References and Notes

1. This second edition is a bibliographic curiosity, because it was published in the form of an offprint from *Isis* (*Extrait anticipé du tome* II, *fasc.* 2), but Belgium was suddenly invaded by the Germans, so that that number did not appear until five years later at the end of 1919, and did *not* contain the *Recommandations*. That pamphlet is thus a "preprint" of an article which was never printed!
2. It may sometimes be necessary to consult rapidly a number of books which one had no opportunity of "reviewing," but casual reference is not real use.
3. *"Ce que l'on conçoit bien s'énonce clairement . . ."* Boileau's saying does not apply as well to our contemporaries as to his. Men of substance, distinguished men of science, presumably educated, often lack a sufficiently deep knowledge of their own language. It may happen then that their clear ideas are betrayed by linguistic impotence, and steady thoughts, by wobbling expressions. See S. E. Morison, "History as a literary art" [*Isis* **39**, 197 (1948)].
4. Strangely enough, some books bear a misleading title. This should be pointed out, for it is a grave defect. Yet, the reviewer should not condemn the book because it does not tally with the title; it is the title which is wrong, not necessarily the book itself. Let him thus condemn the title and then examine the book without allowing himself to be prejudiced by the inadequacy of its label.
5. G. Sarton, "Iconographic honesty," *Isis* **30**, 222–234 (1939); "Portraits of ancient men of science," *Lychnos* (Uppsala, 1945), pp. 249–256.
6. For example, the price should be quoted whenever it is possible to do so. The reader may be anxious to obtain the book, but he cannot buy it unless the price be within his means.
7. In the "Critical Bibliographies" of *Isis*, the title of a book or article is often followed by an extract from the preface, the text, or even the jacket, the extract being quoted as such. That is not a review, but simply a statement of the author's purpose in his own words; no criticism of the book is implied.
8. He died in 79. The remark has been transmitted to us by his nephew Pliny the Younger (*Epistolae* III, 5): *"Nihil enim legit quod non excerperet; dicere etiam solebat nullum esse librum tam malum, ut non aliqua parte prodesset."*
9. Compare the saying of the French critic Edmond Schérer (1815–89), who was in some respects superior to his older and more illustrious contemporary Sainte-Beuve (1804–69). Said Schérer, *"Rien n'est plus répandu que la faculté de ne pas voir ce qu'il y a dans un livre, et d'y voir ce qui n'y est pas"* [*Etudes critiques* **1**, 195 (1863)].
10. It is well to say the writing of a "tolerable" book, for the writing of a bad book may be easy enough (however, some bad books have been composed with extreme difficulty). The art of writing implies many steps: (i) orthography of words, (ii) writing of correct sentences, (iii) composition of paragraphs, (iv) composition of articles, essays, or chapters, (v) composition of books. Some idiots have jumped to (v) in one leap; they have learned some tricks of strategy without bothering about tactics. They are ingenious enough to write books, plenty of them, and hardly think of their substance. Their books may be "paying" books, however, and publishers love them.
11. That comparison has been ascribed to Freud, but as I don't know where and when he made it, I must assume responsibility for it, at least pro tempore.
12. A classical example is the review of Whitehead and Russell's *Principia mathematica* [ed. 2 (1925), vol. 1] by Henry M. Sheffer [*Isis* **8**, 226–231 (1926)].
13. Praise and blame have no absolute value; it all depends on who is praising or blaming. To be blamed by an idiot may be equivalent to being praised by a good man.
14. It was not always so. A little more than a century ago Blomfield received 20 guineas for his review of Samuel Butler's *Aeschylus* in the *Edinburgh* and no less than 100 guineas for that of Barker's *Thesaurus* in the *Quarterly* [Martin Lowther Clarke, *Greek Studies in England* (Cambridge, 1945), p. 6; *Isis* **37**, 232 (1947)]. This was truly a golden age for learned critics; but was it a golden age for criticism? I doubt it.

Modern Science and the Intellectual Tradition

The dissociation of science from the rest of our culture has deep-seated causes and disturbing implications.

Gerald Holton

When future generations look back to our day, they will envy us for having lived at a time of brilliant achievement in many fields, and not least in science and technology. We are at the threshold of basic knowledge concerning the origins of life, the chemical elements, and the galaxies. We are near an understanding of the fundamental constituents of matter, of the process by which the brain works, and of the factors governing behavior. We have launched the physical exploration of space and have begun to see how to conquer hunger and disease on a large scale. Scientific thought appears to be applicable to an ever wider range of studies. With current technical ingenuity one can at last hope to implement most of the utopian dreams of the past.

