## *Public Lecture*

# Science and Mankind

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The Leader of the British Labour Party, Mr. Clement Attlee, recently said that "it is necessary for the peoples of the world to take steps to prevent themselves from being destroyed by science." Only to-day, his Holiness, the Pope, is reported to have used almost the same words. This strange idea, that science is something apart from ordinary men and women, is as unreasonable as is the idea that in a democratic country the destinies of the people are controlled by an impersonal "they", whose home is the seat of government and who are blamed, or very occasionally praised, for everything which happens. To-day, the people of every nation are disturbed by the threat of world war with atomic weapons of unprecedented destructive power. Unaware that these Frankenstein monsters have been called into being by their own actions, they seek to lay the blame for their existence upon other shoulders. The cry "Ban the Atom Bomb" goes around the world, but those who utter it have a faith as unfounded as that of Canute's courtiers in an ability to influence natural events or human nature. The professional scientist becomes the target for abuse and mistrust, but is at the same time urged to set to work to save the people from the fate which threatens.

For these reasons, perhaps, it is worth while to examine the foundations of scientific activity, the part it now plays in any developed community and where it is likely to lead.

## WHAT IS SCIENCE?

Science is that body of knowledge which can be communicated to others and which can be verified by anyone willing to make the effort to do so There are other kinds of knowledge, arising for instance from emotional or religious experience, which are essentially personal and which cannot readily be communicated to others or be verified by them. Undoubtedly this personal knowledge plays an important part in the lives of individuals, but it can only affect the people as a whole if they are willing to accept the experiences of others as an act of faith. There are fashions in science, just as there are in art or literature, but there are never any dogmas and every part of the knowledge it represents is constantly sifted and checked, ideas which prove to be wrong are discarded ruthlessly.

There is an old name for the subjects of major importance studied in a university. They were referred to as disciplines. The body of knowledge which we call science is, perhaps, the greatest of the disciplines of the human mind. Yet it arises from a very primitive instinct of the human animal, curiosity, together with the power to reason, which man alone possesses.

We are told in the allegory of Genesis that Adam and Eve were driven from the Garden of Eden because they disobeyed the law and ate of the fruit of the tree of knowledge. It seems very strange to me that the exercise of


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the greatest faculty with which man has been endowed should ever have been regarded as a sin. If he had been content to continue always to live and behave as the animals, guided by instinct alone, the inference is that he would never have fallen from grace. By a deliberate act, probably the greatest step he ever took, he chose to seek knowledge. thereby setting himself apart from all living things and ensuring his ultimate dominion over the earth, with all the powers and responsibilities which such stature involves. What is called the fall of man should be known as the ascent of man, provided always that he acquires wisdom with his knowledge and is not destroyed by the fruits of his own ingenuity.

Curiosity about the world in which he lives and about his own nature provides the motive power for the search for knowledge The exercise of reason weaves this knowledge into a coherent pattern and provides the means for recording it. There have been recurrent periods in history when the deliberate search for knowledge has flagged, when men have felt self-satisfied, or when they have endeavoured, by reason alone, to find a solution to their problems. Such pauses in the garnering of knowledge have been useful. allowing wisdom to emerge from the digestion of the harvest already gathered, and have often been times of great achievement in the arts and in literature. But such lapses from continued activity in the search for truth occurred in isolated communities, before modern communications made all the world one. The passivity of Asia, which followed its earlier heights of achievement, has been shattered by the intense activity of the West.

For a very long time the patient observation of nature and the recording of the facts observed. was the normal course of science. With few exceptions, man remained a passive agent in the process For instance, from his very beginnings man must have had very complete knowledge of the anatomy of animals and men. for he dissected both. for food or to embalm the dead Yet it was not until about 300 years ago that the English medical man. Harvey. showed that the blood circulated in the body as a result of the pumping action of the heart Similarly, the Persians made surprisingly accurate observations of the apparent movements of the planets and stars. but because of their lack of any knowledge of mechanics. the explanations they gave lacked reality

