Our Splintered Learning and the Status of Scientists

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FEW scientists or scholars realize the sheer volume of our present-day publications. Not so long ago, the editor of one of our great abstracting journals stated that about half a million scientific papers were published each year. We can never know the exact number, of course, for some of them are printed in odd and out-of-the-way journals, and they range all the way from the truly scientific to the trivial. Also, we have no criterion that enables us to decide just when a paper is scientific and when it should not be included in the total. Even if we discard as many as one-half, those we retain would still present an intimidating volume. We can visualize their numbers, perhaps, by noting that during the time it would take to deliver a talk the length of this paper*, some fifty papers would be published. Obviously, we cannot read this paper and 50 others at the same time; no matter what we do, we will miss something. Nor can we ever catch up, because, between dinner one day and breakfast the next morning, another 600 papers will appear. Sometime during the annual meeting of the AAAS, a newspaper reporter had some good clean fun by emphasizing the number of papers the scientists read—and, of course, had to listen to. But during that meeting fewer papers were presented than were published elsewhere.

Our situation is clearly not as desperate as these facts and figures might indicate because, if it were, science would have been suffocated by its own products. After a fashion we have solved the problem of keeping up with ourselves, but the solution has not come cheaply. In fact, we have paid—and will continue to pay—a very high price for a workable method of utilizing the contributions made by our colleagues. Mercifully, perhaps, we do not realize the full cost but, whatever the cost, pay it we must. The solution, as we all know, is reached by dividing up the task, by our becoming specialists, and this means, of course, limiting our individual competence and interests. Now the modern specialist is not one who knows more and more about less and less, in spite of the oft-repeated libel. True, his field is continually narrowing, but the effective specialist who keeps abreast of the times must continually learn more and more about more and more. He must learn to the very limit of his capacity, because the sum total of our knowledge in all-important disciplines is increasing at an unprecedented rate, and so far it shows no symptoms of slowing down. If the specialist keeps up in his own field and understands what his neighbors are doing in adjacent fields—and all of this is necessary if science is to advance—he will clearly have little time or training to investigate or understand what is going on in more distant pastures. Thus, the price the specialist has to pay for his professional competence is often an all-encompassing and, sometimes, a very startling innocence.

The evil consequences of our fragmentary, and hence incomplete, knowledge affect both the scientists and the public at large. Perhaps the result easiest to identify is the slowing down of the progress of science itself. When the data necessary for a scientific advance are scattered and the logical connections between the individual pieces are obscured, the potential advance is simply not made. Important progress —progress in basic theory—is possible only when the raw facts can be collected and organized; only when they can be brought together into some one receptive mind. As long as they remain scattered in the minds of different specialists, the theory remains undiscovered.

Such conditions have existed, of course, from the very beginnings of science—long before our present division of labor, but, as specialization advances, the conditions worsen. Historians of science have recorded any number of instances where all the facts necessary for the birth of an important theory have been known for many years, but, as long as they were scattered, they seemed to be, and actually were, unimportant.

The great contribution of Gregor Mendel may be used to illustrate this point. His discoveries were presented to the world in 1865, but the biologists who read his paper thought nothing of it. Thirty-five years later, in 1900, the paper was discovered and appreciated, and the new science of genetics was born. The original neglect of Mendel's work is truly startling when we realize that every single one of his discoveries had been made previously and that some of them were well known.