Hand in hand with the quality of excitement in scientific work today goes an astonishing quantity. The world-wide output is vast. There are now over 50,000 scientific and technical journals, publishing annually about 1,200,000 articles of significance for some branch of research and engineering in the physical and life sciences. Every year there are about 60,000 new science books and 100,000 research reports (*1*). And the amount of scientific work being done is increasing at a rapid rate, doubling approximately every 20 years. Every phase of daily and national life is being penetrated by some aspect of this exponentially growing activity.

It is appropriate, therefore, that searching questions are now being asked about the function and place of this lusty giant. Just as a man's vigorously pink complexion may alert the trained eye to a grave disease of the circulatory system, so too may the spectacular success and growth of science and technology turn out, on more thorough study, to mask a deep affliction of our culture. And indeed, anyone committed to the view that science should be a basic part of our intellectual tradition will soon find grounds for concern.

Some of the major symptoms of the relatively narrow place science, as properly understood, really occupies in the total picture are quantitative. For example, while the total annual expenditure for scientific research and development in this country is now at the high level of over $10 billion, basic research—the main roots of the tree that furnishes scientific knowledge and the fruits of technology—has a share of about 7 percent at best (*2*). Correspondingly, a recent manpower study showed that of the 750,000 trained scientists and engineers, only 15,000 are responsible for the major part of

The author is professor of physics at Harvard University. This article is reprinted, with some amplification, from the anthology *The Intellectuals* [George B. de Huszar, Ed. (Free Press, Chicago, 1960)], with permission.

the creative work being done in basic research (*3*). Another nationwide survey found that in 1958 nearly 40 percent of the men and women who had attended college in the United States confessed that they had taken not a single course in the physical and biological sciences (*4*, p. 150). Similarly, in contrast to the overwhelming amount of, and concern with, science and technology today, the mass media pay only negligible attention to their substance; the newspapers have been found to give less than 5 percent of their (nonadvertising) space to factual presentations of science, technology, and medicine, and television stations, only about 0.3 percent of their time (*4*, pp. 1–3; *5*). In short, all our voracious consumption of technological devices, all our talk about the threats or beauties of science, and all our money spent on engineering development should not draw attention from the fact that the pursuit of scientific knowledge itself is not a strong component of the operative system of general values.

The Atomization of Loyalties

In the qualitative sense, and particularly among intellectuals, the symptoms are no better. One hears talk of the hope that the forces of science may be tamed and harnessed to the general advance of ideas, that the much deplored gap between scientists and humanists may be bridged. But the truth is that both the hopes and the bridges are illusory. The separation—which I shall examine further—between the work of the scientist on the one hand and that of the intellectual outside science on the other is steadily increasing, and the genuine acceptance of science as a valid part of culture is becoming less rather than more likely.

Moreover, there appears at present to be no force in our cultural dynamics strong enough to change this trend. This is due mainly to the atrophy of two mechanisms by which the schism was averted in the past. First, the common core of their early education and the wide range of their interests was apt to bring scholars and scientists together at some level where there could be mutual communication on the subjects of their individual competence; and second, the concepts and attitudes of contemporary science were made a part of the general humanistic concerns of the time. In this way a reasonable equilibrium of compatible interpretations was felt to exist, during the last century, between the concepts and problems of science on the one hand and of intelligent common sense on the other; this was also true with respect to the scientific and the nonscientific aspects of the training of intellectuals. Specialists, of course, have always complained of being inadequately appreciated; what is more, they are usually right. But although there were some large blind spots and some bitter quarrels, the two sides were not, as they are now in danger of coming to be, separated by a gulf of ignorance and indifference (*6*).

It is of course not my purpose here to urge better science education at the expense of humanistic and social studies. On the contrary; the latter do not fare much better than science does, and the shabby effort devoted to science is merely the symptom of a more extensive sickness of our educational systems. Nor do I want to place all blame on educators and publicists. Too many scientists have forgotten that especially at a time of rapid expansion of knowledge they have an extra obligation and opportunity with respect to the wider public, that some of the foremost research men, including Newton and Einstein, took great pains to write expositions of the essence of their discoveries in a form intended to be accessible to the nonscientist. And in the humanities, too many contributors and interpreters seem to scoff at Shelley's contention in his *Defence of Poetry* that one of the artist's tasks is to "absorb the new knowledge of the sciences and assimilate it to human needs, color it with human passions, transform it into the blood and bone of human nature."