The pursuit of knowledge changed its character and was accelerated greatly through the adoption of the experimental method Man became an active participant in the phenomena he observed. Experiments were devised to test all hypotheses laid down and any theory which did not accord with the results of experiment was discarded. The habits arose of free and open discussion of scientific problems and the publication of the results of investigations. Scientific knowledge was no longer guarded jealously, but became the property of all. An ethic of science developed which made discussion and publication obligatory. Thus. Benjamin Franklin. who founded in Philadelphia a society for the discussion of the problems of his time. imposed upon its members an oath. part of which may be paraphrased as follows: "I swear diligently to seek the truth. and having found it. to impart it to others "

One result of complete openness in science and of the development of the experimental approach. was that many more men became interested. Science rapidly became a branch of learning with all the dignity and depth of the older disciplines. but with far greater vitality. It flowed across national boundaries. There grew up, throughout the civilized world, a body of men devoted to science who, in this matter, were true internationals. Even during the Napoleonic wars the great British chemist, Sir Humphrey Davey, the first head of the Royal Institution in London, was able to travel freely in France and Europe, where he discussed scientific problems with like-minded men.

The great advances made in science in England and Europe during Victorian times, when the industrial revolution was in full swing, led to a belief by many that the nature of things had at last been revealed to man. The inspiring success of mathematical theories applied to quantitative data, bred the idea that it was only necessary to learn how to calculate things more accurately in order to achieve complete understanding. These ideas were less common among the scientists themselves than among those who dabbled in science in order to bolster materialist philosophies or social theories. Among scientists the feeling that the goal was in sight was short-lived, but the concept of certainty in science lived on among others, producing as one of its children the dialectical materialism of Marxism. Even to-day the impression lingers that science, and particularly physical science, is concerned with immutable "laws of nature" which are understood and which govern all processes.

The actual position is quite otherwise. Knowledge is never complete and there remain many mysteries of nature, phenomena which can be observed but for which there is no adequate explanation. Let us consider for a moment the science of dynamics which deals with the motions of material bodies. Newton achieved remarkable success in "explaining" the movements of bodies subjected to forces. Mechanics, as he developed it, accounts with extreme accuracy for the motions of large bodies, such as the planets, in the gravitational field of the earth or the sun. Newtonian mechanics can give a satisfactory explanation of the behaviour of a rifle bullet, a golf ball or an aircraft, and it enables the mechanical engineer to design machinery. However, the Newtonian concepts failed when applied to bodies moving with velocities approaching that of light. Observations of bodies with such very high velocities became possible only after the discovery of the electron, at the end of the last century, because the very great energies required to give speeds of 10,000 or more miles per second to large bodies meant that such velocities were not previously observed A new mechanics, relativistic dynamics, was introduced by Einstein. This accounted very accurately for the observed increase of the mass of a particle with its velocity and showed clearly that velocities in excess of the velocity of light could never be observed.

The theory of relativity helped greatly in the understanding of atomic processes, but it, in turn, was inadequate to account for the emission and absorption of light by atoms. This required a new idea, put forward by Max Planck, that in atomic systems and in light, energy cannot be given out or absorbed continuously, but only in discrete "bundles" called quanta. But again difficulties became apparent and the classical quantum theory was replaced by the so-called wave-mechanics developed by the French scientist de Broglie From this followed the uncertainty principle of Heisenberg and a clearer picture of the limitations of observation in the sub-atomic field

Wave-mechanical ideas were applied with considerable success to explain the properties of the nuclei of atoms, but as experimental knowledge grew it has become clear that it will not explain either nuclear forces or the properties of the fundamental particles of which nuclei are composed Even relativistic wave-mechanics cannot give a complete picture of the motion of matter or of the forces it experiences. Some new concept is required to enable real progress to be made.

These examples will make it clear that scientific knowledge is never complete. As Rutherford used to say, work in basic science is like digging in Tom Tiddler's ground; if the search is diligent, something new is always being turned up, even in regions which have been dug over many times in the past. The so-called laws of nature change with increasing knowledge. There is never certainty in understanding; only a probability that the facts are right and the explanation a good one. There is no place in science for dogmas and no mode of approach to a problem but with an open mind.

