Science and Human Nature*

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THREE hundred years ago a scientific society used to meet in Oxford every week in the rooms of Dr. Wilkins of Wadham College. It was the first of its kind in our country and it had what we should now call an escapist motive. Fifty years before Francis Bacon had published his great plan for a new road to knowledge, by concerted observation and experiment, and Harvey soon after had made the experiments which proved the circulation of the blood. But then the country had been torn by civil war. It had killed its King and could not see how to reach settled government. Dr. Wilkins had collected a band of scholars of inquiring mind, Boyle, Wren, Willis and others whose names are now part of the history of science, and they met together to take what comfort they could in the new kind of knowledge which could be confirmed by experiment instead of the appeal to authority. "Their first purpose was no more than only the satisfaction of breathing a freer air and of conversing in quiet with one another without being engaged in the passions and madness of that dismal age."

So it was here that the scientific age was conceived in England, with the conflicting loyalties of the Commonwealth as a background, and I can admit Oxford's claim the more cheerfully because Dr. Wilkins moved to Cambridge and was for a short time Master of Trinity College, just before Isaac Newton came there as a young undergraduate.

When the King came to his own again the temper of opinion changed. There were great prospects ahead. The philosophers moved to London convinced that their inquiries would lead to material prosperity as well as to deeper knowledge. They founded The Royal Society and Isaac Newton's *Principia* established the mechanical order of the world. The material progress followed more slowly, but 100 years after Newton's death it had already begun to affect the lives of half the people in this country. Scientists as usual were in no doubt about the value of what they were doing and they felt it was high time to share their faith and some of their responsibilities.

In 1831, therefore, the British Association was founded for the Advancement of Science, and at the annual meeting our leading scientists assembled in one big town after another to spread the news of this fresh source of knowledge and of material advance; and the Association has gone round ever since on much the same errand, announcing new discoveries and airing controversies before an audience which has grown steadily in size and in its understanding of what the scientists are about.

But now the products of science are everywhere. Knowledge of the material world is constantly growing and its consequences are of such a spectacular nature that everyone is aware of them: few people now can doubt that the scientist's picture of the world must have some validity if it enables him to deliver such remarkable goods. So it has come about that the advancement of science is in everyone's mind. Why then are we here today? What is there left for the British Association to do if it can only preach to the converted?

For scientists it can do a great deal. We are all specialists nowadays and here we can learn what is happening in fields outside our own, but it is true that these meetings must lack some of the appeal that they had when the whole territory of science was so much smaller. Progress is too rapid for the new discoveries to be saved up as a birthday present and controversies have become too technical to be aired in the market place. Yet there is one very great and worthy task which needs the help of a body like ours which brings scientists and laymen together. The Association must show the layman where the scientific age is leading him. It is by its impact on public opinion that the success of these meetings must be judged.

No meeting of the Association at Oxford could pass without reference to that famous occasion when its impact on public opinion was highest, when it was made quite clear that the pursuit of natural science would mean a painful revision of beliefs as well as a gain of material comfort, when it claimed acceptance for the theory that denied the special creation of mankind.

It was in 1860, the year after the publication of Darwin's book on *The Origin of Species*. Bishop Wilberforce was to speak and Huxley was Darwin's champion. The audience was too large for the lecture room and they moved to the long west room of the Museum, but the first paper was dull, it was on "The intellectual development of Europe considered with reference to the views of Mr. Darwin," and after an hour of it the audience was restless and wanted something more dramatic. They had it from the Bishop, who spoke with eloquence and wit against the idea that man and the monkey could have a common ancestor. He ended with an ill-conceived joke about Huxley's claim that he was descended from the apes, but he sat down to general acclamation and the fluttering handkerchiefs waved by the ladies. Huxley had

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a more harshly colored picture to present, the aim of life was merely to go on living, the road to progress was by the slaughter of the weak and the survival of the strong and man was cousin to senseless brutes. The scientists were demanding that the search must go on, that the evidence must be followed wherever it led, but until then it had not led to anything quite so bleak.