In 1822, the very year in which Mendel was born, two horticulturists, Seton and Goss, working independently, announced most of the facts we label Mendelian. They described dominance and recessiveness and the segregation of these types both in the second hybrid generation and when the hybrid was bred back to the recessive parent. They announced the existence of two kinds of dominants—those that breed true (homozygous) and those that continue to segregate (heterozygous). When Mendel was 4 years old, Sag-

* Based on a Phi Beta Kappa address given on 27 December 1954 at the Berkeley meeting of the American Association for the Advancement of Science.

eret described the independent assortment of what we call Mendelian factors. Indeed, every bit of Mendelism, except the definite ratios, was well known to the plant hybridizers, and in 1854, even the definite ratio was discovered by Dzierzon—in honey bees. It is probably more than a coincidence that Mendel, the man who created Mendelism, both hybridized plants and bred honey bees, and, as far as we know, he was the only man at the time who did. At any rate, the scattered fragments of Mendelism came together for the first time in his mind, and 35 years after he published his classic paper, the importance of his synthesis was finally recognized.

Such examples as Mendel could be cited indefinitely. In 1813, when Charles Darwin was 4 years old, William Charles Wells described evolution by means of natural selection in a work entitled "Two essays, one upon single vision with two eyes, the other on dew, and an account of a female of the white race of mankind part of whose skin resembles a negro! with some observations on the causes of the difference in colour and form between the white and negro races of men," and in 1831, Patrick Matthews did the same thing in a book entitled *Naval Timber and Arboriculture*. Darwin did not know of either work until after he had published *The Origin of Species* in 1859. Whereupon he wondered rather plaintively if he should have explored the field of growing timber for the navy.

Today we have no way of knowing how many great scientific discoveries have already been made—made, but never assembled—discoveries that are hidden because they exist only as scattered fragments. The past is full of such instances. We know now that the raw data for evolution itself were available in classical times. Then species were thought of as being unstable, as being constantly changing units. Also, belief in the inheritance of acquired characters was held almost universally, and a few philosophers even used natural selection to explain the existence of adaptation. The "fact" of changing species, however, never got together with any of its possible explanations. But we can spend no more time on this aspect of our scattered knowledge. It is an inherent limitation of finite minds and will continue to exist in the best of all possible worlds.

Of much more importance are the effects of specialization on the minds of the specialists themselves. These effects are not always happy, but we would be both supercilious and ungrateful to place the blame on the scientists who specialize, on those who concentrate their interests so intensely that they are able to advance the frontiers of knowledge. Without specialization, without the division of intellectual labor, we would have difficulty in living as civilized beings. All of us owe a debt to the scientific specialists, and it is only sporting to give them the respect they deserve. It is silly to allow an occasional lapse of good sense in a minute fraction of the scientists to affect the status of all scientists. This point cannot be emphasized too strongly, for today the American scientists are on the defensive and desperately need all the prestige that is their due—the prestige usually accorded to scientists in other countries.

Scientists now have to deal personally with politicians and with military men. They are not in too strong a position, as many of them have discovered. If scientists can be presented to the public as well-meaning individuals who, by some miracle of nature, have developed into a strange combination of magician and crackpot, and if this caricature becomes the accepted stereotype, the scientists will not be able to protect their interests or maintain conditions in which science can thrive. Scientists, for example, are vitally interested in the loyalty tests and would like to introduce more common sense into the clearance procedures. They would also like to be able to hold international scientific conferences in the United States, but so far they have been too weak to achieve either of these aims. A single Klaus Fuchs or Bruno Pontecorvo, or even a single starry-eyed scientist who makes the headlines from coast to coast, may dissipate more prestige than the scientists can afford to lose.

Then, too, there is the ever-present danger of anti-intellectualism, and anti-intellectualism is a disorder that has accompanied our species throughout its entire history. Socrates felt its full impact. It finally dominated the classical world, and conformity reigned in all cultural fields. For 1000 years, beginning about the 4th century of our era, anti-intellectualism reduced the progress of science to a snail-like crawl. Today, it is stirring restlessly and at any time it may again become virulent. It has already destroyed certain sciences in the Communist world, and it threatens freedom everywhere. We will have to check and control anti-intellectualism if we are to maintain our progress. But scientists often stimulate its growth through sheer naïveté.

