The Educated Man in 1984

J. Bronowski

When we ask what today's education should do, the man we have it in mind to inform and to form is the man of 20 and 30 years hence. And for reasons that will become plain, the year 1984 carries a symbolism that our education ought particularly to keep in mind.

I

Education in schools and universities has many functions. I shall confine myself to two, both of them dominated by the skills that we need in order later to carry on adult life. Education as I shall discuss it is therefore learning to do something quite precise; and I shall not discuss those other general values that the child and the youth must also draw from his life at school and university.

I have said that the part of education that occupies my mind is the learning of something quite precise. Even so, however, there are different things to be learned—or better, there are different purposes for which we learn things. I want to distinguish between two purposes, which differ one from the other in their specificity.

The young man at night school learns bookkeeping in order to keep books. An engineering student learns the calculus in order to become an engineer. A historian learns Medieval Latin in order to read documents. I learned Italian in order to read papers in mathematics. These are examples of education for a very specific purpose, and since this purpose often helps us to earn our living, I think of this as vocational education.

But I knew a man once (he was a schoolmaster who had just retired from teaching mathematics) who learned Italian in order to read Dante. You will see that what he learned was indeed precise, and the purpose for which he learned it was specific. And yet I cannot feel that this was vocational education. The learner was not fitting himself for a task, as if he had been a literary critic by profession. He was fitting himself to derive from the work of Dante a larger, a deeper sense of the many-sidedness of human life than had reached and stirred him in translation. He was fitting himself, even at the age of 65, not to make a living but to live, and to take not merely his place but his share in human society.

This is the purpose for which we learn English and arithmetic and history at school. For these are subjects that do not stop at a single need, at writing letters and at making out bills. To read and write, to reckon, to remember the French Revolution, these are actions that penetrate all through the branching nexus, which underlie the whole fabric, of our society. Everything in these skills is precise, but it is not specific to one purpose; instead, it is part of a hundred arts and a thousand livelihoods. You cannot translate from the Russian unless you learn Russian, but you cannot contribute anything at all to English society unless you learn English. This is the purpose of an education in such subjects as English and arithmetic and history, without which no vocation is accessible to you. These subjects inform and hold together the fragments of society, so that they form and in a sense are its culture.

The subject of this article is science as part of culture, and a scientific education as a necessary part of our cultural education. This is a broad subject and I do not want to gloss over that. I do not want to pretend that it is something else; for example, that it is the more fashionable complaint that scientists themselves are uncultured. Yes, most scientists are uncultured; and so are most surgeons and administrators and Greek scholars and boards of directors and doctors of divinity; so, in short, are most men who are too busy to write letters to *The Times* in their own defense. I want more scientists to be cultured, literate, and human: I hope that I have shown that on other occasions. But I am not in the least impressed when I am lectured on the subject by bishops in the correspondence columns of newspapers, or by generals at school prize-days. When the pundits advise scientists to learn something more, they make it too plain that they find it easier to give good advice than to take it themselves.

Our society is indeed divided between the past and the future, and it will not reach a balanced and unified culture until the specialists in one field learn to share their language with those in another. The scientist has much to learn still, in language and thought, from the humane arts. But the scientist also has a share, a growing share, to contribute to culture, and humanism is doomed if it does not learn the living language and the springing thought of science. The bishops and the generals have some learning to do too: an enormous piece of learning if what they and I value is to survive, and society to become one. My subject is science as part of culture, and a scientific education as part of our cultural education, because for lack of these life-giving parts the ancient cultures are dying at the roots.

II

Here I am often stopped by those whose education and tastes are literary, because they find these claims puzzling. They know what culture is: it is Sophocles and Chaucer and Michelangelo and Mozart and the other figures round the base of the Albert Memorial. And they know what culture is not: it not laundry lists and sleeping-pills and the proved reserves of oil and the *Statistical Digest*. In short, culture is not a body of facts: but what is science but facts? How then, they ask, can science be a part of culture, and why should one learn science to become cultured? There is no scientist in the frieze of the Albert Memorial.

I have corrected this mistaken view of science a number of times, and particularly in my Carnegie lectures to the Massachusetts Institute of Technology. Therefore I will not stop to dispute it now except to say that it misses the very meaning of science; for science is not a set of facts but is a way of giving order, and therefore of giving unity and intelligibility, to the facts of nature.