### Basic and Applied Science

We have been discussing knowledge in what is known as "basic" or "pure" science, which is concerned with the search for knowledge of the world around us. Almost all such knowledge finds application in practical ways. For instance, the researches of Michael Faraday at the Royal Institution, in the first part of the last century, established relationships between electricity and magnetism and showed that electric currents could be generated by moving a conductor across a magnetic field. These facts were used by inventive engineers, enabling them to develop dynamo generators of electric power, electric motors and alternating current transformers. So Faraday became the father of the great electrical industry upon which modern civilization is so dependent. In the last part of the century Clerk Maxwell showed that the properties of light could be explained if it were assumed to be an electromagnetic wave motion in space. He deduced that accelerated electric charges, i.e., varying electric currents, should produce electromagnetic radiation. Hertz, in Germany, was able to prove that the rapidly oscillating current produced by discharge of an electric condenser produced electromagnetic radiation which could be detected at a distance. Marconi, the practical inventor, later used these discoveries as the basis of wireless telegraphy.

Similar examples can be given from the biological sciences. Thus, Fleming observed in London that bacteria died in the neighbourhood of a growing speck of fungus and showed that this was due to a chemical substance produced by the fungus. During the early years of the last war Florey, in Oxford, remembering this observation, developed methods for growing this fungus in quantity and succeeded in extracting from the medium a small quantity of a substance which would kill many varieties of bacteria. He went on to show that the purified extract could be injected into animals without ill effect and that it was extraordinarily effective in killing bacteria in wounds and in many localized infections. When tried upon human beings it showed the same remarkable properties. Thus was born the miracle drug, penicillin.

Scientific activity stretches over a whole spectrum of work, from basic science at one end to the applied sciences, like engineering, agriculture and medicine at the other. There is no sharp division between basic and applied science, but rather a gradual merging of one into the other What is more, applied science is often able to provide tools and ideas for use in research in basic science. For instance, the discovery of the electron by J. J. Thomson was followed by investigations by O. W. Richardson into the emission of electrons from hot bodies. These ideas were used by Ewing and Fleming to develop the thermionic valve which is the basis of modern radio Now, in turn, the radio valve has made it possible to provide the mathematicians with electronic calculating machines, and scientists with instruments for detecting single atoms of matter as well as with a great variety of equipment like oscilloscopes and amplifiers which have been essential ingredients in the development of modern physics, of physiology and of many other branches of basic scientific research. Basic and applied science are complementary activities and both are essential for increasing knowledge of nature and for the improvement of industry.

In general, a considerable period elapses between the making of a fundamental discovery and its successful application for practical purposes. The technological problems associated with the successful industrial development of a discovery nearly always require more effort and expenditure for their solution than did the original basic research. Thus there are few basic problems remaining to be solved in that part of nuclear physics fundamental to atomic energy, but it will require a decade or two to find solutions to the many technological problems which stand between the fundamental principles and the successful atomic power station.

The head of a large American industry which maintained extensive research laboratories was asked some years ago, "What is the difference between pure and applied science?" His reply was "About twenty-five years!" The period of lag between discovery and application on any scale is still of this order of magnitude. Industry is more aware now of the benefits which come from research, but the processes and equipment necessary have become more complex and require greater effort and a longer time.

## THE VARIOUS BRANCHES OF SCIENCE

All natural science, except purely descriptive sciences like natural history, is based firmly upon mathematics and physics. Mathematics is used to deal with quantitative observations of all kinds and gives precision and conciseness to ideas. It is sometimes called the language of science. Physics is concerned with the properties of matter and the space in which it exists. Other branches into which the complex of natural science is divided for convenience are also concerned with matter in its inanimate forms as chemistry, geology, and so on, or in its animate forms as biology and medicine.

The study of inanimate matter, in the physical sciences, is in many ways simpler and more direct than is the investigation of living systems, in the biological sciences. Experiments and observations in the physical sciences are more completely under the control of the scientist and essentially simple systems, e.g., a collection of atoms or molecules all of exactly the same kind, can be investigated. The very precise results that can be obtained under well-defined conditions render it easy to use mathematics to co-ordinate phenomena. As a result, the physical sciences are very highly developed and it has been possible to extend abstract reasoning to its limit in these fields. Indeed, many of the highest flights of human imagination, together with the greatest achievements in reasoning, are to be found in modern physics, which is having a profound influence on philosophy. Speculation about the origin of matter and the evolution of the universe has always fascinated mankind and recent developments in experimental and theoretical physics have shed much light upon these problems.