If scientists are to fight anti-intellectualism effectively, they must look to their armament; they must check and perhaps improve their equipment. Certainly they should know why they are on the defensive and why they are vulnerable. Several times I have heard scientists state that "we have not done a good job in educating the public." It is possible also that they have not done a good job in educating themselves and that it is their own educational deficiencies that are the immediate cause of their lowered prestige.

Every now and then someone discovers that a large proportion of our better Ph.D.'s are uneducated. The discovery is generally announced under humorous or semihumorous circumstances and everyone enjoys the occasion. An editor or two wonders what the world is coming to, those who are not Ph.D.'s feel complacent, and the occasion passes. Yet the question arises: What else should we expect? When we consider what the Ph.D.'s have to go through, how could it be otherwise? True, some centuries ago the doctor of philosophy was a learned man, a philosopher, fairly well acquainted with all that was known, but today, such competence is beyond the capacity of anyone. Historically, the doctor of philosophy was a scholar, and also a man who was more than a dilettante in the sciences. He

was a man who had assimilated that great achievement of our species known as the humanities. During the Renaissance, the scientists were the humanists, and they were humanists because otherwise they could not be scientists. But these conditions no longer exist. If we glance at our educational system, we can easily understand why.

A great part of the freshman year in college, if not all of it, is devoted to learning what the students should have learned in high school, but did not. One year later—at the end of the sophomore year—the student "concentrates his efforts in the field of his greatest interest," and this concentration continues. In graduate school the training will be narrowed even more, and here the student really has to devote his time to acquiring the accumulated knowledge in his field and to mastering the techniques of research and the other holy mysteries of his profession. He also has to eat and sleep and sometimes teach his subject to undergraduates. Even equipped with the enormous energy of the young, he has little time or attention to devote to side issues, to issues that will not help him earn a living or promote him professionally.

Recently, H. J. Fuller [*Science* **120**, 546 (1954)] of the University of Illinois asked 15 candidates for the doctorate in philosophy to identify the Renaissance, the Reformation, the Monroe Doctrine, Voltaire, the Koran, Plato, the Medici family, the Treaty of Versailles, Bismarck, and the Magna Carta. The identifications were satisfactory just 35 percent of the time. Fuller has recorded all the startling details of his experiment, and they are well worth reading. The questions he asked, of course, were completely "unfair" to the students, since they were earnest youths who had been caught in our system of education and were only trying to become doctors of philosophy in one of the botanical sciences. They also have to earn a living in a competitive field; and it is possible that, for this purpose, nothing better than a doctorate in philosophy was available. So they became Ph.D.'s! We are reminded of the famous scene where Dr. Watson discovers that Sherlock Holmes had never heard of the Copernican theory. The good doctor describes it to the great detective, but becomes goggle-eyed when Sherlock states that now that he has learned it, he will forget it as soon as possible since it has no bearing on his profession—the identification of criminals.

We are now faced with the question: How should Ph.D.'s in science be educated? Or the even more fundamental question: Should they be educated at all? There are many considerations. Whichever course we pursue will have both its advantages and disadvantages. There is no easy answer. For example, what effects will education have on a scientist's output? There is no doubt that, no matter how brilliant a scientist may be, he should also be industrious. It is not enough for a man to be a scientist, he must also work. Now, perhaps, the greatest single stimulus for industriousness lies in the ability of a scientist to overestimate the importance of what he is doing. This ability, of course, varies inversely with the breadth of his education.

An argument might be made against educating scientists—if any one could be found who would be cad enough to make it. It might also be urged that the scientist, as an individual, would suffer little through a lack of education. No matter how narrowly his training was channeled—provided it was not so limited as to injure his research—the scientist could still be a happy citizen—provided, of course, that he did not stray so far afield as to become lost or to put his name on too many petitions. Nor would he suffer socially, so long as he had colleagues with whom he could talk shop. He need never be bored, because even the more specialized fields contain enough material to occupy any stray thoughts that might wander into his mind at odd moments. It is doubtful if he would even feel a sense of loss, a sense of having missed something important. Finally he could experience the thrill of being respected by those who understood his work. Certainly he need not be patronized by anyone who has never mastered any field or even by a college graduate who has read 100 books. It is worth noting parenthetically that one does not have to be a specialist to have a defective education.

