the way an innovation diffuses through them, with each person using the communications whenever possible to strengthen his existing attitudes and knowledge or to serve his other needs.

Studies of agricultural innovations, such as the introduction of hybrid corn, have shown that different communication media are characteristically used for different functions: Mass media can arouse interest, but interpersonal communication usually determines whether the innovation is adopted or not. Innovation must involve not one but several networks of relations, each able to carry certain kinds of content.

These empirical studies of diffusion were paralleled by the growth of formal, mathematical models. The simplest group of models assumed separate individual exposure either to a constant stream of messages from a central source or to random contacts with already converted individuals who were randomly mixed throughout the population. The need to consider the combination of these two mechanisms of exposure was soon realized, as was the need to assign a limited time during which a newly converted individual could convert others. As more and more such refinements were added, models for the spread of information, innovations, and rumors came to resemble more and more closely the then-current mathematical models for the spread of contagious disease.

An important consequence of models which assumed random complete mixing was a prediction that diffusion would be more complete in larger groups. This consequence was a crucial one for the assumption of random complete mixing, since this assumption must be a poorer and poorer approximation for larger and larger populations. By using aircraft to drop leaflets that asked recipients to pass on a message and then using surveys to chart the spread of the message through the population, experimenters established how the rate of diffusion of the message was affected by the leaflet-to-population ratio, by population density, and by city size. These leaflet experiments showed more complete diffusion in *smaller* towns, and thus indicated that more realistic assumptions about mixing were essential. Two directions were followed, to good effect. The one assumes that contacts between individuals are governed largely by geographic distance, and leads to models for the geographic spread of an innovation. The other takes account of the tendency of social networks to turn back on themselves, by giving numerical expression to the degree to which "the friends of my friends are my friends," and leads to models for the spread of an innovation through an acquaintanceship structure.

As field studies proved that more and more details were essential parts of mathematical models for the diffusion of innovations and information, the increasing complexity of these models began to threaten their usefulness. At this point, the availability of electronic computers offered new promise. Instead of solving equations for the average behavior of a diffusion problem, one could use the computing machine to simulate individual instances of diffusion. And this could be done repeatedly, revealing the variability inherent in the model as well as its average behavior. It again seemed possible to study models complex enough to fit the actual phenomena.

Important gaps in our present understanding have been identified through attempts to carry out computer simulations. Knowledge that seems quite satisfactory when presented in verbal form is often found to be inadequate when one tries to write a computer program. Recognition of such gaps is now calling for further empirical research to answer newly formulated explicit questions.

Mechanisms of personality development. The study of personality and the investigation of the stars have something in common. In both instances, one must usually begin with a careful study of the available "natural experiments." Then, once a phenomenon is identified, a mixture of laboratory and natural experiments leads to further understanding. Moreover, even when the ultimate concern is with more commonplace instances, the study of extreme instances often provides important leads to the essentials of the situation.

The study of personality is the study of the more or less enduring mental and emotional characteristics of an individual. Some people are fearful and tense while others are calm and relaxed; some are cheerful and friendly, others pessimistic and depressed, still others hostile; and in such psychiatric disorders as depression, paranoid conditions, or psychoneurotic anxiety one finds extreme personality patterns. What causes different patterns of personality? How do they originate? How are they modified in the course of life? And why are they often resistant to change?

Organic, psychological, and social influences all help to form and change personalities. One kind of mental retardation has been traced to a defective enzyme controlled by a single gene. And studies of mental-health similarities in ordinary and identical twins have indicated that heredity may be an important contributing factor in some of the schizophrenias and other psychoses. The effective use of new drugs has for the first time reduced the population in mental hospitals.

On the psychological side, much of our scientific knowledge of personality has come from two separate areas of research: animal experiments on the one hand and clinical observations of humans on the other. Clinical observations have suggested that the major developments in human personality occur in childhood—that there may be periods of special sensitivity when deprivation of particular pleasures or opportunities may have persistent effects on the developing personality—effects that are extremely difficult to change in adulthood.