The physical and chemical basis of biological systems is simple and relatively well established, but because of the very great complexity of even the simplest biological entity, unravelling of the complete picture is a very complicated undertaking. Physical or chemical interference with a living cell or animal is limited in its scope, for such entities are easily killed or subjected to changes which are irreversible. Biological material is seldom under the complete control of the investigator. For these reasons the biological sciences are less highly developed than the physical sciences and less easily decribed in quantitative terms. In medicine, where man is the experimental animal, development is necessarily even more restricted than in general biology. Great efforts are now being made to place biology on a more quantitative basis, aided by rapidly developing new techniques of observation.

The nature of life still eludes the scientist, but the line of demarcation between living and dead matter has become less clearly defined. The nature of consciousness in the higher animals and man is still further from understanding. Something is known of the mechanisms through which consciousness is expressed and a great wealth of qualitative observation has been made, but these studies are so difficult, so complex, and real knowledge is in so rudimentary a form, that it is difficult to separate fact from opinion, or even from pure fiction. Undoubtedly great strides will be made in all branches of science when more is known of consciousness and of the nature of mind.

## SCIENCE AND THE HUMAN MIND

It is known that the capacity of the human mind differs little, if at all between the various races of mankind. Yet the degree to which this capacity has been developed or used varies enormously. The scope of the imagination and the ability to reason are both expanded greatly by education and environment. In particular, the ability to acquire knowledge, to reason and to make constructive use of imagination, increases with the exercise of those faculties The capacity of the human mind has been expanded enormously with the development of scientific knowledge. Perhaps its contribution to the stature of man is the greatest achievement of science.

To this day there remains some prejudice against science as a contributor to culture. There are those who believe that man reached his highest development in the days before the scientific revolution, which they claim has spread materialism and decreased the appreciation of quality in literature and in art. But such thoughts will not bear investigation and show a shallowness of viewpoint which it is difficult to understand. Such work as the development of the nuclear model of the atom by Rutherford and Bohr, or the formulation of the theory of relativity by Einstein, displays all the attributes of art or of literature in their highest forms. It has a beauty and a simplicity which staggers the ordinary man and depth and insight which satisfies the mind.

Whether men like it or not, they are living in an age of science and technology which is not something apart from the people but an activity in which all play some part. A man without some knowledge and appreciation of science is but half educated. He is cut off from the main stream of intellectual and cultural advance more surely than if he knew nothing of literature, drama or the arts.

## THE USE OF KNOWLEDGE

We have seen that the search for basic knowledge merges into the application of that knowledge in industry, in medicine or in other ways. Science and technology have brought such a revolution in our way of life that through familiarity with change we are often indifferent to the full implications of what is happening For instance, there can be little doubt about the positive benefits which mankind has gained from the development of communications—travel by sea, land and air, printing and the press, the telegraph and telephone, the cinema, radio and television. When properly used all these modes of communication aid commerce and technological advance, bring the peoples of the world closer together, so promoting international understanding and goodwill, and above all enable men to share directly their cultural activities and ideas.

The application to medicine of the discoveries of biological science has practically eliminated the threat of death from infectious diseases; technological advances based upon researches in basic science have reduced hard labour and drudgery in almost every walk of life, from the home to the factory and the farm, the yields of produce from agriculture and animal husbandry have increased greatly, the quality has improved and land formerly unfit for farming has come into production; large-scale production methods have brought to the ordinary man much improved standards of housing, and of comfort, beauty and entertainment in the home; leisure has increased and education to the highest levels is open to all

For all these things, which are part of present-day life, men and women who are not blase, disillusioned or soured will give thanks to science and technology. The processes of improvement of knowledge, and hence of its applications, will go on Already we have before us the prospects of the complete conquest of disease in the very near future, of enormously increased agricultural production and of unlimited energy for all purposes from nuclear processes Knowledge is available or is being sought which will bring these benefits to all men and help remove hunger, poverty, degradation and despair from the inhabitants of all parts of the world.

