PONTIFICIAE ACADEMIAE SCIENTIARVM SCRIPTA VARIA

42

SCIENCE AND THE MODERN WORLD

PART I

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EX AEDIBVS ACADEMICIS IN CIVITATE VATICANA

MCMLXXVIII

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INTRODUCTION

During some of the previous sessions of the Pontifical Academy of Sciences it was felt by many of our members that, together with our procedures, a mechanism should be found by which a central point of great interest for the development of science could be freely discussed, drawing on the experiences of our colleagues representing different scientific disciplines and various regions of the world. Later this feeling was the subject of a productive talk I had with Professor A. R. J. P. Ubbelohde at his charming flat in London, together with Professor P. C. Garnham, also a Pontifical Academician. The subject more or less agreed on that time for the purpose is the one so ably treated by Professor Ubbelohde in the present publication.

After many conversations with various colleagues and much reflection, it appeared to me that a more embracing theme should be tried in our first Plenary Session and, if successful, made a formal subject of a series of meetings. This idea was presented to the Academy's Council held in March 1976 and unanimously accepted. It is as short as it is significant: « Science and Modern Society ».

The importance of such a theme needs no emphasis. We all know the place that science and technology have assumed in the contemporary world and we wish to extend our knowledge and strengthen its role in the process of social development. But we know also how much Science and Technology, for better or for worse, are changing, not to say shaping, the pattern of modern culture, displacing sometimes human values and occupying the « space » of other forms of knowledge. I submit that nothing shows this better than the presence in the developing countries — like Brazil, where I come from — of small villages where the most common dwellings are simple huts, and hundreds of television antennas, posted on every home, and giving during the twilight hours the macabre aspect of a petrified forest, or that of the inhuman harshness of the linear and angular drawings of some of the best landscapes of Bernard Buffet. The images on the screen are radically changing the pattern of the secular culture which formerly existed.

Undoubtedly the place of science in modern society has been the occasion for discussion, disagreements, sometimes challenges. This is the result of the confusion established between science and its application, the misunderstanding of the role tbat the advancement of science may play, and partly because of a Faustian attitude taken by a few groups of scientists themselves.

Notwithstanding all these problems, however, the role and place of science in modern society seems clear. Its responsibility, which should never be restricted, is that of opening up new roads of knowledge, widening those already existing, and thus creating the only way which can allow mankind to face the material challenges of tomorrow. In order to play this role, science must overcome some obstacles. By its own strength it has become a component of our social and political structures, if not an asset. Thus the need or desire to keep a permanent and ever-expanding turnover of weaponries, and the supposed need to maintain an ever-developing economic expansion, based on consumerism, undertaken without a profound regard for the real needs of the human condition, creating forces restraining the freedom of science and its growth for the real benefit of man.

On the other hand, from beyond its boundaries comes the outcry of those who are afraid that science and technology are responsible at least for the major part of the anxiety, the division between rich and poor, tbe rebellious mood, the escapsim, the anti-spiritualism, the huge arsenal of weapons, which are the burden of the present world, and of those who say that the advancement of science and technology has done little for the benefit of man and the appeasement of the modern world.

This leads to a limitation of support of basic research and to the concept that the knowledge already gained can solve all the problems of suffering mankind, existing mostly in the developing countries but also in some areas of the industrialized world.

This is partly true because as a matter of fact little has been done in relation to what could have been done. This idea may, however, lead to a gross comedy of errors. This does not mean that greater and greater efforts should not be made regarding the aforesaid application, or that in many cases the pattern of transfer of knowledge should not be modified. New ways to deal with problems in the realm of the application of modern science and technology as well as the old, secular, aboriginal one, must be found.

The idea of banning a certain type of research by political means or for philosophical reasons and religious beliefs, in certain countries, is a good example of the difficulties science is still confronted with.

One must also bear in mind that within the field of science proper the concept of its limitations is being discussed. It is said that some fields are exhausted, and existing manpower lacks mobility to transfer to new fields. They say also that limitations should be imposed on some research as it may lead to disaster. In fact, without going to the extreme of using the word crisis, one may say that science is being re-evaluated, and even by younger scientists. How far we are from the days of glory, when no anti-scientific stand could be found in the scientific collectivity, which was infused rather with the quixotic concept that all sufferings of mankind would disappear with the development of science and that a peaceful new world would emerge.

Happily only a small part of the scientific community thinks in terms of limitations. To them I would like to quote, facetiously, a French historian, rather conservative, who begins his book on the French Revolution by writing: « The Revolution commenced the day in which the aristocrats lost their faith in their privileges ».

Our profound belief in the importance of science, however, does not mean that we must not evaluate its role, its perspective in a political world, its position in relation to other forms of knowledge, its influence on daily life and so forth. On the contrary, it obliges us to find some way in which we can, by the advancement of knowledge, contribute to a harmonious world where the advancement of knowledge by itself is not considered a mere ludic enterprise and where the progress achieved by this advancement may contribute at least partly to meet the needs of social justice, and the benefit of mankind and of each individual.