It is through the accumulation of such neglects just as much as through deterioration in the quantity and quality of instruction given our future intellectual leaders that the acceptance of science as a meaningful component of our culture has come to be questioned. Again, this process is to a large extent merely one aspect of the increasing atomization of loyalties within the intelligentsia. The writer, the scholar, the scientist, the engineer, the teacher, the lawyer, the politician, the physician—each now regards himself first of all as a member of a separate, special group of fellow professionals to which he gives almost all his allegiance and energy; only very rarely does the professional feel a sense of responsibility toward, or of belonging to, a larger intellectual community. This loss of cohesion is perhaps the most relevant symptom of the disease of our culture, for it points directly to one of its specific causes. As in other cases of this sort, this is a failure of image.

Pure Thought and Practical Power

Each person's image of the role of science may differ in detail from that of the next, but all public images are in the main based on one or more of seven positions. The first of these goes back to Plato and portrays science as an activity with double benefits: Science as pure thought helps the mind find truth, and science as power provides tools for effective action. In book 7 of the *Republic*, Socrates tells Glaucon why the young rulers in the Ideal State should study mathematics: "This, then, is knowledge of the kind we are seeking, having a double use, military and philosophical; for the man of war must learn the art of number, or he will not know how to array his troops; and the philosopher also, because he has to rise out of the sea of change and lay hold of true being. . . . This will be the easiest way for the soul to pass from becoming to truth and being."

The main flaw in this image is that it omits a third vital aspect. Science has always had also a mythopoeic function—that is, it generates an important part of our symbolic vocabulary and provides some of the metaphysical bases and philosophical orientations of our ideology. As a consequence the methods of argument of science, its conceptions and its models, have permeated first the intellectual life of the time, then the tenets and usages of everyday life. All philosophies share with science the need to work with concepts such as space, time, quantity, matter, order, law, causality, verification, reality. Our language of ideas, for example, owes a great debt to statics, hydraulics, and the model of the solar system. These have furnished powerful analogies in many fields of study. Guiding ideas—such as conditions of equilibrium, centrifugal and centripetal forces, conservation laws, feedback, invariance, complementarity—enrich the general arsenal of imaginative tools of thought.

A sound image of science must embrace each of the three functions.

However, usually only one of the three is recognized. For example, folklore often depicts the life of the scientist either as isolated from life and from beneficent action (*7*) or, at the other extreme, as dedicated to technological improvements.

Iconoclasm

A second image of long standing is that of the scientist as iconoclast. Indeed, almost every major scientific advance has been interpreted—either triumphantly or with apprehension—as a blow against religion. To some extent science was pushed into this position by the ancient tendency to prove the existence of God by pointing to problems which science could not solve at the time. Newton thought that the regularities and stability of the solar system proved it "could only proceed from the counsel and dominion of an intelligent and powerful Being," and the same attitude governed thought concerning the earth's formation before the theory of geological evolution, concerning the descent of man before the theory of biological evolution, and concerning the origin of our galaxy before modern cosmology. The advance of knowledge therefore made inevitable an apparent conflict between science and religion. It is now clear how large a price had to be paid for a misunderstanding of both science and religion; to base religious beliefs on an estimate of what science cannot do is as foolhardy as it is blasphemous.

The iconoclastic image of science has, however, other components not ascribable to a misconception of its functions. For example, Arnold Toynbee charges science and technology with usurping the place of Christianity as the main source of our new symbols. Neo-orthodox theologians call science the "self-estrangement" of man because it carries him with idolatrous zeal along a dimension where no ultimate—that is, religious—concerns prevail. It is evident that these views fail to recognize the multitude of divergent influences that shape a culture, or a person. And on the other hand there is, of course, a group of scientists, though not a large one, which really does regard science as largely an iconoclastic activity. Ideologically they are, of course, descendants of Lucretius, who wrote on the first pages of *De rerum natura,* "The terror and darkness of mind must be dispelled not by the rays of the sun and glittering shafts of day, but by the aspect and the law of nature; whose first principle we shall begin by thus stating, nothing is ever gotten out of nothing by divine power." In our day this ancient trend has assumed political significance owing to the fact that in Soviet literature scientific teaching and atheistic propaganda are sometimes equated.

Ethical Perversion

The third image of science is that of a force which can invade, possess, pervert, and destroy man. The current stereotype of the soulless, evil scientist is the psychopathic investigator of science fiction or the nuclear destroyer —immoral if he develops the weapons he is asked to produce, traitorous if he refuses. According to this view, scientific morality is inherently negative. It causes the arts to languish, it blights culture, and when applied to human affairs, it leads to regimentation and to the impoverishment of life. Science is the serpent seducing us into eating the fruits of the tree of knowledge—thereby dooming us.