## THE MISUSE OF KNOWLEDGE

These same advances in knowledge, which set so fair a prospect before the eyes of men, for themselves as for their children, bring with them also the possibility of the destruction of man and of his civilisation. Science, used for individual gain without thought for the consequences, can bring disaster. For instance, Sir Edward Mellanby has reminded us forcibly that the rapid development of the preservation of food and its "improvement" by chemical methods, may be decreasing seriously the balanced nutrition of civilized peoples or may even be introducing into food substances which are positively harmful. The use of new materials in industry and applied science, such as additives to motor fuels or new drugs in medicine, may produce dangers of poisoning or of reduced health unless the most stringent precautions are observed For instance, it was discovered only after the death or incapacity of workers that beryllium, used in fluorescent electric lamps and in certain alloys, is a deadly and insidious poison for certain individuals.

The rapid development of technology in the Western countries, and its introduction into Asia and other under-developed areas of the world, makes great demands upon the resources of raw materials available to man. The phosphate deposits, upon which depend the fertilizer supplies for the world, are limited in extent. Already shortages of copper, lead, tin and other metals have raised the prices of these materials to prohibitive levels. The oil resources of the earth are by no means inexhaustible, especially if the Asian nations become large consumers. The timber resources of the nations have been exploited extravagantly. Over-grazing and over-cropping of large areas of the land surface of the earth have resulted in the erosion of soils and serious decreases in fertility, despite the knowledge which agricultural science has made available. Without the development of many substitute materials and very greatly improved methods of conservation of the soil and of all natural resources, it is impossible for all mankind to be given the standards of living of, say, the Americans. Selfishness and wisdom do not go hand in hand where the natural resources of the earth are concerned. The products of the surface of the land and of the rocks beneath it are the property of all men and some sort of international caretaking seems essential to preserve them for our children.

These problems, which arise from the development of science and its utilization by mankind, are continuing questions which must be answered continually as knowledge grows. At the present time we face a crisis in the use of science which is of far greater immediate importance and which must be surmounted if our present civilization is to endure. This is the recurring problem of war, which has been for mankind a sort of undulant fever of increasing malevolence which now threatens his very existence. Man stands on the brink of a precipice of his own devising.

The beastliness of war has been relieved in the past by patriotism and valour Combat was between individuals or groups of individuals and the civilian population suffered only through the occasional sacking of cities, taking of slaves and rape of women, apart from the commandeering of crops and property or the levying of taxes to pay for the war. If world war should come again, it is certain that all that we value will be destroyed, hundreds of millions will die and the surface of the earth be so despoiled that recovery may take a million years. These possibilities of destruction arise from the application of science and technology to warfare.

Before the advent of the atomic bomb the increasing mechanization of war had introduced new and inhuman characteristics into fighting. The development of "push-button" warfare, whereby a guided torpedo may be launched, a load of bombs dropped or a pilotless guided missile be sent on its deadly mission, had made of war an impersonal and immoral business A warrior of the past experienced a peculiarly personal relationship with his adversary: skill, physical fitness and bravery were the hall marks of the victor What Professor Julius Stone calls the "dehumanizing" of warfare through mechanization has made these qualities of negligible importance. In a future war a girl sitting at a telephone in a deep dug-out, may misinterpret a message over a bad line with the result that she launches a missile, which will destroy a city and its million inhabitants, in the interval between gossip about last night's dance. An electrical fault in a complex control network may release such a weapon by accident. Problems of navigation of a high-flying aircraft, moving in bad weather to eliminate an industrial target of strategic importance, can lead to the destruction of a neutral city, its inhabitants and priceless treasures The kind of mistake which occurred again and again in the last war can now have incalculable consequences and in the atmosphere of war is inevitable.

The banning of weapons of mass destruction offers no solution, for any nation facing defeat abandons all scruples and uses every weapon which could decimate the enemy. Excuses can always be found for the use of any diabolical weapon in retaliation. Both sides in the last war were fully armed with the banned weapons of gas and chemical warfare. The only reason that these were not used was that they were not good weapons: it paid to use aircraft to carry explosive and incendiary bombs rather than gas. Atomic weapons *were* used, and by us

In order to understand more clearly just how the misuse of scientific knowledge comes about, it is worth considering briefly, as an example, the way in which the study of nuclear physics led to the release of atomic energy and to the development of atomic weapons.

## NUCLEAR PHYSICS

During the closing years of the last century the course of physical science was changed by three great discoveries. J. J. Thomson discovered the electron, or elementary unit of negative electric charge, Roentgen discovered X-rays and Becquerel discovered the phenomenon of radioactivity. This was the dawn of modern physics. Since those days all these discoveries have been applied in a number of ways. Electrons, given off by heated cathodes, are the agents employed in all electronic devices. X-rays are employed in medicine and in industry in a variety of ways; radioactivity led to the development of nuclear physics and hence to the release of atomic energy.