Are there really such periods during infancy and childhood? And, if so, do particular types of interference during these periods have predictable results later on? Some studies have compared child-rearing practices in different cultures and have related them to adult personality characteristics. Such cross-cultural studies have indicated rather strongly that the inquiry was on the right track. More specific and conclusive research has been carried out on animals. Studies of animal behavior have demonstrated that there are brief periods in the early life of birds and mammals, including primates, during which the development of certain behavior patterns is especially susceptible to distortion. One example involves the disposition of certain birds to follow. During a short sensitive period the young animal can be induced to follow a particular kind of object. In the normal course of events this object is the mother (or both parents). If, however, no normal object is available during the sensitive period, and if a strange object such as a human being or an effigy or even a flickering light is substituted, the young animal will have strong motivation to follow that object and will later continue to show various consequences of this early exposure.

Systematic observations of natural experiments in our own culture, as when an accident to the mother results in her hospitalization, have convinced many psychologists that there is also a sensitive period in human infancy during which separation from the mother may have serious consequences for adult personality, shifting it toward chronic mistrust, hostility, and delinquency. The convergence of these various lines of evidence is encouraging, but we need to know much more about details, complications, and mechanisms. Why, for instance, does separation from the mother produce such serious aftereffects in some cases but not in others?

On the social side, study of the relation of social conditions to personality is just well begun; as a consequence, attention has been centered on psychiatric disorders as extremes of personality, and on the identification of related social phenomena. Although predisposition to psychiatric disorder is in some measure controlled by genes, and although recent advances in biochemistry are demonstrating the role of organic factors, social and cultural influences clearly contribute to the incidence of psychiatric disorders. In one recent, community study, for instance, the percentage of psychiatric disorder was found to be more than twice as large where community relations showed disintegration as in neighboring communities where they did not. Experience is showing that it is quite difficult, but possible, to get good data on the incidence of psychiatric disorders, and that the results are worth the effort. The way is now opening up, not only for more extensive and sophisticated surveys, but also for more incisive attempts to identify the psychological links through which social factors have their effects on the individual personality.

Motives and the brain. A combination of physiological and behavioral techniques is producing an accelerated output of fruitful research on how injuries to specific parts of the brain affect speech, memory, and problem solving, how the brain selects and analyzes information from the sense organs, and how it controls emotions and drives.

Some studies of hunger provide a typical example. To the layman, hunger usually means an uncomfortable feeling in the stomach, a feeling that is associated with missing meals and that sharpens the pleasure of eating. The behavioral scientist is interested in the effects of hunger on a wide range of behaviors that can be involved in finding and consuming food, and he is interested in the brain mechanisms that control food consumption.

Association of abnormal obesity with certain lesions of the human hypothalamus first suggested that this primitive part of the brain regulates eating. Experiments showed that small bilateral lesions appropriately placed in the brain would cause various species of animals to overeat enormously until they became extremely fat. The first hypothesis was that these lesions intensified hunger by releasing it from inhibition.

Normal hunger can be measured behaviorally, either by the rate at which an animal works at pressing a bar to get food, or by the minimum amount of quinine required to cause the animal to avoid food. Although rats with lesions in the critical areas ate more than normal rats, they pressed the bar less rapidly, and the amount of quinine needed to make them stop eating was smaller. Thus, the behavioral tests showed that the first hypothesis was incorrect; the lesions appeared to interfere with both the maximum level of hunger and the completeness of satiation.

The lesion method has been supplemented by new techniques for stimulating, electrically or chemically, specific areas in the brain. Adrenalin and noradrenalin were first noticed for their effects on the heart and vascular system as parts of the general reaction to stress. When minute crystals of these chemicals are implanted in the "feeding area" of the brain, they cause satiated animals to eat, and to perform specific learned patterns of working for food. But minute quantities of a different class of substances, acetylcholine or carbachol, elicit drinking and working for water, but not eating, when they are implanted in the same place. Injection, into the body, of agents that block the classical responses to each class of substances also differentially blocks the effects of brain implantation of the corresponding crystals, and somewhat reduces differentially normal hunger or thirst. Thus, the brain seems to respond to a chemical code in distinguishing hunger from thirst.

This bird's-eye view of work on hunger and food-seeking behavior could easily be paralleled by similar examples of research on other drives, such as fear. Fear can be learned. We are discovering how fear can be affected by various drugs, how it can be unlearned, and how experimental subjects can be taught to persist in the face of fear. But we need to know much more in order to complete our theoretical understanding of its mechanisms, and of its effects, which may include stomach ulcers and perhaps decreased resistance to infection.

