SCIENCE AND HUMAN WELFARE

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In recent years there has been a world-wide —and at times over-emotional— awakening to the dangers of such matters as pollution and destruction of our environment, of indiscriminate use of drugs and of biological warfare, to mention but a few. Now it is, of course, true that many of these dangers originate in the misuse of the careless use of scientific and technological advances, but it seems to be forgotten by many that man is responsible for that misuse and not science itself. Whether the forgetting is deliberate or accidental is beside the point; the fact is that there have recently been clear signs of a kind of anti-science attitude developing among the general public and, most regrettably perhaps, among some of its younger members. It is interesting to look back just a quarter of a century to the end of the Second World War. The discovery and rapid development of revolutionary new materials and techniques from radar to penicillin and their harnessing of the needs of total war had culminated in the explosion of the atomic bomb which brought hostilities to an abrupt close. Even if the use of the atomic bomb in war did pose some disturbing moral questions there is no doubt that the vista it opened of unlimited nuclear power was the thing that caught man's imagination. In those days we needed no convincing —science and technology could solve all our problems and if we only made the effort the millennium was just around the corner. So the cry went up —we must have more scientists and technologists and let them have all the facilities they need; thus and only thus can states survive and their citizens achieve and maintain happiness and a high standard of living. Well, it hasn't quite worked out like that; science and technology have done prodigious things— we enjoy the benefits of nuclear power, we have further lessened the ravages of disease and increased our expectation of life and nowadays we can even go to the moon. But as regards human happiness we don't seem to have done so well and now we see this anti-science attitude appearing and with it even demands for a moratorium on research. Even in the highly developed countries these demands

have some attraction for governments under economic presures and there are signs today of a diminution in the support given to science and in the encouragement given to young people to follow it as a career. Now, I am convinced that this is utterly wrong and that those aspects of our present civilisation which cause distress can only be put right by the proper use of science and technology; it is indeed more rather than less research that is needed. Before elaborating on this belief, however, it is, I think, desirable that I should give you my view of the relation between science and society and how that relation has developed.

Man differs from all other animal species in that he can and does seek consciously to alter his natural environment for his own benefit. This he has done from the time his forebears abandoned their arboreal habitat for the more perilous plains and became hunters. Every step forward was the result of a technological advance. Technology is simply the application of discovery or invention to practical ends. There is nothing new about it —it is as old as man himself; moreover, it need not have anything to do with science and, indeed, it had very little to do with it until the middle of the last century. Until then technological advance or innovation depended for the most part on chance discovery or invention and on the fortuitous presence of some entrepreneur (not necessarily the inventor) who would put an invention to practical use. When we look at the modern world it is perhaps too easy to think that major technological advances are very recent. But this is not so; the introduction of agriculture, for example, was a technological innovation fraught with at least as many consequences for man as the harnessing of nuclear energy. Nevertheless as long as progress depended on chance discovery or invention it was necessarily slow and erratic. Another reason for slow progress is to be found in the inadequacy and slowness of methods of transport and communication which prevented the rapid spread of new technology on a world-wide scale. It is, of course, true that poor communications were not without advantages; not all technological advances are successful or even desirable and no doubt on many occasions in the past man was able to discard undesirable advances before they coul do damage on any but a very local scale.

Despite his constant efforts to modify his environment man, in common with all other animals, is essentially conservative and he seeks to avoid changes which will radically alter the pattern of his existence. Over the millennia during which he built up his civilisation the rate of technological advance, although it increased, did so slowly enough for change to have no major effect during the space of one lifetime. The whole pattern of society was built up on the assumption that this should be so and its institutions