The phenomenal growth of the study of nuclear physics was due to the genius of that very great New Zealand scientist, Ernest Rutherford. He realized the significance of Becquerel's discovery and set to work to find out what was the nature of the radiations given off spontaneously by the naturally radioactive substances, uranium and thorium. With the help of his many colleagues and students, to whom he communicated his own infectious enthusiasm and perhaps a little of his insight, he unravelled the nature of radioactive change and of the radiations which accompanied it. He then used these radiations, and especially those to which he gave the name alpha-rays, to probe the interiors of atoms.

With Geiger and Marsden, who became another New Zealander, he studied the scattering of alpha-particles by matter. He showed that the observed effects could be explained only on the assumption that an atom was like a solar system, consisting of a concentrated core which he called the nucleus, which carried a charge of positive electricity and almost all the mass of the atom. Around the nucleus rotated a number of negative electrons which rendered the atom as a whole electrically neutral and which moved in orbits like planets around the sun

An atom is about one hundred millionth of an inch in diameter, the nucleus is ten thousand times smaller Yet the methods devised by Rutherford enabled the size of the nucleus and many of its properties to be determined with precision

In 1919 Rutherford observed for the first time the artificial transformation of one kind of atom into another He made oxygen from nitrogen. This revolutionary discovery changed the conception of the nature of the nucleus, which was clearly a composite structure He went on to show that all the lighter atoms could be transformed into other species, and that the energy required to do so was millions of times greater than the energy associated with chemical change.

In the year 1932 two further major discoveries were made in Rutherford's laboratory. Chadwick discovered an electrically neutral particle, the existence of which Rutherford had postulated more than a decade earlier He had given it the name neutron Cockcroft and Walton showed that artificially accelerated particles were even more effective in producing nuclear transformations than were the alpha-particles hitherto used by Rutherford.

Until this time nuclear physics had been more or less the private preserve of Rutherford's laboratory. To many men this playing with the interiors of atoms was so far removed from the practical world that Rutherford and his colleagues were looked upon as purists who wasted their time in fruitless inquiry in a highly speculative field. The new discoveries, however, opened up the exciting possibility of the philosopher's stone The urge to smash atoms led to the eruption of a rash of cyclotrons and other equipment for producing bombarding particles, and nuclear physics became fashionable all over the world. Neutrons turned out to be extraordinarily powerful agents for the transformation of atoms.

In 1938, the year following Rutherford's death, one of his former colleagues, Otto Hahn, discovered in Berlin that when neutrons were absorbed by the nuclei of uranium atoms, these atoms broke down into two simpler kinds of atoms. This fission process was accompanied by the release of very large amounts of energy. Soon afterwards, Joliot proved that in the fission process several neutrons were set free. It was immeditaely obvious that these neutrons could be absorbed into other uranium nuclei, causing them to undergo fission, and so on, ad infinitum. A nuclear chain process releasing very large amounts of energy became possible.

Rutherford had never believed that nuclear energy could be set free in a practical way so that it could be used for industrial purposes. He often speculated on the energy which could be derived from another nuclear process, the combination of hydrogen nuclei to produce heavier elements. In 1934, when I was working with him, we were able to demonstrate that the nuclei of the newly discovered heavier isotope of hydrogen, deuterium, reacted with one another with surprising ease, releasing considerable energy. I spent some time endeavouring to induce this process by passing electrical discharges through the gas, but Rutherford was quite convinced that I was wasting my time. The recent explosions of deuterium weapons—H-bombs—by both U S A. and U.S S R have demonstrated that the central idea was correct, but it has shown also that it is just as well that I was not successful!

The energy released by the fission of 1 lb. of uranium is equal to that set free when 1,500 tons of good coal is burned. The energy available when 1 lb. of deuterium undergoes "fusion" in a thermonuclear reaction is equivalent to that released by burning 15,000 tons of good coal. The fission process can be made to take place in a controllable way and it is quite clear now that industrial power will be produced economically from uranium. The fusion process cannot yet be used for the production of useful power. Fission explosions equivalent to the detonation of tens of thousands of tons of high explosive can now be produced at will. Hydrogen bombs equivalent to the detonation of tens of millions of tons of high explosive are in the possession of America and Russia.