Other motives have been partially explored. There is already experimental evidence that, just as satiation or deprivation affects the way in which an animal works for food, so satisfying a child's need for praise or depriving him of approval can affect the speed with which he works. There is experimental evidence, in both rats and monkeys, that curiosity can produce learning, maintain performance, and be a strong enough motivation to entice a hungry animal away from food. While a promising beginning has been made, most of the important problems lie ahead. We do not know the factors responsible for inhibiting or enchancing either the development of simple curiosity in a cat or the development of intellectual curiosity in a classroom. We know much less about the principles that govern the learning of human social motivation than we do about those governing the learning of information or of skills. But we already have promising ways to attack many such problems and are rapidly finding new ones.

Study of cultures and societies. Comparative study of different cultures began in the 19th century, stimulated by interest in human evolution. At first, anthropologists assumed that differences in custom would reflect different levels or steps on an orderly path of evolutionary ascent, with their own European, upper-class, late-Victorian society representing the highest stage. The customs and institutions of the technologically "backward" societies were expected to reveal the steps through which more civilized man had evolved.

As ethnographers began to collect their data, however, these early theories had to be discarded. Data showed clearly that each complex of interrelated customs, however strange and bizarre by Western standards, served the group's needs. It became increasingly evident that customs tend to be internally consistent, to hang together in structured systems.

The interdependence of the parts of such systems is a major determinant of the way innovations are resisted under some conditions and accepted under others. A corollary is, of course, that an imposed change in one custom will usually have widespread effects. For example, chiefs in the Trobriand Islands had many wives, a practice that some of the earlier Western authorities discouraged. In that society, instead of a husband supporting his wife, a brother supports his sister, and if his sister has the honor of being married to a chief, she has to be well supported. Wives were the source of a chief's economic power; they enabled him to supply the food and drink for work parties to accomplish necessary civic projects, such as hollowing out huge logs to produce the ocean-going canoes used in trading. When polygamy was abandoned, the chiefs were too poor to hold work parties, their prestige and authority declined, and certain necessary civic tasks were neglected. Thus, a change in one aspect of the society had unexpected, far-reaching effects.

The study of kinship systems was especially productive in revealing the structure of a strange culture. Kinship terminology proved to be closely associated with forms of family, customs of inheritance, and kin-group organization. If, as in our society, the same behavior is expected toward the mother's sister and the father's sister, they are given the same name "aunt." But if it is important to behave differently toward these sisters, they are given different kinship names. Rigorous methods and concepts which have been developed for the analysis of kinship systems are now being applied to the analysis of other terminological systems—to the native vocabularies for describing animals, plants, colors, and diseases—in order to understand how other peoples organize their perceptions.

More and better ethnological data are raising new questions. For example, do the obvious physiological changes of adolescence inevitably produce emotional disturbances? Many believed this must be so, yet in some societies adolescence occurs without emotional disturbances. Perhaps social conditions play a major role in the problems of adolescence. Ethnographers have discovered many such exceptions to plausible behavioral propositions.

To test any hypothesis on a cross-cultural basis required the accumulation of reliable information for a large sample of the world's societies, a task that often required years of search through the voluminous ethnographic literature and careful evaluation of the reliability of the sources for each society in the sample. In the end, the work was likely to turn up too few well-documented observations of the relevant variables. As a result, the comparative study of culture was largely anecdotal or based on samples too small to provide conclusive answers. Progress was made in solving these problems by the establishment of the Human Relations Area Files. This systematic organization of ethnographic material showed startling gaps in the data, even for societies that had presumably been the most thoroughly studied and described. These files, which now cover about 200 of the world's societies, provide a valuable but limited basis for comparative studies on a variety of subjects.

Studies of thinking processes. "Insight" is a term commonly applied to the achievement of understanding, particularly when it takes place suddenly and dramatically. It is a genuine, if elusive, phenomenon. When people, and even chimpanzees, are faced with certain kinds of novel problem situations, their behavior often makes it appear that solutions occur suddenly and without appreciable connection to previous trial-and-error behavior. Careful studies, however, have shown that in many if not most situations the appearance of solutions is gradual, and is accompanied by much trial-and-error search. Accordingly, it was natural to feel that instances of sudden solution were probably artifacts resulting from crude description. If descriptions were sufficiently refined, would not all solutions be seen to emerge gradually, in ways following simple laws of association?