But, collectively, scientists suffer because of their lack of education, and society suffers even more. As things are today, scientists would be better off if they enjoyed more public esteem. Scientists do not thrive when anti-intellectualism grows, but, instead of diminishing this blight, many scientists have unwittingly helped it along. For the last two decades, far too many scientists have had too high a *G.Q.*, or gullibility quotient. When the gullibility of one scientist becomes public knowledge, all scientists suffer. I can sympathize with one of my learned friends who said that he had a divine right to make a fool of himself whenever he wanted to, and that he would not let anyone stop him. This is an important right, of course, and we should not surrender it lightly. More of our fundamental freedom rests upon it than appears on the surface. The right to make honest mistakes is basic to all progress, but if we exercise the right to excess, the more unsophisticated of our fellow citizens will misunderstand. We should remember that the right of a scientist to make mistakes does not include a right to indulge in slovenly or escapist thinking. A few years ago a C.I.O. official said to me, "We in the C.I.O. caught on to the Commies long ago, you college boys were the suckers." The truth is that most of "us boys" were not suckers, but the sad fact is that some of us were, and they were the ones who made the headlines.

In spite of much adverse publicity, we know that only a very minute fraction of the scientists have been disloyal—and that fraction is, in fact, vanishingly small. The number of good scientists in the free world who are Communists or who follow the Communist line in science can be counted, perhaps, on the fingers of one hand. If we think for a moment, we can readily understand why first-rate scientists do not become

Communists. Scientists do not like to be disciplined, and few would tolerate the rigid intellectual and political discipline of the Communist Party. Scientists like to talk about their interests, but the party does not approve of garrulity or of men who are independent or who show individual initiative. Our scientists are even chafed by and resent having their work classified, and, by comparison, this involves the mildest of possible disciplines. Certainly the party would never trust honest scientists too far. After all, scientists have to be completely honest in their work, and this honesty tends to become a state of mind. Thus, scientists are really very poor material for any conspiratorial organization. Outside of the party, however, and without too many contacts with practicing Communists, the scientists' very virtues may dupe them. To the pure, unfortunately, all things seem pure, and scientists are remarkably pure in thought and can be innocent in more than one sense. But, in spite of this, the percentage of scientists who were duped by "our gallant ally" was probably just about the same as that of the whole population. After all, in spite of his concentrated interest, a good scientist must have a certain amount of native intelligence, and when he is well informed, he tends to think clearly.

When we examine the whole picture and balance all the conflicting factors, we can probably agree that even specialized scientists would profit by an education. Their lives would be richer and their standing in the community enhanced. They should not wander too far into the fields of scholarship, however, as time is fleeting and they have a job to do. Perhaps they could adopt scholarship as a hobby, provided they did not let the hobby get out of hand or select some one small aspect of learning and make it into a secondary specialty. We may agree that we would all be better off if our scientists were truly educated, but the method of accomplishing this is, at present, not at all clear.

Meanwhile, we should protect our scientists both from the anti-intellectuals and from themselves. Some temporary expedient may prove valuable. Perhaps our scientists could learn caution and learn to evaluate their training realistically—to recognize their academic degrees for what they are really worth. A rewording of the diplomas might help in the reorientation. The completely imaginary certificate shown here will illustrate the point. The wording, of course, may be altered to suit the occasion. This is a very tentative suggestion.

The Johns Hopkins University
certifies that
John Wentworth Doe
does *not* know anything but
Biochemistry.

Please pay no attention to any pronouncement he may make on any other subject, particularly when he joins with others of his kind to save the world from something or other.