All this was no doubt implicit in Huxley's speech, but the audience at the British Association is human and what really stirred them was Huxley's grand indignation at the idea of a bishop condescending to such a paltry joke on so high a theme. His scorn forced the excitement to such a pitch that one lady fainted and had to be carried out, and afterwards no one, not even Huxley, could remember exactly what he had said. It did not matter so much, for the chief issue was no longer the origin of species but whether the Bishop had really been guilty of a breach of good manners. But the dispute had been on the scientific plane and the evidence could not be ruled out because it was unpalatable: within a few years the battle for Darwin's theory was won and it seemed that the discoveries of science had forced the human race to give up beliefs on which it had relied for centuries.

Naturally the change came gradually, bringing discord into a good many families where the rising generation were zealous converts to the new creed. But now the scars are mostly healed. Advancing understanding of what was really at stake has made it possible for both sides to keep their ideals. The theory of evolution has lost its power to arouse passionate resentment or passionate faith.

I have mentioned that meeting for two reasons: because it emphasized that man himself was part of the natural world and because it emphasized also his right, at all events his determination to go on searching for knowledge, for without his curiosity he would be nothing.

We all know where our curiosity has now landed us; with advances in atomic physics which might be applied to devastate half the world and if they were so applied would certainly make life in the other half extremely precarious. Our grandfathers here were faced with scientific discoveries which were no laughing matter, for to many of them they spelled the end of all worthy human aims, but we face discoveries which might spell the end of all human aims, worthy or not.

We can regret that atomic bombs are possible without regretting the discoveries that have led to them. Advances in natural science cannot avoid advancing the methods of warfare; they do so when they make armies more healthy as well as when they increase the power of their weapons. But although the strategists have to think mainly of immense explosions and great devastation, it would be a mistake to suppose that these are the only dangers. Even if we can survive then we must face the possibility that repeated atomic explosions will lead to a degree of general radioactivity which no one can tolerate or escape.

The level would not rise rapidly and there is a large margin in hand but the physicists can estimate the persistent contamination which must follow an atomic explosion of a given magnitude and the biologists can assign limits to the amount of contamination which could be let loose on the world without serious danger to every part of it. When atomic energy is used to supply power for industry the dangers of contamination are real enough, but due precautions can be taken to avoid them. In a major war they would soon be set aside. Powerful nations who think they could win quickly might accept the risk. A few hundred large bombs would not raise the level of radiation to the point where it would become a general danger, and no doubt a country of small area like ours could be reduced to ashes by a relatively small mass of explosion. Though the ashes would be deadly, the rest of the world might escape them. But a long war between powers well armed with bombs would certainly produce an order of radioactive contamination which would involve us all, victors as well as vanquished.

Arguments that war does not pay will not count much when ideals are threatened. It is true that a war which would probably end in wholesale destruction can appeal only to people who are desperate, but they can be made desperate and that is the end we have to guard against. There are conceivable safeguards, of course, but controls and conventions are not foolproof, and in future whenever the world is split into two opposing groups with large stores of atomic weapons it must face this added risk of catastrophe.

Yet we have surely no right to feel that our predicament is so much worse than that of earlier generations. Our grandfathers could do nothing to ward off the danger which seemed to face their cherished beliefs, but our fate is in our own hands. We are afraid, and rightly, because we cannot trust ourselves to act peaceably, because we know that unless we are ready to give up some of our old loyalties we may be forced into a fight which might end the human race. Our predicament is the inevitable result of our curiosity and of the physical nature of the world we live in, but if we can make our behavior worthy of our increased knowledge we can live safely. The scientist, therefore, has a double responsibility. He must apply his science to learn as much as possible about the mental and physical causes which make us behave as we do, he must study human nature to prevent its failures; but he cannot wait for the discoveries which might make us act more wisely: he must take us as we are and make it his task at meetings like this to point out that the human race cannot stand more than a few thousand large atomic explosions whether they hit their target or miss it. If we can make this known universally, our Association will not have failed in its purpose.

It may be optimistic to think that our dangers would recede if we had a better understanding of human reactions: in fact if we must continue to make war there is no kind of scientific investigation which might not be used to make it more effective and there can be no

guarantee that discoveries in the field of human conduct would be harmless. A drug or a system of education which would make us all do as we are told, a method of producing radical conversion to a new system of belief, a knowledge of new ways of rousing patriotic ardor, all these might be used with consequences almost as grim as the genetical deterioration in a radioactive world. The psychiatrist who discovers a cure for paranoia may find that he has also revealed a convenient way of producing it.