But I do not need to discuss this large question at present, because the history of education shows that, whatever culture itself may be, the means by which we must teach it are always precise: as precise as my old schoolmaster learning Italian. When the Society for Establishment and Support of Sunday Schools was founded in 1785, it opened the path by which its teachers were to take the children into the Bible with the words: "Be diligent in teaching the children to read well." About the same time, the great dissenting academies (speaking through Joseph Priestley) held that all education must have for its end the pursuit of truth and the practice of virtue;

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and they taught both, as Oxford and Cambridge did not teach them, in a factual curriculum of logic and medicine and modern languages and mathematics and some science. Against this range of subjects, Lord Eldon long defended the culture of the old grammar schools; for example, in the famous case of the Leeds Grammar School in 1805; but even that dying culture was built, as Lord Eldon's judgment insisted, on two precise subjects, Latin and Greek. The founding of the University of London on the initiative taken by the poet Thomas Campbell in 1825, the changes at Oxford and Cambridge about the same time, the rise of the Red Brick Universities later in the century—all these are signs of a profound buckling and shifting of culture. But they are not vague signs, and the changes they made are not imponderable. They are precise changes in what was taught.

The fact is that the syllabus of schools and universities is always in movement from the first of the two educational modes that I am examining here to the second: from vocation to culture. No doubt reading was first taught at Dame Schools as a strictly useful skill; certainly Latin and Greek were first taught at grammar schools for clerical use; and arithmetic and technical drawing and debating were taught in the Mechanics' Institutes in order to help those who learned them to make their way in the world. I will remind you that the show of industrial drawings which the Society for the Encouragement of Arts, Manufactures, and Commerce held is one of the beginnings of the Royal Academy.

This example makes my point trenchantly. Some subjects in the syllabus remain vocational subjects; indeed, even their vocational use may shrink in time until, like spherical trigonometry and graphical statics, they shrink out of the syllabus. Other subjects turn out to have a wider range of uses; men find that, whether they are farmers or mechanics or bank clerks, they cannot do without them; and, above all, that they cannot do without them as members of society, whatever their profession. So in time these subjects cease to be the prerogative and the burden of specialists, and become general needs. English and arithmetic and history and now French have moved in this way, from the special to the universal, from the vocational subject to a place in our culture. This is the sense in which I have defined a cultural subject. And it is this sense, this movement, that is now patent in the growth of science in our society.

III

Science was once the concern of specialists, and now enters into the life of everyone. The switchboard and the motor car, the treatment of flour and of cigarette paper, the building of a crèche and of an atomic pile, are our daily concerns; by these we move and act and live. We simply cannot dissociate ourselves from the hot-water system and the air-mail and frozen food and the Linotype machine. A nation unskilled in these, a nation in which the screwdriver and the fuse-box are still handled with suspicion, is today a backward nation.

And this goes deeper than the mechanics of earning our living. When a society is penetrated, as ours is, by technical skills and engines, the decisions of state cannot be taken out of the context of science. You cannot as a voter advocate a policy on myxomatosis with any responsibility unless you have a general sense both of the ecology and of the economics of rabbits. You cannot ponder the decisions that we have to make on the development of atomic energy without some understanding, among other things, of how human inheritance works; you have no right to talk about war and peace, and to vote for rearmament or disarmament, without that. And no member of Parliament and no minister can make intelligent judgments on that most profound of contemporary issues, the secrecy that surrounds fundamental atomic research, until he is at home in the tradition of science since Giordano Bruno and Galileo.

The fate of a nation may hang on an error of judgment here. Let me give you a slightly mischievous example. In 1945, the British Government published (as a parallel to the American Government's Smyth Report) a White Paper on the wartime development of atomic energy. Among the documents in this White Paper is the directive by which Mr. Winston Churchill, as he then was, set up the project to make an atomic bomb. This directive begins with the words: "Although personally I am quite content with the existing explosives. . . ."