However, he worked hard for this degree and is potentially a most valuable citizen. Please treat him kindly.

Such a diploma might have a healthy psychological effect upon its recipient. It might serve as a warning to him not to rush into complicated problems with some innocent and naïve solution. This is important, for the fewer the scientists who are caught off base, the less their prestige is lowered.

Obviously the specialized scientist pays a very high price for his professional competence. He has compensations, however, and his pursuit of happiness need not be too greatly handicapped. But the price that society pays for the unintegrated state of its knowledge is much higher, and society has no compensations whatever. I do not mean to imply that society will meet disaster unless the millions of facts recorded in the millions of scientific contributions are organized and made available to all. The lack of integration is on a much more fundamental plane. Even the basic concepts and verified generalizations of science are scattered, and many obstacles other than their number and complexity stand in the way of their proper integration. Much scientific knowledge is hostile to some of our best-loved oversimplifications, and this knowledge, of course, will not be welcomed. When unwelcomed facts are scattered, they are much easier to avoid since we can deflect our minds from them at the first hint of their presence and before we have to face the implication of their meaning. For a long time we have had well-tested ways of disposing of facts and ideas we do not like, and we do not hesitate to use them. A partisan mind has undoubtedly been standard human equipment for the last million years. It is, and probably always has been, standard mammalian equipment. The partisan mind is one of the most effective of all isolating mechanisms. It establishes the vicious, little personal censorships that segregate us into groups and keep our information scattered—such censorships that keep us from reading certain books and periodicals that present unwelcomed facts.

Often the individual oversimplifications, which mean so much to us personally, were acquired in adolescence or even in preadolescence. To alter them we might have to rearrange our neural circuits, and this might even result in ulcers or in a nervous breakdown. It would certainly be painful. There are no limits to the examples we might cite of this craving to avoid the complex and the puzzling and to live in a simple "yes-no" universe. In almost every field we tend to classify the actors into "the good guys and the bad guys." In politics especially! It is really amusing to contrast the clear, logical, and accurate way we evaluate the campaign speeches of the politicians of the *other* party, with the semiconscious euphoria we exhibit when listening to the oratory that emerges from our own party, the party of the "good guys." We are able to apply even an ethical or an orthodox test to scientific hypotheses: some are forward-looking and virtuous, others are evidence of sin. Thus, a complete integration of all human knowledge, which, incidentally, is impossible, would involve a great deal of re-education, and re-education is always more painful than education itself since it involves unlearning

as well as learning. Officially we are all in favor of the truth, no matter how disconcerting it might be, but we do not feel the need of going around looking for trouble. Perhaps, without admitting it, we are convinced that the truth that, proverbially, will make us free, will, at least temporarily, make us unhappy.

It is hardly feasible to list all the impediments to a proper integration of human knowledge. We have become so accustomed to viewing the universe in splintered bits that many of us really assume that it has a cellular structure and that each cell can be treated conveniently as if it were a pigeonhole. This view is widespread even if it is not held overtly. It is the view that college and university administrators seem to favor, for it promises to simplify their always-too-complex problems. Whenever they can, they assign a single pigeonhole to the custody of the corresponding academic department. Thus, by increasing the number of departments, the larger colleges and universities may, literally, cover the universe, neatly, completely, and without jurisdictional conflicts. And each savant on the faculty will know just where he stands. Well, the concept at least is orderly!

Fortunately, in the physical and natural sciences, the partitions between pigeonholes are becoming very permeable. Ideas are percolating, and the scientists themselves are beginning to wander about and to explore adjoining compartments. Many a specialist finds himself working in two or more compartments and, often before he knows it, finds himself able to communicate with two or even three different groups of natives. These scientific explorers make excellent liaison officers. Although as individual scientists they retain the usual human limitations, they are beginning to tie the sciences together, and, professionally at least, they rarely wander far enough to get lost. Neighboring pigeonholes are being welded together even if they are not coalescing, and we can be grateful for this. There is still no prospect of unifying distant compartments, however, or of discovering the proper system for organizing the information that is widely dispersed.