Our novelists have made us aware of these dangers, but it is some comfort to feel that in this case the increased knowledge could be used for defense as well as attack. We can only be protected from radioactivity by living in caves on uncontaminated food and drink, but an increased knowledge of how the mind can be influenced could certainly forestall many of the influences which might be used to undermine our integrity.

It is certainly true that discoveries relating to our own nature may mean a painful readjustment of our beliefs: that, however, is a fair price for increased understanding and in fact our ideas about our own behavior have already been assailed in such a way that further revelations are unlikely to shock us. There is a fairly close parallel between the impact of the theory of natural selection 100 years ago and that of Freud's theories on our own generation. The British Association does not come into it, because Freud's evidence was all on the medical side, but his views made the same kind of attack on our pride and met with the same passionate resentment or approval. The theory of unconscious forces molding our thought has certainly diminished our stature as intelligent beings; yet the parallel still holds, for again we have recovered our equanimity. We are reconciled to the unconscious, though we may not have digested all the elaborations of psychoanalytic theory. We are no doubt less sure of ourselves, inclined to spare the rod and to put nothing in its place, but, on the whole, Freud has left us with a better understanding of human conduct and we are not downhearted at finding it less rational than we used to suppose.

Freud would have liked to build up a system based on the physiology of the brain, but he was soon too deeply committed to the psychological side. Pavlov's conception of human behavior was based on brain physiology and it was less disturbing because it did not go into such uncomfortable detail. It is now perhaps more disturbing than Freud's, because Pavlov's notion of the conditioned reflex has come to dominate one side of the world, but we must not think the less of it because it has been used to justify a political system foreign to ours. Pavlov and Freud were both scientists of surprising originality. They gave a new impetus to research on human activity, but the fields they explored are still waiting for the next advance to show how much they will yield.

The difficulty is that there are so many fields of inquiry to cover, each with its own limited range of facts and deductions. Freud studied dreams and neuroses and explained them as the product of repressed desires. Pavlov studied learning in animals and explained it in terms of conditioned reflexes, but physiologists ever since Galvani have studied the reactions of the nerve fibers and nerve cells, the units of the nervous system, in the hope of explaining what they do in the terms of physics and chemistry. This approach at the lowest level can tell us little about the way in which units are organized, but when we keep to physical and chemical problems we are in the familiar territory of the exact sciences, we know how experiments should be conducted and there are great technical advances at our disposal. It is when we begin to think of organisms rather than molecules that we seem to part company with mechanism.

At this end of the scale then our actions are found to depend on the vast mass of cellular material which makes up the nervous system, receiving signals about the outside world from the sense organs and sending out signals to the muscles to produce the complex movements of intelligent behavior. The nervous signals can be recorded and analyzed because they are revealed by brief electrical effects and we are rapidly gaining a fairly clear picture of the energy transformations which make them possible (and incidentally we should never have gone so far if there had been no radioactive sodium and potassium for tracing ionic movements).

The sensory inflow brings information about the events taking place outside us and progress reports to show how successfully we are dealing with them; signals from the muscles are needed to adjust the simplest movements and we are handicapped if we cannot hear what we are saying and cannot watch our step. But the great central mass of nerve cells has to fabricate a radically different pattern of messages to send out to the muscles and it is a pattern which depends on past as well as present information, on what happened to us a year ago as well as on what is happening now. Unfortunately, it is a great deal easier to study the immediate reactions of the nervous system than the more persistent changes which alter its habits and give us our memories. We know next to nothing about the plasticity which is the most important feature of the brain and that is the next hurdle for the biophysicists and biochemists.