The fear behind this attitude is genuine but not confined to science; it is directed against all thinkers and innovators. Society has always found it hard to deal with creativity, innovation, and new knowledge. And since science assures a particularly rapid, and therefore particularly disturbing, turnover of ideas, it remains a prime target of suspicion.

Factors peculiar to our time intensify this suspicion. The discoveries of "pure" science often lend themselves readily to widespread exploitation through technology. The products of technology—whether they are better vaccines or better weapons—have the characteristics of frequently being very effective, easily made in large quantities, easily distributed, and very appealing. Thus we are in an inescapable dilemma—irresistibly tempted to reach for the fruits of science, yet, deep inside, aware that our metabolism may not be able to cope with this ever-increasing appetite.

Probably the dilemma can no longer be resolved, and this increases the anxiety and confusion concerning science. A current symptom is the popular identification of science with the technology of superweapons. The bomb is taking the place of the microscope, Wernher von Braun, the place of Einstein, as symbols for modern science and scientists. The efforts to convince people that science itself can give man only knowledge about himself and his environment, and occasionally a choice of action, have been largely unavailing. The scientist *as scientist* can take little credit or responsibility either for facts he discovers—for he did not create them—or for the uses others make of his discoveries, for he generally is neither permitted nor specially fitted to make these decisions. They are controlled by considerations of ethics, economics, or politics and therefore are shaped by the values and historical circumstances of the whole society (*8*).

There are other evidences of the widespread notion that science itself cannot contribute positively to culture. Toynbee, for example, gives a list of "creative individuals," from Xenophon to Hindenburg and from Dante to Lenin, but does not include a single scientist. I cannot forego the remark that there is a significant equivalent on the level of casual conversation. For when the man in the street—or many an intellectual—hears that you are a physicist or mathematician, he will usually remark with a frank smile, "Oh, I never could understand that subject"; while intending this as a curious compliment, he betrays his intellectual dissociation from scientific fields. It is not fashionable to confess to a lack of acquaintance with the latest ephemera in literature or the arts, but one may even exhibit a touch of pride in professing ignorance of the structure of the universe or one's own body, of the behavior of matter or one's own mind.

The Sorcerer's Apprentice

The last two views held that man is inherently good and science evil. The next image is based on the opposite assumption—that man cannot be trusted with scientific and technical knowledge. He has survived only because he lacked sufficiently destructive weapons; now he can immolate his world. Science, indirectly responsible for this new power, is here considered ethically neutral. But man, like the sorcerer's apprentice, can neither understand this tool nor control it. Unavoidably he will bring upon himself catastrophe, partly through his natural sinfulness, and

partly through his lust for power, of which the pursuit of knowledge is a manifestation. It was in this mood that Pliny deplored the development of projectiles of iron for purposes of war: "This last I regard as the most criminal artifice that has been devised by the human mind; for, as if to bring death upon man with still greater rapidity, we have given wings to iron and taught it to fly. Let us, therefore, acquit Nature of a charge that belongs to man himself."

When science is viewed in this plane —as a temptation for the mischievous savage—it becomes easy to suggest a moratorium on science, a period of abstinence during which humanity somehow will develop adequate spiritual or social resources for coping with the possibilities of inhuman uses of modern technical results. Here I need point out only the two main misunderstandings implied in this recurrent call for a moratorium.

First, science of course is not an occupation, such as working in a store or on an assembly line, that one may pursue or abandon at will. For a creative scientist, it is not a matter of free choice what he shall do. Indeed it is erroneous to think of him as advancing toward knowledge; it is, rather, knowledge which advances towards him, grasps him, and overwhelms him. Even the most superficial glance at the life and work of a Kepler, a Dalton, or a Pasteur would clarify this point. It would be well if in his education each person were shown by example that the driving power of creativity is as strong and as sacred for the scientist as for the artist.

The second point can be put equally briefly. In order to survive and to progress, mankind surely cannot ever know too much. Salvation can hardly be thought of as the reward for ignorance. Man has been given his mind in order that he may find out where he is, what he is, who he is, and how he may assume the responsibility for himself which is the only obligation incurred in gaining knowledge.

Indeed, it may well turn out that the technological advances in warfare have brought us to the point where society is at last compelled to curb the aggressions that in the past were condoned and even glorified. Organized warfare and genocide have been practiced throughout recorded history, but never until now have even the war lords openly expressed fear of war. In the search for the causes and prevention of aggression among nations, we shall, I am convinced, find scientific investigations to be a main source of understanding.