were so planned as to reinforce stability. The general method of education was apprenticeship while the social order and the state hierarchy were divinely ordained and unchanging. In the maintenance of stability religion played a very important part. Religion was involved not just in ethical and moral questions, but also in the task of legitimising and sustaining the entire social order. I do not, of course, suggest that there were no disturbances in the course of developing civilisation. I think, however, it is fair to say that, broadly speaking, the pattern I have just outlined was on the whole sufficiently resilient to keep society in Western Europe on a fairly even keel until about two hundred years ago when what we now calle the Industrial Revolution began. Now, the Industrial Revolution was the result of the chance appearance of a few inventions at about the same time and in that respect was no different from other technological advances which had ocurred in he past. One of these inventions, however, —that of the steam engine— far trascended the others in importance because it put, for the first time, almost unlimited mechanical power in the hands of man. The consequences were tremendous; industrialisation, Improvement of communications, rapid increase in population, colonial expansion and exploitation —all these and more raced ahead. The rate of change was enormously increased; no longer could stability within one lifetime be assured to the rapidly growing industrial proletariat. The old patterns, in seemed, no longer held and as a result there was a growing swing away from traditional religion towards new beliefs and social patterns represented by such creeds as socialism, Marxism and so on. While there is no doubt that the Industrial Revolution of the late 18th and early 19th centuries had a shattering effect on western society (and indirectly on the entire world) it is possible that it might still have been contained had not a new factor put in its appearance about the middle of the 19th century. This was the solution of practical problems. From the time of the so-called Scientific Revolution in the 17th century science had been advancing steadily as a cultural pursuit largely in the hands of amateurs. Although its progress clearly must have had some social effects its direct effect on material civilisation was small. It is technology rather than science which has a direct effect on society, and it was the application of science and the development of science-based technology about the middle of last century that ushered in what I call the second Industrial Revolution which has had and effect on human society far trascending anything in recorded history and perhaps in the wole history of our species. By bringing science to bear directly on practical problems the element of chance in technological advance was enormously reduced and the pace of advance correspondingly increased. To meet the needs of advancing technology there was a corresponding increase in the effort devoted to the advancement of science itself and

so the acceleration of change increased even more. The practical results we have all seen during this century —nuclear energy, space travel, widespread elimination of disease, televisión, computers and so on— and there is no sign that pace is slackening. And yet if welook around us we must admit the world is not a very happy place, despite all this progress. My own view is that most of our present troubles are due to the inability of society as yet to adapt itself to such a rapid rate of change. Social attitudes are always slow to change and the widespread rejection of organised religion has, I believe, gravely weakened the fabric of society; until it is replaced by some new belief or is adapted to play itself the role of such a belief we may continue to flounder. It is for this reason that I believe the development of the so —called social sciences is a matter of urgency— if we are to cope with progress we must learn to understand ourselves far more fully than we now do.

Although I believe that it is our failure to adapt society to the rate of technological change which is at the root of our troubles, the changes themselves have come through science and the tecnology based upon it and it is possible to identify a number of current problems were I believe science and technology can provide a solution. It is to some of these that I wish to address myself in this lecture.

The problem of overpopulation is not new —only its urgency. More than two thousand years ago Aristotle drew attention to the danger and advocated abortion as a means of control. Over the intervening centuries various individuals have drawn attention to it, the best known, or at least the most videly quoted, of them being Malthus who, in the late eighteenth century, advanced the view that human population would grow until the limit of food supply was reached. Wars, famine and pestilence would inevitably be the result of such growth and in the end a crisis of starvation and death would be our common lot. We do not fully understand the factors which govern human fertility, but there is no doubt that with the industrial revolution a rapid increase in human population set in and there is surely little reason to doubt that increases in food supply and material prosperity (Malthusian factors, if you will) were largely responsible. The views of Malthus were, of course, violently opposed by the Christian church and by the Marxists who held that the threat of overpopulation was a capitalist myth designed to restrict and control the working class. It was the continued rise in prosperity and the vast improvements in agriculture and in medicine consequent on the introduction of science-based technology (neither of which could have been foreseen by Malthus) that for a time seemed to belie Malthus and support Marx. But things were not quite so simple; world population has continued to rise at increasing pace and the spectre of Malthus is again abroad.

The natural power of reproduction of human beings in normal circumstances is thought to correspond to an increase of 1 to 1.5% per annum. Such a figure was probably never reached in practice before modern times; it is thought, for example, that the increase in population of the Roman Empire in the first century A.D. was about 0.1% p.a. Today in the less developed countries the combined effects of natural fertility and a reduced death rate produce increases of 2 - 3% p.a. and rates as high as 3½% are not unknown. Such figures have never been reached before and today the figure for the world as a whole is estimated to be about 1.8% p.a. which means doubling every 45 years. Some idea of the significance of such figures is provided by the world population statistics given by the United Nations.

In 1750 world population was 719 million
In 1850 world population was 1,136 million
In 1900 world population was 1,594 million
In 1970 world population was 3,650 million

and it is expected that in 2000 it will be 6,305 million.