The wonderfully fruitful field of human endeavour, nuclear physics, which had led to such insight into the structure of matter and which for fifty years had been the preserve of the pure scientist, has assumed over-riding importance as the basis of both unlimited power for the future of man and unlimited powers of destruction of all that he holds dear. The nuclear scientist has come into the limelight in two guises, as the saviour of the Western world from Communist domination and at the same time as the inventor of the diabolic weapons which may destroy civilization.

It is an unfortunate fact that scientific advances yield guns as well as butter Almost every discovery can be used for evil as well as for good. Even the medical sciences have produced the spectre of bacteriological warfare.

## WILL SCIENTIFIC KNOWLEDGE DESTROY MANKIND?

Sir Winston Churchill has said these words: "Man, in this moment in his history, has emerged with greater supremacy over the forces of nature than he had ever dreamed of before. He has it in his power to solve quite easily the problems of material existence

"He has conquered the wild beasts, he has even conquered the insects and microbes. There lies before him if he wishes, a golden age of peace and progress. There only remains for him to conquer his last and worst enemy—himself."

Some blame the very rapid progress of science and technology, saying that the moral nature of man has not been able to advance fast enough to keep pace with material progress I can find no evidence whatever that the morality of mankind has improved in the 5,000 years or so of recorded history. The evil which even the most Christian of us is prepared to do impersonally in war is far greater in its effects than the most bestial acts of the ancient conqueror. The great religions of the world all condemn war and its immorality, but it remains the primary sin of mankind Few men nowadays have the courage to abide by the teachings of Christianity, which preaches the universal brotherhood of mankind

In any modern community its citizens are able to go their ways in peace only because of the rule of law and the existence of police to enforce it. Criminals and gangsters exist, probably, in as great proportions as ever before. Yet their activities are severely curbed and the ordinary citizen feels safe because of the force available to sustain law and order. In a large federal community, as in Australia or the United States, local laws are enforced by local police, but the powers of the Commonwealth are necessary to enforce laws affecting the whole nation Surely, it is logical to extend this concept to the whole world, envisaging a form of limited world government with powers to prevent war and to prohibit all national armaments, and with the necessary police force to enable it to exercise those powers? Such a world authority should have also the positive functions of encouraging co-operation between nations of conserving natural resources, and of carrying out those large-scale developments of science and technology which are beyond the powers of any one nation.

I have been accused of naivete and of impracticable idealism for joining with far greater men in advocating what seems to me to be so simple and so logical a solution to the problems of war and the misuse of knowledge. Many agree that this may well be the answer in some distant future, but that such ideas promulgated at this time, hinder rather than help those who are politically skilled and who are seeking a practical answer. Perhaps compromise is the wisest course, but I cannot help feeling that in this, as in other things, the truth alone will save us. There is nothing more certain than that another world war will devastate the globe, destroy our civilization and bring about just those conditions where fascism and the Russian form of communism, which we fight, will reign on earth. Speaking of a relatively small war, fought with conventional weapons, General MacArthur has said: "The outstanding impression emerging from the Korean scene is the utter uselessness of the enormous sacrifice. . A nation has been gutted and we stand to-day where we stood before it all started. . . . This experience again emphasizes the utter futility of modern war and its complete failure as an arbiter of international discussions. Those who lack the enterprise, vision and courage to try a new approach, fail completely in the most simple test of leadership."

The only way I can see of avoiding world war, with certainty, is to give up our national rights to armies and weapons of destruction and to endeavour to rule the world. in matters affecting all the world, and those only, through a single organ of government which alone possesses military power.

In this way we could not only preserve our civilization, but could carry forward the search for knowledge with the assurance that it will not be used for war. Progress would be more rapid because less creative effort would be devoted to preparations for war, and attention could be given to the major problems of our age—population and food supplies, conservation and world distribution of raw materials, and universal education at a high level

## The Responsibilities of the Scientist

The part played by science and applied science in the modern community is so great that the control of activities in these fields can no longer be left to the scientist alone. This statement will sound like heresy to many men of science who believe sincerely in the established conception of complete freedom in the search for truth. In the realm of basic science investigations must continue in an atmosphere of complete freedom, for no one can know from one day to the next, where, how or when the next major discovery will be made, or in what direction the seekers for knowledge will turn tomorrow. Complete freedom does not imply freedom to injure other human beings, to commit acts of cruelty or to neglect the interests of others. The pursuit of knowledge must be governed by the ordinary rules of social conduct.