Ecological Disaster

A change in the average temperature of a pond or in the salinity of an ocean may shift the ecological balance and cause the death of a large number of plants and animals. The fifth prevalent image of science similarly holds that while neither science nor man may be inherently evil, the rise of science happened, as if by accident, to initiate an ecological change that now corrodes the only conceivable basis for a stable society. In the words of Jacques Maritain, the "deadly disease" science set off in society is "the denial of eternal truth and absolute values."

The main events leading to this state are usually presented as follows. The abandonment of geocentric astronomy implied the abandonment of the conception of the earth as the center of creation and of man as its ultimate purpose. Then purposive creation gave way to blind evolution. Space, time, and certainty were shown to have no absolute meaning. All a priori axioms were discovered to be merely arbitrary conveniences. Modern psychology and anthropology led to cultural relativism. Truth itself has been dissolved into probabilistic and indeterministic statements. Drawing upon analogy with the sciences, liberal philosophers have become increasingly relativistic, denying either the necessity or the possibility of postulating immutable verities, and so have undermined the old foundations of moral and social authority on which a stable society must be built.

It should be noted in passing that many applications of recent scientific concepts outside science merely reveal ignorance about science. For example, relativism in nonscientific fields is generally based on farfetched analogies. Relativity theory, of course, does not find that truth depends on the point of view of the observer but, on the contrary, reformulates the laws of physics so that they hold good for every observer, no matter how he moves or where he stands. Its central meaning is that the most valued truths in science are wholly independent of the point of view. Ignorance of science is also the only excuse for adopting rapid changes within science as models for antitraditional attitudes outside science. In reality, no field of thought is more conservative than science. Each change necessarily encompasses previous knowledge. Science grows like a tree, ring by ring. Einstein did not prove the work of Newton wrong; he provided a larger setting within which some contradictions and asymmetries in the earlier physics disappeared.

But the image of science as an ecological disaster can be subjected to a more severe critique (*9*). Regardless of science's part in the corrosion of absolute values, have those values really given us always a safe anchor? A priori absolutes abound all over the globe in completely contradictory varieties. Most of the horrors of history have been carried out under the banner of some absolutistic philosophy, from the Aztec mass sacrifices to the auto-da-fé of the Spanish Inquisition, from the massacre of the Huguenots to the Nazi gas chambers. It is far from clear that any society of the past did provide a meaningful and dignified life for more than a small fraction of its members. If, therefore, some of the new philosophies, inspired rightly or wrongly by science, point out that absolutes have a habit of changing in time and of contradicting one another, if they invite a re-examination of the bases of social authority and reject them when those bases prove false (as did the Colonists in this country), then one must not blame a relativistic philosophy for bringing out these faults. They were there all the time.

In the search for a new and sounder basis on which to build a stable world, science will be indispensable. We can hope to match the resources and structure of society to the needs and potentialities of people only if we know more about man. Already science has much to say that is valuable and important about human relationships and problems. From psychiatry to dietetics, from immunology to meteorology, from city planning to agricultural research, by far the largest part of our total scientific and technical effort today is concerned, indirectly or directly, with man —his needs, relationships, health, and comforts. Insofar as absolutes are to help guide mankind safely on the long and dangerous journey ahead, they surely should be at least strong enough to stand scrutiny against the background of developing factual knowledge.

Scientism

While the last four images implied a revulsion from science, scientism may be described as an addiction to science. Among the signs of scientism are the habit of dividing all thought into two categories, up-to-date scientific knowledge and nonsense; the view that the mathematical sciences and the large nuclear laboratory offer the only permissible models for successfully employing the mind or organizing effort; and the identification of science with technology, to which reference was made above.

One main source for this attitude is evidently the persuasive success of recent technical work. Another resides in the fact that we are passing through a period of revolutionary change in the nature of scientific activity—a change triggered by the perfecting and disseminating of the methods of basic research by teams of specialists with widely different training and interests. Twenty years ago the typical scientist worked alone or with a few students and colleagues. Today he usually belongs to a sizable group working under a contract with a substantial annual budget. In the research institute of one university more than 1500 scientists and technicians are grouped around a set of multimillion-dollar machines; the funds come from government agencies whose ultimate aim is national defense.

Everywhere the overlapping interests of basic research, industry, and the military establishment have been merged in a way that satisfies all three. Science has thereby become a large-scale operation with a potential for immediate and world-wide effects. The results are a splendid increase in knowledge, and also side effects that are analogous to those of sudden and rapid urbanization—a strain on communication facilities, the rise of an administrative bureaucracy, the depersonalization of some human relationships.