We must recognise that in the absence of global catastrophes a substantial increase in world population is now inevitable; it is too often forgotten that the generations already born will ensure this, since they are from the outset more numerous at every age than their predecessors and will benefit during their lives from lower death-rates. When we look forward to what will happen with generations as yet unborn it is clear that in order even to keep the number of births constant a very large drop in births would be necessary in existing generations. Such a large drop, would have its own riks; if the number of births dropped to the same level as deaths there would be serious disturbances in age structure, the effects of which might persist over several centuries. According to proyections made by the United Nations, even assuming a substantial introduction of birth control from now onwards, we are likely to have a population of 14 billion by the year 2100 and this estimate may well prove optimistic.

Even with increases on this scale we would not need to encouster a global Malthusian crisis in food supply for at least a few centuries. But we do face crises of this type in some of the under developed areas of the world today. In quite a number of countries the combined effects of growing population and inadequate capital for development are making the problems of malnutrition and disease of frightening urgency. No doubt these problems could be eased by improvements in food production and distribution and by aid from more developet countries, but these things take time no act and during the next ten or twenty years we may see several local catastrophes.

The world could, of course, support or at least feed many more people than it now does. It has been estimated that if all land now under cultivation were managed as it is in Holland the world could support a population of 60 billion on a typical Dutch diet. This estimate does not take into account the possibility of furher agricultural improvements or extension of the cultivated areas and ignores completely the contributions which could be made by fish farming and the known "unorthodox" methods of producing food from algae and many other microorganisms. We are thus not in imminent danger of starvation. But even if we could feed them do we really want to, or can we even afford to have such huge numbers of people? The answer to that question must surely be no.

Even in the absence of any conscious effort at control, human population would ultimately stabilise itself just as animal colonies, given adequate food and water, but limited space, ultimately stabilise themselves. Just how large the population would be I would not care to predict, but it would certainly be much larger than the figures I have quoted if we left control entirely to the natural processes of biology; moreover, if experiments with animals are any guide there could well be a considerable deterioration in the species before a stable situation was reached. For various reasons we dare not leave it all to the natural process of biology. The view of Malthus that man will multiply to the maximum permitted by available food supply is a little too simple. In fact not only food is involved; man will increase to the number permitting the minimum acceptable standard of living to each individual. That minimum has been rising rapidly ever since the Industrial Revolution and nowadays man expects that any technological advance shall be made available for his personal benefit. Standards of living have everywhere risen, but are perhaps at their highest level in the United States. When peopble talk of aid to underdeveloped countries the aim, whether spoken or unspoken, is to raise the standard of living to something like the American or West European standard. Personally I don't think this aim can possibly be achieved unless something drastic is done to control population. Given an aprroximate doubling of world population by end of this century then, for that population to enjoy the current American Standard of living, the demand on our natural resources would be 70 times what it is today and the drain on the biosphere would be 6 - 8 times its present size. This is based on *current* American consumption and takes no account of the fact that, assuming technology to advance at the current rate between now and the year 2000, oil consumption in the United States would rise by 500%, automobile construction by 700%, house building by 1000%, chemical production by 1200% and electric power consumption by 1800%. Even when one makes allowance for the dangers of extrapolation, these figures are frightening for most of them

involve what I call non-renewable (metals, minerals, fossil fuels) as distinct from renewable (e.g. animal, vegetable, sunlight etc.) resources. Until the so-called oil-crisis of 1973 far too few people gave any thought to the fact that, next to population, our biggest problem is energy, for modern civilisation depends on massive and growing energy consumption. Until brought up with a shock in 1973 people were wildly prodigal with energy forgetting that almost all of it was being obtained by burning fossil fuels which are not, within the time-scale we are considering, renewable; we are certainly using them up far faster than they are being renewed and so sooner or later they must be used up. Another thing to remember is that petroleum and coal are our main carbon sources for the chemical industry on which the maintenance of sour living standards and indeed of our whole way of life depends absolutely; we cannot afford simply to burn them all. Fortunately I believe we can solve our energy problem —not by solar, tidal or wave power but by the harnessing of the hydrogen bom i.e. thermonucelar power based on fusion of deuterium and tritium to yield helium + a neutron and lots of energy. But I think we will be into the 21st century —possible as lat as 2050 before thermonuclear power stations are in operation. Until then we cerainly have our problems. For I have little faith in the claims made by some that solar energy, wind or wave power can solve them in the short term— after all the preliminary experimental work has not yet been done. As for coal, the oultlook if we have to rely on traditional mining methods isn't too encouraging and to date we have not been very successful either in mechanised mining or in such things as underground gasification. During this difficult interim period nuclear energy by fission will play a vital part and that means the breeder reactor about which there has recently been much wholly unnecessary fuss by environmentalists.