But we do know that the cells of the brain do not behave as passive agents for conducting and combining the signals that reach them. As long as we are awake many of them are in continuous rhythmic activity. The system has its own reserves of energy and is unstable, at all events it is so constituted that a slight disturbance of equilibrium will start up a cycle of discharge and recovery repeated many times a second and extended through much of its substance. It is no great surprise to find that we are driven to our daily activity by a cell system of this kind with energy to be dissipated, but we are now learning something about the interplay of the different parts of the system. It is found, for instance, that a relatively small collection of cells at the base of the brain has a pro-

found effect on the general level of activity, so that we are aroused when it is stimulated and fall into coma if it is injured. We can see too how the chief focus of disturbance shifts from one region of the cerebrum to another when we transfer our attention. In fact we are beginning to trace a closer connection between what is going on in the different parts of the brain and what we happen to be doing from moment to moment. For what it is worth we can see a physical reason for our restless lives and our insatiable curiosity.

One may well feel that the most detailed knowledge of brain physiology will never help us much in our efforts to live peaceably, but it would be rash to prophesy. Certainly there are people now who lead more placid, if perhaps less useful lives, because their anxieties have been diminished by leucotomy, an operation on the frontal lobes of the brain. And long before the advent of leucotomy we had become accustomed to adjusting the activity of our nervous system by chemical agents. Tea and coffee, alcohol, and tobacco are the stimulants and sedatives of the prescientific age and now, to quote the preacher, there is no end to the works of the apothecary, and we seem to be much less afraid of using the confections he gives us to take away our pains.

Only the writers of science fiction would suggest a future in which the problems of civilization will be dealt with by tampering with the brains of some or all of mankind. It will help us a little to settle our differences if we have the means of ensuring a clear head and an even temper after a long journey and a resetting of the daily rhythm, but clearly we must look beyond physiology for an adequate picture of the human brain in action. Though it should start at the molecular or the cellular level, the evidence for it must include the activities of the finished product. We must find out what human behavior is like before we try to explain how it is produced.

We do know, of course, an immense deal about human behavior, from our own experience and from the accumulated wisdom of the past, but it is only in recent times that we have tried to check our knowledge by the methods of natural science. The development of physical science dates from the time when direct observation and experiment were accepted as better guides than the principles which had seemed self-evident to the philosophers and the schoolmen. They were wise enough but it was found that they could be mistaken. And so now we can look to the many branches of social science to make a dispassionate study of what actually happens in our society without regard to what might be expected to happen if we are to believe all we have been taught.

The picture of human behavior which the social scientist has to draw is of a system in which the units are men and women rather than cells or molecules. It is true that one man behaves very differently from another—it is part of our political creed that they must be allowed, within limits, to differ as much as they like. But, although we can insist that the units are not all alike, the general principles which determine their behavior ought to stand out when we deal with millions rather than individuals.

There is, in fact, one branch of social science which can adopt this plan without difficulty. This is the science of economics which considers only the human activities of producing and consuming and studies the way in which these activities are to be balanced. When the balance is lost, credit and currencies fail and we may blame the economists for the plight we are in, but the status of their science is unquestioned, and no one would dream of saying that our complex civilization could have done as well without them.

It must be admitted, however, that the strength of economic theories rests very largely on the fact that they can be worked out with very little regard to human nature. Men must be assumed to be capable of trading with one another and they must have a variety of skills and needs and possessions, but that is all, or nearly all, that the economist has to consider. Few of the many branches of social science can proceed on such a simple basis, and it is because of this that the subject as a whole has still to win full recognition in this country where the science of economics is so firmly established.

Theories describing or explaining other kinds of social activity are nothing new, they existed long before the theories of economics; but the economists have had the figures to check their conclusions and until recently the sociologists have had little but their own philosophy and their own reading of history. Even Durkheim, who broke away from the philosophic tradition, could only point the way to a truly objective study of human society. Now the position is quite different. A century and a half ago it had only just been decided that the population of this country was on the increase. Many had thought that might be so but there were no figures to show whether they were right or wrong. Now there are all the modern techniques for fact finding, the questionnaires, the punched cards, the sorting machines, and the statistical methods. It is far easier now to deal with large groups and the psychologists have far more knowledge of the irrational factors which can sway the smaller groups as well as the family and the individual. The stage seems to be set for the new development and it might well be the most important scientific development of this century. Why are we still so reluctant to think well of it?