Experiments on problem solving by animals made important contributions to these questions, partly because animal subjects, which cannot report their introspections, impose a valuable discipline on the experimenter. In general, animal studies corroborated human studies. Problems that were easy for the subject were solved smoothly, undemonstratively, and routinely. At the other extreme, difficult problems generally evoked large amounts of trial-and-error behavior. Insightful problem solving appeared to be more usual with problems of intermediate difficulty.

It was further discovered that so-called trial-and-error behavior was rather complex, even in lower animals. Rats placed in an insoluble maze do not explore it at random but develop patterns of search (taking the right-hand alley, choosing the lighter path), which they shift from time to time, behaving rather as though they held hypotheses. Monkeys can go further, "learning to learn" by developing general and transferable ways of responding to problem situations.

Experiments on human subjects also illuminated the differences between insightful and noninsightful problem-solving behavior. If the basic structure of a problem is shown to a subject, his learning transfers much more readily to new tasks and is retained much longer than it is if he is given detailed and specific instructions for solving each problem. Good teachers have long acted on this principle, but its unequivocal and reproducible demonstration in the laboratory has now opened the way to a study of the detailed mechanism involved.

Further study of insightful problem solving showed that the process of means-end analysis is quite fundamental. People analyze a problem situation in terms of goals and subgoals and, drawing upon their memory of past problem situations, set out to find means for reaching the goal step by step, by solving one subproblem after another. Thus, a chess-player may set up the subgoal of protecting a piece from capture. Associated with this subgoal in his memory might be such means as moving the piece or defending it with an additional piece. Considering one of these means might lead to a new subproblem, such as finding a safe square to move to. Continued observation of problem solving led to more and more adequate description of what is involved in such means-end analysis.

With more detailed observation of the problem-solving process, the jumps of insight became smaller, and more easily explicable by interpolating hypothetical steps, although sudden intuitions still seemed all too numerous to justify full confidence in the detailed correctness of what was interpolated. Certain basic questions remained: To what extent did these descriptions constitute an explanation of mechanism, and not simply a step-by-step narrative of events? Were the processes that had been observed sufficient to account for the problem solving?

A more formal description of problem-solving tasks as mazes or trees in which solutions are scattered, often very sparsely, was an essential tool in answering these questions. Such trees are often very large, the tree for the game of chess, for example, having some 10^{120} branches. Unselective searches of large trees require impractically long times. A successful problem-solver must, even when he employs trial-and-error methods, search in a highly selective way, describable in terms of appropriate rules of thumb. Means-end analysis is but one of the general rules of thumb applied by human problem solvers.

The use of rules of thumb to reduce the effective size of the problem maze provides a plausible explanation for the selectivity that had been observed in trial-and-error search. In every novel situation, the rules of thumb are poor, hence search must be extensive and will appear to an observer as almost random. In familiar situations, the rules of thumb are so good that the solution can be found with hardly any backtracking. Situations of medium difficulty require a modest amount of search, which often appears to be directed rather than blind or random. Thus, solutions of such problems are most likely to appear "insightful."

Applications of these ideas left many of the central problems about problem-solving processes unanswered: What kinds of rules of thumb (in addition to means-end analysis) do human problem solvers employ? How can these rules and their organization be precisely and rigorously described? How can the completeness of a set of rules be tested empirically? What basic symbol-manipulating processes are required to perform the tasks we observe human subjects performing? How must these basic processes be governed and interrelated?

Initial answers to these questions have been found. The key has been nonnumerical simulation of mental processes by the use of digital computer programs and programming systems which focus on combining and modifying symbolized information, rather than on doing arithmetic. The resulting models of human mental processes are essentially nonarithmetical and can be tested by presenting identical problems to the computer and to human subjects and then comparing, sentence by sentence, the output that each produces while seeking the solution. One particular information-processing system (the General Problem Solver, which possesses a few basic mechanisms for manipulating symbols and which can carry out means-end analyses and certain abstracting and planning processes) has been able to solve such problems as discovering proofs for conjectured mathematical theorems, solving puzzles, and even writing simple computer programs.

Experience with such information-processing systems shows that the simple processes mentioned above are sufficient to solve certain classes of problems. Moreover, many details of the computer's performance seem to be closely similar to those of a human subject's performance. Computer simulations exhibit most of the phenomena that have been regarded as symptomatic of insight. They sometimes reach solutions suddenly, and they do this under circumstances in which human subjects are likely to have an "aha!" experience. On the average, they spend the most time on the parts of problems on which human subjects spend the most time. They acquire specific patterns of approach to problem solving—patterns which facilitate the solution of certain subsequent problems while impeding that of others—under the same circumstances that cause human subjects to acquire them. Detailed correspondences of this kind provide a severe test for the theory, which is now rigorously stated, partially tested, and able to explain a number of the important processes involved in interesting sorts of human problem solving.