Some partitions between the pigeonholes serve as real isolating mechanisms. In spite of the fact that the scientists and the humanists were originally the same individuals, today they have few points of intellectual contact, for their professional interests are now too far apart. The case is not hopeless, however, because they do have some personal and social contacts and they even seem to admire each other as individuals. They now serve together on college committees, compete for their shares of the academic budget, and, occasionally, unite to oppose some bright scheme of the administration or of the athletic department. They are natural allies, and if only they had the time, each could understand and respect what the other is doing.

The partitions separating the biological and the social sciences are also nearly impervious, and intellectual contacts between the disciplines are difficult and uncertain.

I have recently had the task of tracing the history of the Communist line in biology, the line that was drawn by Marx and Engels in the 1870's. It was the resurgence of this archaic biology that destroyed genetics in the Communist world, and this biology also sets the standards in much of our own culture. It permeates our belles lettres and runs right through the social disciplines. It affects the thinking of many people who are unaware of its origin or of its implications. Nowhere else are the evil consequences of our scattered data more obvious or more crippling than when an archaic quackery is interposed between the separated splinters of learning and used to muddle the thinking on which our welfare depends. The continued existence of this Marxian biology is possible only in those fields that are isolated from biology proper; it is possible only where communication is defective. Biology is found in the elementary textbooks of sociology and, of course, will be found there as long as *Homo sapiens* remains a mammal. It is not the biology of the biologists, however, nor, fortunately, is it the biology of Marx and Engels. It can be described only as sociological biology. It is a law unto itself, although it overlaps the other two biologies—the Marxian perhaps more than the biology of the biology departments. There is not much we can do about this at present. As long as our learning is splintered, such anomalies as sociological biology will arise.

As individual scientists and scholars, all that we can do is to make the best of our personal limitations and, within our limitations, to lead lives as useful and happy as we can make them. After all, we will not live very long. But we are also members of society and we are citizens in a state, and as citizens we, or at least those we choose as leaders, will have to make decisions. If some of the decisions are uninformed and based on faulty data, we may expect them to be expensive, may expect their cost to run to 10 or 11 figures—not to mention the cost that cannot be expressed in money. Perhaps all the data we need for wise decisions are not in existence, but in the past we obviously did not use all the information we had.

The unavailability of our scattered information has seriously reduced the efficacy of our thinking on the national level. In retrospect, many of our collective decisions seem uninformed and even naïve. We need not go very far back in our history for illustrations—no further than to the war that ended all war and made the world safe for democracy. We are unanimous in not wanting war, and our reactions are reasonable. To achieve our desires—to abolish war and make the world better—we have only to discover the causes of war and remove them—or refuse to fight or do something.

During World War I, the majority opinion seems to have been that the war had come upon us through the fact that the Kaiser, the Crown Prince, and the German army wanted war. We succeeded in removing these causes, but after the Treaty of Versailles, things looked different. Then we were led to believe that we had been involved because of the machinations of the international bankers. These bankers were bad men

who had loaned money to the Allies and then tricked us into saving their investments when the Allies were threatened with defeat. This notion was actually endorsed by our government, and Congress passed a law forbidding our banks to lend money to nations at war. The policy we adopted was known as "cash and carry." This policy, however, lacked something, and after World War II started we swapped it for "lend-lease," and in so doing made one of the neatest flip-flops in our history. We still hated "foreign wars," but we would become the "arsenal of democracy." However, Pearl Harbor changed all this. Incidentally, we are definitely showing signs of maturity and are no longer seriously trying to blame Pearl Harbor on a single individual. But, in retrospect, we know that before the debacle at Pearl Harbor we had all the facts that could have prevented the surprise had they been organized and their significance understood.