To a large degree, all this is unavoidable. The new scientific revolution will justify itself by the flow of new knowledge and of material benefits that will no doubt follow. The danger—and this is the point where scientism enters—is that the fascination with the *mechanism* of this successful enterprise may change the scientist himself and society around him. For example, the unorthodox, often withdrawn individual, on whom most great scientific advances have depended in the past, does not fit well into the new system. And society will be increasingly faced with the seductive urging of scientism to adopt generally what is regarded—often erroneously—as the pattern of organization of the new science. The crash program, the breakthrough pursuit, the megaton effect are becoming ruling ideas in complex fields such as education, where they may not be applicable.

Magic

Few nonscientists would suspect a hoax if it were suddenly announced that a stable chemical element lighter than hydrogen had been synthesized, or that a manned observation platform had been established at the surface of the sun. To most people it appears that science knows no inherent limitations. Thus, the seventh image depicts science as magic, and the scientist as wizard, *deus ex machina*, or oracle. The attitude toward the scientist on this plane ranges from terror to sentimental subservience, depending on what motives one ascribes to him.

Impotence of the Modern Intellectual

The prevalence of these false images is a main source of the alienation between the scientific and nonscientific elements in our culture, and therefore the failure of image is important business for all of us. Now to pin much of the blame on the insufficient instruction in science which the general student receives at all levels is quite justifiable. I have implied the need, and most people nowadays seem to come to this conclusion anyway. But this is not enough. We must consider the full implications of the discovery that not only the man in the street but almost all of our intellectual leaders today know at most very little about science. And here we come to the central point underlying the analysis made above: the chilling realization that our intellectuals, for the first time in history, are losing their hold of understanding upon the world.

The wrong images would be impossible were they not anchored in two kinds of ignorance. One kind is ignorance on the basic level, that of *facts*—what biology says about life, what chemistry and physics say about matter, what astronomy says about the development and structure of our galaxy, and so forth. The nonscientist realizes that the old common-sense foundations of thought about the world of nature have become obsolete during the last two generations. The ground is trembling under his feet; the simple interpretations of solidity, permanence, and reality have been washed away, and he is plunged into the nightmarish ocean of four-dimensional continua, probability amplitudes, indeterminacies, and so forth. He knows only two things about the basic conceptions of modern science: that he does not understand them, and that he is now so far separated from them that he will never find out what they mean.

On the second level of ignorance, the contemporary intellectual knows just as little of the way in which the main facts from the different sciences fit together in a picture of the world taken as a whole. He has had to leave behind him, one by one, those great syntheses which used to represent our intellectual and moral home—the world view of the book of Genesis, of Homer, of Dante, of Milton, of Goethe. In the mid-20th century he finds himself abandoned in a universe which is to him an unsolvable puzzle on either the factual or the philosophical level. Of all the bad effects of the separation of culture and scientific knowledge, this feeling of bewilderment and basic homelessness is the most terrifying. Here is the reason, it seems to me, for the ineffectiveness and self-denigration of our contemporary intellectuals. Nor are the scientists themselves protected from this fate, for it has always been, and must always be, the job of the humanist to construct and disseminate the meaningful total picture of the world.

To illustrate this point concretely we may examine a widely and properly respected work by a scholar who warmly understands both the science and the philosophy of the 16th and 17th centuries. The reader is carried along by his authority and enthusiasm. And then, suddenly, one encounters a passage unlike any other in the book, an anguished cry from the heart (*10*): "It was of the greatest consequence for succeeding thought that now the great Newton's authority was squarely behind that view of the cosmos which saw in man a puny, irrelevant spectator (so far as a being, wholly imprisoned in a dark room, can be called such) of the vast mathematical system whose

regular motions according to mechanical principles constituted the world of nature. The gloriously romantic universe of Dante and Milton, that set no bounds to the imagination of man as it played over space and time, had now been swept away. Space was identified with the realm of geometry, time with the continuity of number. The world that people had thought themselves living in—a world rich with colour and sound, redolent with fragrance, filled with gladness, love and beauty, speaking everywhere of purposive harmony and creative ideals—was crowded now into minute corners in the brains of scattered organic beings. The really important world outside was a world hard, cold, colorless, silent, and dead; a world of quantity, a world of mathematically computable motions in mechanical regularity. The world of qualities as immediately perceived by man became just a curious and quite minor effect of that infinite machine beyond. In Newton, the Cartesian metaphysics, ambiguously interpreted and stripped of its distinctive claim for serious philosophical consideration, finally overthrew Aristotelianism and became the predominant world-view of modern times."