This bland phrase is a monument to a nonscientific education. Think what it would have implied in a dictatorship—in which, as the example of Germany shows, the dictator is surrounded by specialist advisers who are yes-men, and who are therefore bigoted and ignorant even in their specialty. In a dictatorship, Mr. Churchill's satisfaction with existing explosives would have been the end, not the beginning, of serious research toward an atomic bomb. The great man says that he personally is content with the existing state of science; who then would be strong enough to show discontent? I do not much care for atomic bombs myself, but still less do I care to have them judged in phrases like Mr. Churchill's. In 1941, they might have weighed life and death between this country and Germany; and what brought down the scales was not the wisdom of statesmen, but the democratic tradition which caused Mr. Churchill to waive his own unwisdom.

This example shows us succinctly what voters and statesmen do not know. I have called Mr. Churchill's astonishing phrase a monument to a nonscientific education. For it could have been written only by a man, an intelligent man, who simply does not understand how big a million is. The difference between atomic explosives and ordinary explosives is the difference between the length of a nuclear bond and a molecular bond; and this is a factor of more than a million. To suppose somehow that, in multiplying the energy of an explosive by a million, you are doing nothing very different from multiplying it by 2, or 5, or 10—this is simply not to grasp the scale of the world.

And the public does not grasp it. To say "ten to the sixth" to anybody today, however educated, is still to invite the reproof that one is stressing mere numerical detail. The nonscientist lacks such conceptions, and their lack cripples his judgment in the modern world.

Here we reach the nub of what we mean by a culture. Of course, we do not want members of Parliament to be atomic physicists or experts in virus diseases; I do not even want them to be mathematicians. Why should they be? They are not literary critics or historians. Yet, without being specialists, they know the difference between Milton and Kipling, and what sentiments each of these minds stands for. They know that Pitt and Napoleon were contemporaries and that, in the nature of things, the Industrial Revolution in England came before and not after the American Civil War. But in the field of science, the voters and those whom they elect have absorbed no such implicit knowledge. They have no framework into which to fit new information, no standards to test it by, and no vocabulary with which to handle it. If I were to say with enough solemnity that the stars must be very young because they are made of neurons and enzymes, no statesman would wink at me. Indeed, in Nazi Germany Himmler planned to found an institution to prove that the stars are made of ice.

IV

To make science familiar as a language, we must start in the schools. In England, a beginning has been made in the general science course in grammar and public schools. Yet this course still leans too far toward vocational detail, and is not bold enough in the belief that the concepts and principles of science are part of our culture. General science suffers, of course, from two handicaps: it has to be planned as part of the education of the scientist as well as of the nonscientist, and it has to be tied to the moderate and rather dull resources of

school laboratories. I accept these handicaps, but, even so, I want to fix our minds much more firmly on the lively nonscientist. What can I propose for him?

First, I want to propose less mathematics than he studies now, but of a more practical kind. That is, I want to change the stress from mathematical manipulation to the meaning of the sales tax and the twinning rate. The language of mathematics is still taught as a dead language, nearly all grammar. I want instead to teach more translation, from the everyday facts into mathematics and thence back into the everyday.

As one corollary, I believe that we need to make statistical methods part of the education of everyone in schools and universities: and this for two reasons. One is that only from statistics can the nonscientist learn to use averages and approximations with confidence, to be unafraid of dividing the national debt or the German battle losses by the population, and to know in his bones the difference between a million and ten. The other is that modern mathematical statistics is a new view of science, which I believe will transform it and will replace the mechanisms of Newton by the more subtle concepts of modern physics.

There is another way in which I want to see the teaching of mathematics changed. I think we should be less preoccupied with number and quantity and more with relations of order and arrangement. This vision of the world by shape and structure is, I think, characteristic of the newer sciences, and the mathematics teacher can help to make it familiar.

I am thus brought to my second group of proposals, which concern physics and chemistry. Here I think that we should make the atomic picture central to the teaching of both subjects much earlier than we do. There is no need to wait until the chemistry student gets to organic compounds, or the physics student to crystal structure. These pictures of the way atoms are assembled can be made real and exciting to the nonscientist, whose visual sense is often much stronger than his gift for handling either concepts or symbols.

And I think the nonscientist can in the same way be inspired by the outlook of statistical mechanics, much more than by doing Boyle's law with a piece of barometer tubing. This is really the strength of the atomic model for the nonscientist, that it lends itself both to geometrical and to statistical thinking; and I should like to see it fully used for both.