Further comparison of computer simulation with human performance will now lead us to new empirical studies of human behavior and to a steady increase in the predictive power of the theory and the adequacy of its correspondence with human behavior.

Closing remarks. Anthropological research on changes in primitive societies, sociological research on communication, and psychological research on perception and problem solving are, as we have seen, beginning to fit together to provide an understanding of the conditions under which innovation occurs or fails to occur. This is but one instance of the many ways in which the behavioral sciences are cooperating with one another more frequently, more deeply, and more broadly.

The need of similar cooperation to exploit present opportunities for studying other cultures is now clearly recognized. Social and economic change is a world-wide fact. Western industrialized civilization is spreading explosively. As cultures everywhere become more similar, opportunities are fleeting, especially for the study of societies, and of changes in societies, as varied as these are today. But it has become increasingly clear that decisions as to which aspects of these societies will be most usefully studied must be made with the knowledge and insight of all branches of behavioral science, and that all branches must contribute to the techniques by which such studies are made. For these studies should not only help answer today's questions but should contribute as much as possible to answering those of tomorrow.

Although the particular examples of behavioral study described here are scattered, and thus at best illustrative, they should have delineated a few key points.

1) Progress in behavioral science has come about by using the scientific processes of observing, experimenting, and extensively following up and correcting working hypotheses. Indeed, all the general attitudes and strategies of physical and biological science have found a place in behavioral science.

2) The behavioral sciences are diverse in subject matter and state of development, yet ideas and concepts circulate quite freely among them (and techniques circulate steadily, if more slowly).

3) The division between laboratory experiment on the one hand and observation of what occurs without intervention (often in "natural experiments") on the other is both clear-cut and extremely noticeable in behavioral science, yet neither method can operate at full effectiveness without the other.

4) Unsolved behavioral-science problems that are clearly solvable, and for which methods of attack are already identified, are no longer minor and trivial. Instead, both their scope and their scientific importance are substantial and steadily increasing.

Recommendations

The continuing development of the scientific study of behavior requires that certain underlying needs be met. This section of the report identifies certain of those needs and makes suggestions for action to meet them.

General education in behavioral sciences. Students should be exposed earlier and more effectively to the possibility of investigating behavioral phenomena by scientific techniques. The scientific approach to behavioral problems would be a valuable part of the general education of all students. This goal might be achieved in the secondary schools by inserting material on behavior in existing courses in biology and by emphasizing newer, empirical approaches in existing courses in social studies. Introductory undergraduate courses should be similarly strengthened.

Outstanding men in the behavioral sciences should follow the lead of their colleagues in physics, mathematics, and biology by devoting special efforts to preparing superior instructional materials for use at the secondary school and introductory undergraduate level.

Specific training of behavioral scientists. The demand for behavioral scientists, as for all scientists, is outrunning the supply. Shortages exist now in each of the recognized behavioral fields; in each we anticipate an increasing need for well-trained persons in university teaching, in basic research, and in applied research and development. The needs for applied work are especially important in industry and national defense, and in emerging programs such as education and foreign aid. In each of these areas the shortage of trained personnel is likely to set a limit on useful developments. The education of behavioral scientists is such a key problem that a number of different steps should be taken; some of these are needed also in improving the general education of those students who do not go on to specialize.

1) The recommendations of the Seaborg report (*1*) are as applicable to the behavioral sciences as they are to other sciences. We agree that the universities need to be strengthened, that first-hand experience with research is an integral part of graduate education, and that it is essential to increase the support for training.

2) The need for special educational facilities is not as well recognized in the behavioral sciences, perhaps because of their recent emergence as empirical disciplines, as it is in the physical and biological sciences, where educational budgets include the cost of equipping and operating laboratories and field facilities. Both colleges and graduate schools should increase their effort to give students first-hand contact with behavioral-science data and techniques by exposing them to the appropriate clinical material, field trips, or laboratory work. Adequate provision for such

work should be made in their budgets.