In the last few years we have begun to suspect that our negotiations at Teheran and Yalta were not only uninformed, but were in part actually misinformed. We do not yet know all that happened in these negotiations, but we are beginning to suspect that our decisions did not represent the ultimate in foresight or wisdom. Our chief representatives were undoubtedly sincere, but even able diplomats will be overly handicapped if they are uninformed on basic theory. No matter how wise an individual may be, he is bound to err if he has to rely on inadequate or faulty data. Although our ignorance of Russia seems to have been a trifle excessive at Teheran and Yalta, we are now judging the effects in the light of our hindsight. Today we are Monday morning quarterbacks and are not forced to make decisions under pressure. But this does not alter the probability that, had our negotiators been better informed, we would be better off today. The less we say about the loss of China to the free world, the better.

All our mistakes, of course, are not in the past. We are certainly making mistakes now and will do so in the future, but some time will have to elapse before we can learn what we are doing that is wrong. Our need for accurate information is pressing. Any number of questions are presenting themselves, and our welfare will depend upon the answers we obtain. What are the important facts we are now overlooking? Obviously, we do not know, nor can we expect even an I.B.M. machine to organize our data and give us the answers we need. Basic theory is involved and, of course, this always impinges on our most sacred beliefs and on our emotional irrationality. Needless to say, political predilections will obscure much of the picture. We have to act, however, and take calculated risks, knowing that we have all too little upon which to base our calculations.

We will indeed make mistakes, and when we look back on our present actions, we will undoubtedly find that many of our errors of judgment were unnecessary. Fortunately, most of our individual errors are trivial, but a major danger exists if our errors become synchronized. Disaster will threaten our way of life if a majority of us are fooled in the same way and at approximately the same time. But, even if this should happen, a vigorous minority functioning as a negative feedback may give us sufficient stability so that we can recover from even the most popular aberration. Incidentally, we have some horrible examples in what happened to several great and learned nations when they succumbed to an aberration and would not let their negative feedback work—when all minorities were silenced or liquidated. These nations were unable to hold to a rational course; they fell into totalitarianism and, once there, they stuck.

But we can take comfort in the fact that we are not the only ones who appear ignorant in retrospect. Up until now, and fortunately for us, our enemies have blundered more than we have. Hitler's many idiocies are now a matter of record. Stalin's application of Marxian biology to Russian agriculture was stupid and uninformed, but very lucky for us. It is, perhaps, the greatest single deterrent to World War III. At present the Russians simply do not have enough spare food to allow them to take major risks.

To err is certainly human, but we would like to reduce the incidence of error in our society. If international tensions mount and the cold war continues to be waged on many fronts, victory might well go to the side that is less confused intellectually, to the side that is less scatterbrained. Today our nation definitely needs all its brain power, and this means that it needs the help of our scientists not only as creators of military gadgets, but as citizens who possess unique and valuable information. If our scientists could truly pool their knowledge, if the pool could be organized into a whole that could function undisturbed by the partisan limitations of individuals, and if the scientists, politicians, and military men could learn to speak the same language, we would go well ahead of the Communist world, and victory in the cold war would be assured. Before we can reach this desideratum we will have to learn how to pierce the isolating partitions that dissect the world of learning and to remove the artificial impediments to communication. We will also have to establish an atmosphere in which good and loyal scientists may function effectively, unhindered by bureaucratic formulas or by demagogic attacks.