The answer, I suppose, is that we are not yet convinced that the kind of observations that the social scientist can make will be sufficiently objective and sufficiently precise. Those of us who work in laboratories have a far easier task in selecting what we should observe, yet we know how difficult it is for us to select and observe fairly. We have to school ourselves not to reject the exceptional result as worthless when it does not fit a cherished theory: we have to be continually aware of our own fallibility even though we have all the figures and controls to keep us straight. We are loath to believe that the social scientists are more open-minded than we are and the material they

have to deal with seems to need an almost superhuman open-mindedness combined with an almost superhuman power of selection, of seeing the wood as well as the trees in it. We feel that we should be lost in such a wood where everyone must feel the bias of his own upbringing and social ties, where there is so much that cannot be measured and may or may not be relevant and where there is rarely any opportunity to check the conclusions by experiment.

Our distrust is probably intensified by the layman's tendency to speak of experiments in the social field as though they were comparable with the experiments which obey all the exacting rules of the laboratory. There we can at least hope to proceed by changing one factor at a time. The social scientist would be the last to cherish any such hope: his whole training warns him of the complexity of any situation where human beings are involved. But many people seem to think that if something in the social field is done in a new and usually more expensive way we have only to call it an experiment to justify the conclusions we wish to draw. Certainly we must try new methods and hope to find out why they succeed or fail, but although a new way to check juvenile delinquency or to develop a housing estate may give the most favorable results, it is very seldom an experiment from which one can infer the precise factors that have made for its success. A change in the birth rate, a wet summer, or a newspaper campaign are the kind of disturbing element which would be too obvious to mention were it not that everyone who has worked in a laboratory must be aware of having overlooked disturbing factors which should have been just as obvious. We were lucky if our control experiments saved us from exposing our folly, but controls are far easier in the laboratory than in the world outside.

This is a minor grudge. If we harbor it we shall be visiting the sins of the enthusiast on the very people who exist to keep them in check and we must surely welcome any new branch of study which tries to substitute the methods of natural science for unchecked speculation. It is very easy for us to forget our own rules when we allow our feelings to take charge, to say that a result was too obvious to be worth the proof if we happen to like it and if we dislike it to say that statistics can be made to prove anything. Perhaps we have forgotten how much we distrusted some new development near to our own field of science because it was unfamiliar and because we thought its backers claimed too much for it. We ought to remember that the now flourishing science of biochemistry was once distrusted by chemists as well as physiologists. It is human nature for the guild of natural scientists to delay admitting a new member till he has paid his dues and satisfied the examiners of his competence in the craft.

At present there are many kinds of investigation grouped under the umbrella of social science: the groups seem to have little in common and few of them can put their results into figures, but I think all of us, scientists and laymen alike, are becoming more aware of the value of social investigation and of the degree of certainty it can bring. We may have distrusted the army psychologists who classed us by our aptitudes, we may have read the Kinsey report from unscientific motives, and we may continue to allow the accident prone to drive their cars. We can see nonetheless that there are facts to be found out about our usefulness in society, about our relations to one another, and about the risks we take. We can see too that the search for these facts can be conducted on reasonably scientific lines. It is too early to be cautious in spending money on large-scale investigations. They are bound to be costly, but those of the social scientist deserve not only the support of national and international funds. There is this kind of support for the subject already, but it is too important a plant to be left in the hot-house atmosphere of research institutes and Unesco teams. It deserves to be in full contact with all the conservative and academic people in universities, the lawyers and historians as well as the economists, biologists, and statisticians. There must be more social scientists in our universities so that the rising generation can see what they are like.

I have put in this plea for a subject about which I know so little because it seems to be developing more rapidly in other countries, particularly in the United States. We are handicapped, no doubt, by smaller resources and perhaps by the remains of a national temperament which has made us prefer to work by ourselves and not as members of a large team. We ought not to expect too much. Social scientists like economists may be able to foretell the consequences which are likely to follow in a particular situation, but the statesman who goes to consult them may come away with little to comfort him and may turn to the quack doctor in the next street. We may find out a great deal about the tensions which lead to war without seeing the way to keep ourselves clear of it.