3) There is a special need for summer institutes, or other short-term instructional arrangements, to bring research workers and selected teachers up to date in new techniques and experimental procedures. Experience suggests that such arrangements would be more effective if they were set up on a relatively long-term basis and in a suitable research environment. There should be a small core staff to plan during the entire year for the instruction program as well as to work on research. As one specific step in this direction, such a special instructional program should be centered upon the applications of mathematics and computers to the behavioral sciences.

Systematic collection of basic behavioral data for the United States. Both fundamental research in the behavioral sciences and the application of scientific knowledge to human problems could be substantially assisted by making available better and more illuminating basic data about the structure and functioning of American society. We call attention to the great advance over the past generation in the quantity and quality of our information about the economy and to the effective use that is now made of such information in formulating and administering national economic policy. Similar benefits would flow from a corresponding advance in the quantity and quality of information about noneconomic aspects of behavior.

A significant start has been made on the borderlines of economics—the collection of data on family budgets, for example, and on businessmen's expectations—and on the composition, characteristics, and movements of populations. A similar promising start has just been made with the establishment of a National Health Survey. A proposal has been made to establish a special National Family Welfare Survey in the Social Security Administration. But there are many significant aspects of behavior about which systematic data are almost completely lacking. We know something of how people spend their money, but almost nothing of how they spend their time. In addition to uses in basic research, behavioral data will become increasingly important in exploring the problems of the aged, in forecasting the effects of increased leisure on our society, and in many other matters of public policy. There are other areas where good systematic data would be invaluable and where they are now almost wholly lacking: travel and commuting habits, occupational aspirations, the preferences and choices of youth, and the incidence of mental disturbance.

Fortunately, progress has been made in recent years in developing methods for collecting and processing data of these kinds. Available skills in sample design, in survey technique, in construction of interview schedules, and in electronic data-processing make such data collection feasible and meaningful. The family budget studies already mentioned, and recent surveys of scientific manpower, are examples of what can now be done, and of what needs to be done more often, more systematically, and over a wider range of phenomena. In particular, data that are comparable, systematic, and periodically gathered will be essential for establishing and interpreting trends. Such work should, of course, be planned with definite research purposes in mind. Experience shows that without this, the mere collection of data often proves a fruitless enterprise.

A clear responsibility—already partially recognized in activities of the Census Bureau, Department of Labor, and other agencies—lies with the federal government to exercise leadership in extending and improving the data on which sound behavioral-science knowledge and intelligent application of that knowledge to public affairs rests. The responsibility is enlarging as the need for good behavioral data grows, and as our technical abilities to provide them advance.

There is need for both a reexamination of today's needs and opportunities and a continuing careful review of what is being done. Accordingly, we suggest that:

1) The Social Science Research Council be invited to appoint a standing committee to review and study present practices, needs, and opportunities for gathering information about noneconomic aspects of behavior in American society.

2) A group broadly representative of relevant government agencies be appointed to follow current and planned activity in this field and to provide appropriate advice in the light of the current possibilities and needs of behavioral science.

Collection and processing of data on other societies and cultures. Reliable data systematically collected on the conditions, customs, and patterns of behavior in societies other than our own are indispensable to the behavioral sciences. Comparison across societies provides information which it would be impossible to obtain in our society even by deliberate experiments. Such data are essential for testing the generality of conclusions from studies within a single society and are a fruitful source of hypotheses.

For studies of this kind, comparable data are required on a large sample of the world's societies, representing major cultural differences and all levels of complexity. These data include, among other things, ethnographic material, results of statistical surveys, and abstracts of the content of communications. Several partial repositories of such data presently exist—a file of ethnographic materials on a sample of about 200 societies, a file of survey results obtained in various countries, and materials in area institutes at universities. Much of what these repositories contain is neither widely known nor accessible, the collection of data is not well coordinated, and what is collected often fails to meet the developing requirements of behavioral sciences.

Because these data are collected throughout the world by scientists representing many countries, a special study is needed to determine what data about other societies are presently collected by agencies in and out of the government; whether some of the activities just mentioned can be consolidated; what new types of data are most needed to fill in serious gaps; what data of continuing significance will be lost forever if they are not gathered soon; what sorts of data should be collected both systematically and regularly; and how relevant data can best be procured and stored so that they are maximally available.

To answer these questions, a special study group is required, and we suggest consultation with the National Science Foundation, the Smithsonian Institution, the National Research Council, the National Institutes of Health, and the U.S. National Commission for UNESCO in forming it.