We can summarize the effect of our splintered learning briefly. The history of science contains many instances where facts, which could have led to major advances, were so scattered that the advances were not made. Progress had to wait until the facts were rediscovered in a context where their significance was understood. This slows up the progress of science, but its ill effects are not irreparable, for science still manages to advance with ever-increasing speed. Far more important are the effects of the fragmented learning on the scientists themselves. The limited interests and the lack of background of a few scientists do affect their behavior, and these few lower the standing and prestige of all scientists. This is serious because, in dealing with the political authorities and with the mili-

tary, the scientists need prestige and respect. As it is, the scientists are not in a position to lead from strength. They are not even strong enough to look after their own proper interest or to combat effectively the anti-intellectualism that is ever present. The status of science can be lowered by a single naïve scientist in spite of the unprecedented accomplishments and contributions of science. Also, the general repute of scientists can suffer from the public activity of any small group that believes that all scientists should be supported automatically, and that whatever a good scientist does is good. Scientists would be in a much stronger position if they had the respect that society generally gives to the "practical" man or even accords to the gentleman and scholar who is a judge of the finer things of life.

In many of the sciences, the Ph.D. is a vocational degree, a preliminary step in getting a job. The acquisition of the degree, however, is no light task. It takes a minimum of five years away from the education of the candidates and devotes the time to their professional training. In spite of their native intelligence, many scientists show the effects of this sacrifice and, when they wander too far from the fields they know, they get lost.

Society also suffers from its inability to utilize fully the data that are now accumulating so rapidly. Decisions on the national level frequently have to be made suddenly, and those who act on the higher levels have to take calculated risks. Practically no individual is equipped for such a task, and we have learned to substitute small groups for individuals when crucial decisions have to be made—such groups as a cabinet or general staff, or even a research team. But all too often, when fundamental theory is involved, serious gaps of information appear in the collective knowledge of the group. Sometimes the knowledge that could fill these gaps is simply lost in the vast fund of our undigested learning, sometimes it is excluded by partisan thinking or by the human desire to evade what is complicating. Whatever the cause, the effect has been an inability to focus all the relevant data on the questions that so vitally concern our national well-being. Errors of judgment, of course, are inevitable. True, we are often able to correct our past mistakes—we have a major opportunity every 4 years—and this ability may be our greatest source of strength. It may give us the adaptation that we need for survival in the world of today. All nations do not have this ability; for example, Hitler and Stalin could be removed only by death, and death does not always arrive when it can do the most good.

Today we are faced with a real struggle for existence, and it is not just a competition between individuals, but a contest between systems—between different ways of life. The fit, of course, are not those who do no wrong, but those who can learn more quickly by experience. We may take some comfort in the fact that the enemies of the free world also make errors, but they cannot correct their errors as easily as we can correct ours. Our ability to correct our mistakes gives us a very real advantage, and we would be silly to throw it away. Since we do not have our facts well enough in hand to escape even the avoidable errors, we must preserve our freedom to change our course of action—we must preserve enough freedom to give our hindsight a chance. Our chronic lack of foresight then need not be fatal.

The Use of Material*

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LAST year *Biological Abstracts* printed references to 33,498 publications. As science has grown in extent and complexity, the volume of scientific publication has expanded to phenomenal proportions. We scientists are busy men, and when we are confronted with the flood of journals pouring into our libraries, journals containing hundreds of articles that we should read to keep abreast of our fields, we are sometimes tempted to throw up our hands in despair and give up the one-sided fight—the fight to add our own share to the flood. Whatever we do, it is a safe bet that none of us read all the papers we should read or even all the papers that their authors hoped we would read.

Now it is obvious that this deluge of literature is not presented to the scientific public without a purpose. The purpose, of course, is a mixed one. The ego is inflated when one sees one's self in print. Besides, one gains scientific standing by means of published contributions, to say nothing of promotion in academic rank when the number of titles becomes sufficiently multiplied. On the other hand, there is an altruistic motive behind all of this publication. Scientists as a group do not attempt to gain financially by control of their product. For the most part they tend to present their findings to their colleagues as a gift, and scientific writing is their medium for making this gift available. The purpose of scientific communication is therefore a compound of the desire to get ahead and the desire to make a contribution to the progress of science and civilization.

* Read at a symposium, The Communication of Research Results, at the annual meeting of the American Institute of Biological Sciences, Gainesville, Florida, 7 Sept. 1954.