Until recently very few voices were raised about pollution outside the ranks of biologists and naturalists, but now the world is on everyone's lips. In the last few years global pollution and deterioration of the natural environment have suddenly become fashionable. Not only do we hear about them everywhere, but all kinds of individuals and organisations clamour of speedy action. Just what that action should be is not always clear nor is the evidence upon which the agitation is based always secure. Yet there are serious problems to be faced; they need to be faced in an objective manner, however, and there is at times a certain lack of objectivity in the statements wich are bandied about by pressure groups of one kind and another —and regrettably these groups sometimes include scientists. Pollution, of course, is no new thing; it has always been associated with man and his development. Pollution of rivers ands streams by sewage has always been a problem and it will increase continuously with rising population; indeed human and animal

sewage between them represent perhaps the greatest pollution problem we face today. Garbage disposal has always been a baffling problem in urban societies and industrial pollution is as old as industry. The tremendous developments following the industrial revolution were bound enormously to increase the pollution problem. Since the objetc of industry is to produce at the lowest cost, the obvious way to deal with a noxious effluent is simply to get rid of it. Why not just tip it into the river flowing past the town? That river is probably already receiving the town's sewage and has long since lost its purity. Why should one worry about smoke and fumes from the factory chimney — the wind would, sooner or later, blow them away? Not only are city sewage, soluble garbage and industrial wastes factors in pollution, but modern developments in intensive farming have made the disposal of animal sewage a major pollution problem and the leaching of nitrates and phosphates from soils heavily dosed with animal manure or fertilisers, coupled with the discharge of phosphates from detergents, could well change radically the fauna and flora or our inland waters.

All these problems exist, but this kind of pollution and destruction of our environment can be prevented and where it has already occurred it can usually be reversed — witness the restoration of some inland waters in America. The necessary technology is either available now or could be developed by further research. Then why does it continue? The answer is simple; it costs money and it demands care and forethought to avoid it. Sadly we seem reluctant to face up either to the price or the personal inconvenience involved. The cost of prevention is now and is likely to remain high, but it is no use our bleating and wringing our hands about pollution unless we are prepared to pay it. But we must, all of us, be so prepared to pay it. But we must, all of us, be so prepared. I see little hope, however, unless all countries can agree on uniform codes of practice; in their absence price differentials wil always operate in favour of the polluter.

The related problem of nature conservation is again a very difficult one. Clearly we would all wish to see the beauty of the earth and the plants and animals it supports preserved — although for our own rather than their sakes. But how much are we prepared to pay for this — what restriction on our own activities we accept? From the beginning man has consistently sought to bend the environment to his own selfish needs. In so doing he has destroyed for ever large numbers of others species and he will no doubt continue to do so. Certainly we must avoid wanton destruction, but we must face the fact that with a rising population man's needs will often be incompatible with the wishes of the conservationist. Pesticides will be needed if food is to be produced on a suficient scale; to take an extreme case, the danger of the widespread distribution of DDT must be set against the enor-

mous benefits to health and nutrition conferred by its use in malaria-infested countries. The best we can hope for is to minimise the disturbance of nature and perhaps maintain selected areas in the world as nature reserves. But we won't do it for long unless we can bring our population under control.

I have discussed at considerable length some of the formidable problems facing modern man and put before you perhaps a rather gloomy picture; you may wonder indeed whether on that basis the contribution of science to human welfare might be negative. But in that you would be wrong. Major problems lie ahead to be faced; but let us not forget the enormous benefits we now enjoy through the application of science in our daily lives. Today we live longer, are healthier, better fed, better clothed and housed and enjoy a vastly higher standard of living than our parents, let alone our grand-parents. If I underline some of the problems it is in the hope that you may be encouraged to tackle them speedily and sensibly so that the forward march of mankind may continue and that his age old search for happiness may ultimately succeed. I hope I have succeeded in conveying to you that in all these problems it is more rather than less science that we need. That I should have sought so to convince you stems from the fact that chemistry is going to be central to the solution of many of them — whether it be control of reproduction or of disease, the provision of new materials to husband natural resources or preserving the environment by minimising pollution. I can, of course, hear a certain kind of critic observe that chemistry bears a measure of responsibility for many of the problems which I have mentioned. This is the kind of criticism which lies behind the development of the anti-science which I mentioned a the outset of this lecture and it is wholly mistaken. Problems like pollution arise through the misuse or careless use of science and technology. But it is mand and not science who is responsible for that misuse; in this as in other directions mankind's worst enemy is man himself.