The need for larger units of support for basic research. The scholarly disciplines from which behavioral sciences sprang were in most cases able to carry out their studies without the appurtenances of the empirical sciences. There is little general realization of what special research tools the behavioral sciences now require and insufficient acceptance of the need for providing them. A stage of growth has been reached where some kinds of research cannot be adequately conducted without substantial specialized laboratory equipment or extensive field research organizations.

Furthermore, part of the difficulty lies with behavioral scientists themselves. Feeling that it is almost impossible to secure the really large funding required for a full-scale attack on many basic problems, most behavioral scientists have adapted their ideas and plans to fit available resources. For example, many inquiries that really require national sample surveys, covering people in various strata of society, in fact are based upon a purely local survey or are confined to data from a few haphazardly chosen individuals. Many laboratory experiments which require expensive equipment are not made, or are made inadequately. Sufficient funds to make possible the really large-scale support of fundamental projects that are intellectually and scientifically large have been lacking. There has tended to be a relatively lower upper limit on the size of grants for basic research in the behavioral sciences, as compared to those in the physical and biological sciences.

Behavioral scientists can take a first step toward the solution of this problem by making serious and carefully-thought-through proposals for basic research whenever these proposals are justified by research opportunities, whether or not the required scale of support has been traditional. The existence and consideration of good proposals will do much to increase the possibilities of adequate support.

We suggest that a particular effort be made to support basic-research ideas for behavioral science on a scale consistent with their importance and without regard to previous levels of funding.

Providing advice to government. In view of the relevance of the findings and methods of behavioral science to a very broad range of governmental operations, the present facilities for providing advice on questions in this area are inadequate. The role taken by the National Academy of Sciences–National Research Council in physical and biological science is unfilled in behavioral science. At present the National Academy of Sciences represents only restricted segments of anthropology and psychology. Most areas of behavioral and social sciences, although relevant to many programs of governmental action, are entirely unrepresented in the National Academy and are included in the National Research Council in only a fragmentary way.

Two courses of action would be highly desirable, in order to provide effective sources of behavioral-science advice to government agencies.

1) The structure of the National Academy of Sciences–National Research Council should be broadened to include the areas of behavioral and social science not now represented.

2) Federal agencies should make more effective use of the resources of the Social Science Research Council and the other national, professional organizations of the behavioral and social sciences.

Research and development in agencies with action missions. Expanding programs at state and national levels in areas of action such as urban renewal and transportation have created a demand for applied research. This demand has been largely unmet, or met in piecemeal, after-the-fact ways. Careful pilot studies have been made in a few instances, as in the introduction of certain new agricultural processes. But in most instances, applied research, if carried out, has been restricted to following after the action and evaluating its effects. Although the few such studies that have been conducted have clearly proved to be valuable, large-scale action programs have seldom been accompanied or preceded by pilot studies which evaluated the several alternative actions that appeared equally attractive. In urban renewal, for example, the data necessary for rational actions in large-scale programs could be provided by the establishment of pilot redevelopment programs of various types and the early comparison of their results. The need is especially great in those areas where an action taken now has consequences that continue far into the future. The establishment of a research and development section of the Agency for International Development is an excellent step. Whenever feasible, agencies whose missions involve actions that will have long-lasting effects should conduct pilot programs incorporating adequate behavioral research prior to the activation of large-scale programs, or at the very least, research on action programs should be undertaken simultaneously with the initiation of action and used to guide further development. This means starting trials now to prepare for the problems of the future.

Research relevant to education. The behavioral sciences can contribute to many problems of education, such as increasing insightful learning in the classroom and changing those strong influences from fellow students that run counter to the goals of parents and teachers. Basic research has already led to programmed learning, both by programmed texts and teaching machines.

Education has a national budget second only to that of national defense. Yet only a small fraction of 1 percent of this budget has been spent on research and development. This is one obvious reason for the failure of education to make technical advances comparable to those seen in other aspects of our national life. Moreover, for the past 25 years few outstanding research workers in the behavioral sciences have exhibited interest in educational research. Both of these deficiencies are beginning to be corrected, but more remains to be done.

International relations. Some of the most difficult, complex, and vital problems confronting our country are in the area of international relations. Behavioral science is relevant to various aspects of these problems. For example, in dealing with nations whose cultures are radically different from our own, much of the intuitive knowledge which the talented man-of-affairs uses so effectively in dealing with our own society may be irrelevant or actually misleading. Technical knowledge about the detailed nature of the society and the functional interdependence of its components is essential for effective communication, for judging the probable course of events, for leading cooperative efforts, or for giving the proper kind of assistance in the right way.