But human beings, when we consider them as material for the biologist, are not to be thought of as incapable of improvement. Other kinds of animals have been found to possess unexpected power of communicating with one another, but we are the one kind endowed with a brain which gives us the power of communicating by putting our impressions into words and appreciating the meaning of the words we hear. Speech would be little use to us unless we could remember what it meant, but memory, the ability to learn, is a property of the simplest kinds of nervous system. We alone possess a nervous system which gives us the power to order our ideas in words. We alone have this way of thought which allows us to compare a new problem with an old one.

With this unique equipment for thinking and communicating, we can form our habits not only from what happens to us personally but from what happens to our fellows and from what has happened to countless generations in the past. And although the storage capacity of a single human brain is limited we have learned to make permanent records of what has occurred, in visible symbols, so that what cannot

be remembered can be found in a book. In this scientific era our store of knowledge is growing so fast that we shall soon need new ways to keep it available. Books have done duty for a thousand years and we should be sorry to lose them, but we can change our habits rapidly and it is already old-fashioned to write a letter with a pen.

This increasing background of experience has meant that we are constantly acquiring new habits and new ways of thought. It does not take us very long to see the way round old quarrels. Darwin and Freud no longer trouble us. We are no doubt born with brains like those of our remote ancestors and when we are grown up we have no more native intelligence than they had, but our brains must have been so modified by what we have learned that they are physically and chemically different, better adapted for the complex social life of our time. We have more knowledge at our disposal. If all goes well with our training, the brains we have ought to be more civilized than those of our fathers and those of the next generation more civilized than ours.

I have claimed that the scientific investigation of mankind can help the process of civilization by finding the weak points in our equipment and suggesting remedies, but these scientific activities will play only a limited part in the development of human society in the scientific age. The power we have acquired over the forces of nature has made it possible to increase our mental training as well as our standard of comfort. Of the two or three thousand million people in the world perhaps not more than five million are receiving a full university training though no doubt more are trained in a narrow technology. Yet the number has risen steeply in spite of wars, perhaps even because of them, and it continues to rise. In the United Kingdom we have 85,000 students at our universities, about 1 in 30 of the whole age group, and that may be all we should contemplate with our present system. A few years ago, however, it was only 1 in 60, and there must be many parts of the world where the university, as we know it, is only now beginning to play its part in civilizing the most intelligent citizens. This could never have happened without all the scientific inventions which have been blamed for our troubles, the improved transport, the cheap printing, the electricity, and the internal-combustion engine. And a university training would have been far less civilizing if it had never left the old authoritarian pattern which roused Huxley to speak in Oxford nearly 100 years ago.

University students, however intelligent, are not usually considered to be the most peaceful members of the community. They have been more welcome in small country towns than in the capitals where they can join revolts against the government of the day, and they tend wherever they are to be critical of those in authority. Long may students remain so. If they were not, if they believed all they read in an officially inspired press, or even what they were taught by unrestrained professors of the greatest integrity, there would be little chance of their learning how to use their knowledge for solving the new problems of our time. The plodding methods of the laboratory and the card index must be there to check their enthusiasm and to show them how the problems have come about. Even if they get no help from that it is something to know that there are many more people in the world today with brains trained better to deal with their environment by learning how its problems have been dealt with in the past.

Our Association is concerned with the advance of natural science. It began when we had little control over the forces of nature and we have now so much control that we might soon become able to destroy two-thirds of the world by pressing a button. Yet the control which has been achieved by science has made it possible for us to improve our own natures by more education in the arts of civilized life. We may perhaps improve ourselves more rapidly if we can gain more insight into human behavior. That is something which the Association can encourage, but it is only a small part of what it must do. It must not cease to encourage every kind of scientific inquiry, for it is human nature to inquire, to learn by experience, and to profit by what it finds out.

An Explanation of the Lake Michigan Wave of 26 June 1954

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THIS paper (*1*) proposes that the unusually high velocity of about 66 mi/hr with which an atmospheric disturbance crossed Lake Michigan on 26 June 1954 was responsible for the disastrous wave that occurred.

On the morning of 26 June about 9:30 CDT an abrupt increase in the level of Lake Michigan occurred along the water front in the vicinity of Chicago, at the southwestern corner of the lake. At least seven lives were lost in the Chicago area as a