For once, the curtain usually covering the dark fears modern science engenders is pulled away. This view of modern man as a puny, irrelevant spectator lost in a vast mathematical system —how far this is from the exaltation of man that Kepler found through scientific discovery: "Now man will at last measure the power of his mind on a true scale, and will realize that God, who founded everything in the world on the norm of quantity, also has endowed man with a mind which can comprehend these norms!" Was not the universe of Dante and Milton so powerful and "gloriously romantic" precisely because it incorporated, and thereby rendered meaningful, the contemporary scientific cosmology alongside the current moral and esthetic conceptions? Leaving aside the question of whether Dante's and Milton's contemporaries, by and large, were really living in a rich and fragrant world of gladness, love, and beauty, it is fair to speculate that if our new cosmos is felt to be cold, inglorious, and unromantic, it is not the new cosmology which is at fault but the absence of new Dantes and Miltons.

And yet, Burtt correctly reflects the present dilemma. What his outburst tells us, in starkest and simplest form, is this: By having let the intellectual remain in terrified ignorance of modern science, we have forced him into a position of tragic impotence; he is blindfold in a maze which he cannot traverse.

Once this is understood, the consequence also becomes plain. I find it remarkable that the intellectual today does not have even more distorted images and hostile responses with regard to science, that he has so far not turned much more fiercely against the source of apparent threats to his personal position and sanity (*11*)—in short, that the dissociation has not resulted in an even more severe cultural psychosis.

But this, I am convinced, is likely to be the result, for there is at present no countercyclical mechanism at work. Some other emergencies of a similar or related nature have been recognized and are being dealt with: We need more good scientists, and they are now being produced in greater numbers; we need more support for studies in humanities and social science, and the base of support is growing gratifyingly. We sorely need to give our young scientists more broad humanistic studies —and if I have not dwelled on this it is because, in principle, this can be done with existing programs and facilities; for the existing tools of study in the humanities, unlike the tools in science, are still in touch with our ordinary sensibilities. But hardly anything being done or planned now is adequate to deal with the far more serious problem, the cultural psychosis engendered by the separation of science and culture.

One may of course speculate as to how one could make science again a part of every intelligent man's educational equipment—not because science is more important than other fields, but because it is an important part of the whole jigsaw puzzle of knowledge. A plausible program would include sound and thorough work at every level of education—imaginative new programs and curricula; strengthened standards of achievement; extension of college work in science to comprise perhaps one-third of the total number of courses taken by the nonscience student, as used to be the rule in good colleges some 50 years ago; greater recognition of excellence; expansion of opportunity for adult education, including the presentation of factual and cultural aspects of science through the mass media. But while some efforts are being made here and there, few people have faced the real magnitude of the problem, aware of the large range and amount of scientific knowledge that is needed before one can "know science" in any sense at all. Moreover, while some time lag between new discoveries and their wider dissemination has always existed, the increase in degree of abstraction, and in tempo, of present-day science, coming precisely at a time of inadequate educational effort even by old standards, has begun to change the lag into a discontinuity.

This lapse, it must be repeated, is not the fault of the ordinary citizen; necessarily, he can only take his cue from the intellectuals—the scholars, writers, and teachers who deal professionally in ideas. It is among the latter that the crucial need lies. Every great age has been shaped by intellectuals of the stamp of Hobbes, Locke, Berkeley, Leibnitz, Voltaire, Montesquieu, Rousseau, Kant, Jefferson, and Franklin—all of whom would have been horrified by the proposition that cultivated men and women could dispense with a good grasp of the scientific aspect of the contemporary world picture. This tradition is broken; very few intellectuals are now able to act as informed mediators. Meanwhile, as science moves every day faster and further from the bases of ordinary understanding, the gulf grows, and any remedial action becomes more difficult and more unlikely.

To restore science to reciprocal contact with the concerns of most men—to bring science into an orbit about us instead of letting it escape from our intellectual tradition—that is the great challenge that intellectuals face today.

References and Notes

1. "Improving the Availability of Scientific and Technical Information in the United States," President's Science Advisory Committee Report (1958).
2. "Reviews of Data on Research and Development," *National Science Foundation Rept. No. 15* (1959); "Federal Funds for Science," *National Science Foundation Rept. No. 8* (1959).
3. *Naval Research Advisory Committee Report on Basic Research in the Navy* (1 June 1959), vol. 1, p. 29; *ibid.* vol. 2, p. 34.
4. *The Public Impact of Science in the Mass Media* (Univ. of Michigan, Ann Arbor, 1958).
5. There is evidence that these figures have been increased by a factor of perhaps 1.5 since the survey was conducted. See H. Krieghbaum, *Science* **129**, 1095 (1959).
6. Perhaps the most eloquent and influential voice among those who have recently addressed themselves to this problem is that of

C. P. Snow in the Rede Lecture, *The Two Cultures and the Scientific Revolution* (Cambridge Univ. Press, Cambridge and New York, 1959). I recommend his book, although with certain reservations. See also E. Ashby, *Technology and the Academics* (Macmillan, London, 1958) and F. Burkhardt, *Science and the Humanities* (Antioch Press, Yellow Springs, Ohio, 1959).