There are many reasons for the fact that an enormously disproportionate part of the social contacts of a businessman or diplomat in a foreign country is likely to be with the very top social classes. These classes usually represent a minute fraction of the total population; their members lead completely atypical lives and not infrequently have interests and views opposite to those of the majority of the people. Thus, it is easy for the visiting American to be seriously misled, unless he possesses suitable attributes and uses suitable methods of reaching a more adequate sample of people.

Behavioral scientists have no "miracle solutions" to problems of international relations, but they can help. Anthropologists and certain sociologists, for instance, have had much experience with the problems of attitude and methods just mentioned. A study of the practices, special problems, and views of the various government agencies involved must precede any detailed recommendations as to how the principles, facts, and techniques developed in behavioral sciences can be best used in international relations.

Reference

1. "Scientific Progress, the Universities and the Federal Government," statement by the President's Science Advisory Committee (The White House, Washington, D.C., 1960).

Dating of Fossil Bones by the Fluorine Method

Fluorine analysis by indirect methods is not a reliable means of determining age.

Duncan McConnell

Attempts to determine the age of fossil bones from their fluorine contents seem to have first been made more than a century ago (*1*), although the method does not seem to have attracted considerable attention prior to the work of Carnot, in 1893 (*2*). Recent discussions on analytical methods are contained in papers by Baud (*3*) and Cook (*4*).

Some of the recently applied variations of the fluorine method suffer from all of the geochemical and geological uncertainties and, in addition, have introduced analytical procedures which depend upon elusive crystal-chemical and mineralogical principles.

I am concerned primarily with the x-ray diffraction methods for fluorine determination, as applied by Périnet (*5*), Gottardi *et al.* (*6*), van der Vlerk (*7*), and Niggli *et al.* (*8*). Before appraising these methods I shall review briefly what is known about the crystal chemistry (that is, the chemical composition and crystal structure) of bones and teeth of living vertebrates.

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Crystal Chemistry of Bone

The chemical composition of the "mineral" component of bovine bone has been determined for all of the essential oxides, except water, through the diligent efforts of Armstrong (*9*). Compositional differences exist, depending upon the treatments utilized to free the mineral component from the organic matrix, but certain quantitative facts emerge which are of great significance: bone mineral (including dentin and dental enamel) is composed essentially of a calcium carbonate-phosphate containing much smaller, but measurable, amounts of sodium, potassium, magnesium, fluorine, and chlorine. Other inorganic consitutents are normally present merely as traces, except for water.

Table 1 shows the results of analysis of dry, fat-free, cortical, bovine bone, as recalculated in the form of oxides. It may be noted that about 28 percent, by weight, is not accounted for in the summation. This portion includes the chemically combined water of the mineral as well as all organic matter. The calcium-phosphorus ratio is 1.688 (atomic basis), which is above the theoretical value for hydroxyapatite (1.667); the ratio becomes still greater when equivalent amounts of sodium and magnesium are summed with the calcium.

However, in order that valid conclusions may be drawn concerning the mineral phase of bone, it is essential that the quantity of chemically combined water be known. Inasmuch as any treatment (such as the use of ethylenediamine) which will remove organic matter of bone is also capable of altering the amount of chemically combined water of the mineral phase, the problem of determining the amount of this water is best approached through consideration of fossil dental enamel. Not only is dental enamel comparatively free from organic matter but the fossilization process has stabilized the mineral composition and it has even further reduced the amount of organic matter.

Included in Table 1 are results of the analysis of the enamel portion of the tooth of a post-Wisconsin mastodon (*10*). This analysis was made by C. O. Ingamells, a highly qualified mineral analyst, using standard macro methods. Again, it may be noted that the calcium-phosphorus ratio (1.692) exceeds the theoretical value for hydroxyapatite (1.667), provided the magnesium and sodium are summed with the calcium. Many analyses made by reliable macro methods show that the calcium-phosphorus ratio exceeds 1.667 for bones and teeth (*11*), and this is true also for the minerals dahllite and francolite (*12*).

Dental enamel, dentin, and bone are composed of a single crystalline phase, a carbonate hydroxyapatite (dahllite), in which there is substitution within the crystal lattice of carbonate groups for phosphate groups. No other interpreta-