However, in the applied sciences—and we have seen how difficult it is to draw a line between basic and applied science—the social consequences of development are all important. Ruthless exploitation of men and of raw materials has followed many developments in applied science. Grave dangers can arise to life and to health through the adoption of new equipment or processes which have not been tested thoroughly or which produce unexpected side effects. The deliberate design and development of weapons of destruction is an activity unworthy of science, essential though it may be until a stable state of the world has been established. Activities in these fields must be subjected to social controls.

Technological development proceeds so rapidly that dangers and difficulties arise before external social controls can be established or made effective. Proper supervision can then come only from within the ranks of scientists and technologists. Men of science can no longer deny all responsibility for the uses which may be made of their discoveries or developments. The ethic of social responsibility must be made an integral part of the spirit of the search for knowledge and its applications. Such a feeling is growing rapidly, but it needs to be established on a stronger and more formal basis so that some restraints are imposed upon the ruthless, the cruel or the foolish scientist comparable with those exercised in the practice of law and of medicine.

## SCIENCE AND EDUCATION

The primary aims of education are twofold: firstly to give a citizen that essential knowledge which enables him to live usefully, and, secondly, so to develop his mind that he can appreciate the arts and learning and contribute something to them.

In the past the basic disciplines of educational curricula have been the humanities and especially the classics Because we live in a technological age these disciplines are being replaced by science and by technical subjects, emphasis being given to studies which will be of direct use in earning a living. As a result, a large proportion of the population of a modern nation cannot think, write, spell or even read with facility and discrimination.

I do not think that the inevitable change of emphasis from the humanities to science and technology need have produced this form of illiteracy. Scientific studies, properly developed and presented, can contain almost all that the humanities offered in human interest, social understanding and mental discipline. The history of the growth of science and the study of its social impact can be woven into courses in science and technology. The proper expression of thoughts and ideas in science demands the deepest familiarity with the language, and the same practice in its use. The difficulties have arisen from emphasis upon factual knowledge of a purely utilitarian kind. Overhaul of methods of teaching science in schools and universities could restore literacy, awaken an appreciation of human problems, of art and of literature, and make of education something finer and more satisfying intellectually than anything which has gone before

Sad though the tale be of the man put through the utilitarian mill of modern education on the science side, the state of the man who does no science is far worse. This poor unfortunate often pretends to be proud of his lack of knowledge of science, he is cut off from the real world in which he lives among people whose technology he despises, if he attains a position of authority he is apt to make decisions unrelated to reality with appalling results for others, his knowledge of the past often obscures his vision of a different future. Of course, wisdom is not confined to men of science, and the wise administrator, whatever his background, always seeks information from those with real knowledge: but such wisdom is rare and authority breeds intolerance rather than understanding.

## Science and Religion

Finally, I wish to venture into a dangerous field and express a few thoughts about the controversial subject, science and religion.

In contrast with general belief, I am convinced that most real scientists are deeply religious men. I do not mean that scientists are in general strong adherents of any church, or that they practise any of the outward accepted forms of religion. On the contrary, they are repelled by dogmas or by beliefs which rest upon emotion or personal salvation. They will not accept that there exists any body of knowledge, religious or otherwise, which should not be questioned or carefully examined in the light of new knowledge of the world in which they live.

What I do mean is that the real scientist, the seeker after truth, is aware of the paucity of his real knowledge, but has an infinite faith in the ability of man to know and to understand. He experiences humility in the face of the immensity of nature, but he is impressed deeply by the capacity of the human mind. He knows that he is part of nature, but feels that because he can comprehend it he must in some subtle way be superior to this environment. For him nature has a beauty, a dignity and a reality which transcends even that sensed by the artist, for he apprehends not only with his senses and his emotions but with his mind. His knowledge is never certain, but rests on the sure foundations of his belief in the capacity of men to seek, and some day perhaps to find, the truth.