7. See, for example, the disturbing findings of M. Mead and R. Metraux, "Image of the scientist among high-school students," *Science* **126**, 384 (1957). I have presented the approach in this middle section in the "Adventures of the Mind" series, *Saturday Evening Post*, 9 January 1960.
8. It is, however, also appropriate to say here that there has been only a moderate success in persuading the average scientist of the proposition that the privilege of freely pursuing a field of knowledge having large-scale secondary effects imposes on him, in his capacity as citizen, a proportionately larger burden of civic responsibility.
9. See, for example, C. Frankel, *The Case for Modern Man* (Beacon, Boston, 1959).
10. E. A. Burtt, *The Metaphysical Foundations of Modern Science* (Doubleday, New York, ed. 2, 1932), pp. 238–239.
11. For a striking recent example see the virulent attack on modern science in the final chapter of Arthur Koestler's *The Sleepwalkers* (Macmillan, New York, 1959).

Science Reporting—Today and Tomorrow

It's better than you may realize, but improvements are needed—and here's how they're being achieved.

John Troan

In its report "Education for the Age of Science" (*1*), the President's Science Advisory Committee notes:

"A democratic citizenry today must understand science in order to have a wide and intelligent democratic participation in many national decisions.

"Such decisions are being made now. They cannot be postponed for 20 years while we are improving our present educational system so that its products will constitute a significant fraction of the mature voting population.

"There is, therefore, no escape from the urgency of providing high-grade and plentiful adult education in science now, planned for those who are unprepared even in the fundamentals."

The committee makes it clear it is not referring strictly to classroom instruction for adults. Indeed, it lays emphasis on the mass communications media—newspapers, magazines, books, radio and television—for, like it or not, this is how most Americans receive their "postgraduate education."

How well are these instruments of informal education playing their part in making the American public scientifically and technologically literate? They are doing much better than many scientists and engineers realize. Yet they are not doing as well as many editors, publishers, and producers believe. Certainly, both the quality and quantity of science reporting in the United States have improved during the past quarter century. But there remains much room for further improvement—and serious efforts are being devoted to this end.

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Growth of Science Writing

Twenty-five years ago there were only 12 full-fledged science writers in this country—men who spent all or most of their working hours reporting news of science and technology. Today, the National Association of Science Writers (NASW)—founded in 1934 by these 12 to "foster the dissemination of accurate information regarding science"—has 372 members who are principally engaged in this endeavor. They form the backbone of the "science reporting team" in the United States. They write for newspapers and magazines. They write books. They edit magazines, books, journals, and newspapers. They serve as science information officers for universities and colleges, government and private research institutions, industrial research laboratories, pharmaceutical manufacturers, voluntary health agencies, medical societies, and other professional organizations in various fields of science. They give lectures. They teach science journalism.

In the group are reporters who specialize in writing science news for 48 newspapers in 32 metropolitan areas—Albany (N.Y.), Atlanta, Baltimore, Boston, Buffalo, Chicago, Cleveland, Columbus, Dallas, Detroit, Fort Worth, Houston, Kansas City, Los Angeles, Memphis, Milwaukee, Minneapolis, Newark, New Orleans, New York, Oakland (Calif.), Phoenix, Pittsburgh, Portland (Ore.), Salt Lake City, San Bernardino (Calif.), San Diego, San Francisco, Syracuse, Toledo, Washington, and Winston-Salem (N.C.). Also in this group are science writers for six major news agencies which serve virtually every daily newspaper in the United States. In addition, there are 18 nationally distributed magazines and two book-publishing firms represented.

Together, these science writers could reach almost every adult American reader. Yet, in reality, they don't. One reason is the fierce competition for space in newspapers and magazines. After all, readers are not interested in science alone. They are interested also in politics, sports, business, labor, society news, neighborhood doings, accidents, crime. And they want to be entertained, too—with comics, crossword puzzles, novels, other features. Thus, much science news which is written fails to get into print. It is shucked aside in favor of other news items which are deemed to be more appealing to the readers. To the scientist, this may seem deplorable. But it is a fact that cannot be wished away.