My third plea is for more biological teaching than we have now. There is a wealth of natural material and natural interest in plants and insects and the animal processes, which somehow we allow to wither in the grammar school. And as in the other things that I have underlined, it has both a geometrical side, for example, in plant structure, and a statistical side, for example, in animal genetics.

But more than this, I have the sense that biology offers us a path into scientific thinking by way of the pleasures of collecting and of skill of hand. Liking to collect, to observe, to draw, to take apart and to put together—this is how many children and adults of little other education find their way into the arts. And I feel that there is a way through these also into the sciences: a way that is valuable exactly because it makes art and science one, as Leonardo da Vinci and Andreas Vesalius did.

Fourth, I think we need to teach science, even at school, not as a collection but as an evolution of knowledge. I think this important for three reasons. Because it sees science as a historical development, it offers links with history and literature and geography that can give help and a vivid perspective to the nonscientist. Because it presents science as changing, questioning, and argumentative, it can teach the methods of rational debate to everyone in the classroom, and this can be a lifelong lesson. But most important, the evolution of science goes to the heart of the scientific method: for it shows at each step how the logical deduction from what seems to lie behind the known facts must be confronted with experience. We make an induction, we put the deductions from it to test, and on the results of the test we base a new induction. This to and fro between the logical and the empirical is the core of the scientific method, which nonscientists never seize because they do not see science as a progress.

To these four general points I will add a fifth. It is that every boy and girl, every undergraduate, should do one small piece of personal scientific research. It need not be a pompous project, with much search among reference books and writing to distinguished strangers. It can be as simple as the pitch of an insect's wing-beat, or the composition of a rock, or growing a crystal. What is needed is that it should take a little time, a little reading, and more thinking, and that it should be done alone. I believe that this small practical experience could change the light in which nonscientists see the long and unsung vigils of the solitary research worker.

V

I do not want at the moment to open the practical questions that these proposals raise. For example, if we put what I suggest into the syllabus, then we shall have to take something out. What is it to be? What can we sacrifice in the rich distillate of human knowledge—and in the ancient and forbidding history of human error? I have, of course, thought about this, and I hope at another time to discuss it; but now is not the time. For if I were to discuss now the merits of rival subjects in the syllabus, we should at once lose the sense of the urgency of what I propose.

And it is urgent. Science must become as a subject part of our culture, or we shall fail, not to train scientists, but to preserve our culture. This is the danger that the letters to *The Times* and the prize-day speeches miss. They speak as if we need do no more than give a little grace and dignity to a few uncouth scientists. But the scientists are inheriting, they are conquering the earth, and if you do not speak their uncouth language, then you will sink to the status of the native yokels when the Normans overran England.

I have called my article "The educated man in 1984" in order to warn of this danger. It is certain that the educated man in 1984 will speak the language of science. This is not at issue. The issue is something else. Will the educated man in 1984 be a specialist, a scientist or technician with no other interests, who will run his fellowmen by the mean and brutal processes of efficiency of George Orwell's book? Or will he be a statesman, an administrator, a humanist who is at home in the methods of science, but who does not regard them as mere tools to efficiency? The choice between 1984 and an earthly paradise does not depend on the scientists but on the people for whom they work. And we are all the people for whom science works.

H. G. Wells used to write stories in which tall, elegant engineers administered with perfect justice a society in which other people had nothing to do except to be happy: the Houyhnhnms administering the Yahoos. Wells used to think this a very fine world: but it was only 1984 or Aldous Huxley's *Brave New World*. A world run by specialists for the ignorant is, and will be, a slave world. A man of taste who sneers at machines, a housemaster with his eye on the preponderance of university scholarships in classics, a civil servant who still affects to despise science, is abdicating his share of the future and walking with open eyes toward slavery. By leaving science to be the vocation of specialists, they are betraying democracy so that it must shrink to what it became in the decline of Athens, when a minority of educated men (who had to be paid to make a quorum) governed 300,000 slaves. There is only one way to head off such disaster, and that is to make the educated man universal in 1984. This is the force of my argument here, to make the language of science part of the education, the cultural education, of the young who will have either to make or to suffer 1984.