The present publication, No. 42 of the Collection « Scripta Varia » of the Pontifical Academy of Sciences, presents the papers and the discussions held during the first meeting on the subject. We all believe this is important. It is a beginning and has to be judged as such. However, I am sure that the ideas and opinions expressed by my colleagues, whose wisdom, experience and collaboration I wish to commend, are important and may help many people to reflect on such a momentous subject.

I do not wish to end this introduction without thanking all the participants in the Plenary Session for their help and their contributions.

My thanks go also to Padre di Rovasenda, Director of the Chancellery, and Michelle Porcelli for their assistance. I wish to express particularly my gratitude to Gilda Massa for the arduous work she has so beautifully undertaken in reviewing and editing these texts.

Roma, 1978

CARLOS CHAGAS

SCIENCE IN THE MODERN WORLD

MARCEL ROCHE

My father, who was born in 1888, saw the transition between the horse and buggy period and that of the automobile. He lived long enough to travel in a jet plane. And he never ceased to express wonderment about these changes. He also marvelled about the progress of surgery, about the discovery of penicillin, and many of the other science-based modifications humanity had experienced in his lifetime. He belonged of course to another era, which had begun in the XVIIth century, with the Industrial and later with the Scientific Revolution, during which time the idea of progress, with Condorcet and others, arose and prospered. Even before, Bacon had visualized a future humanity in which the toil and suffering of daily life would be alleviated through *experimenta fructifera.*

Karl Marx saw science as a means of liberating man, and Lenin saw the future of the USSR as a combination of the Soviet plus electrification of Russia.

Science thus in its modern sense arose from a demand on the part of humanity for a better, fuller life. But it had had an earlier beginning, from a root which is more essentially its own: from the simple, child-like curiosity to know nature and man. Thus from these two indissoluble roots, we have science as we know it today: science as culture and science as action.

Culture has at least two meanings: one of them expresses the idea of something spiritual, as opposed to material. And the other, a more anthropological one, means groups of ideas, practices and values derived socially and historically, which characterize human communities. These ideas and practices include beliefs, knowledge, art, morals and laws, science and technology and lead to a pattern of behavior which may be observed directly, or through literary products, musical manifestations or through manufactured objects: tools, machines, buildings, etc.

Science is of course part of culture in both senses of the word, particularly when it is considered together with technology. As a spiritual cultural factor, it is characteristic of modern times and has given them its own special tinge. Born in a few Western countries, it now extends all over the world, with its characteristics of critical open-mindedness and objectivity.

Although science as such is disinterested science, we cannot, in the twentieth century, leave aside from our definition technology, the employment of knowledge for useful ends. As Veblen (1961) states, "The reason why scientific theories can be turned to account for these practical ends is not that these ends are included in the scope of scientific inquiry. These useful purposes lie outside the scientist's interest. It is not that he aims, or can aim, at technological improvements. His inquiry is as 'idle' as that of the Pueblo myth-maker. But the canons of validity under whose guidance he works are those imposed by the modern technology... His canons of validity are made for him by the cultural situation; they are habits of thought imposed on him by the science of life current in the community in which he lives; and under modern conditions this scheme of life is largely machine-made. In the modern culture, industry, industrial processes, and industrial products have progressively gained upon humanity, until these creations of man's ingenuity have latterly come to take the dominant place in the cultural scheme; and it is not too much to say that they have become the chief force in shaping men's daily life, and therefore the chief factor in shaping men's habits of thought... This is particularly true of those men who by virtue of a peculiarly strong susceptibility in this direction become addicted to that habit of matter-of-fact inquiry that constitutes scientific research" (p. 16-17).

Classically, it has been said, by Merton (1937), that science ethos consisted of 1) Universalism in the sense that "truth claims, whatever their sources, are to be subjected to *preestablished impersonal criteria*" (p. 607); 2) "Communism" in the sense of common ownership of goods, of scientific ideas, meaning that: "The substantative findings of science are a product of social collaboration and are assigned to the community" (p. 610); 3) Disinterestedness, which is probably true of basic science, but not if the term is made to include technology: and 4) Organized shepticism or "the suspension of judgment until 'the facts are at hand' and the detached scrutiny of beliefs in terms of empirical and logical criteria" (p. 614).

Science as a whole reveals certain important characteristics: "one is the strong aversion to anthropocentrism and anthropomorphism characteristic of all scientific disciplines. This is manifested in many ways: *a priori* opposition to teleological argument and theorizing, aversion to anthropomorphic or animistic theoretical entities, an insistent differentiation of fact and value, a cosmology firmly denying man any special significance, and, finally a tendency to reject or devalue scientific work on hypnotism, extrasensory perception or similar topics. This trend is reflected in the rites and customs of science, notably in the style and form of the scientific paper, where the passive tense is now *de rigueur* and verbs, wherever possible, are converted to nouns" (Barnes, 1974, p. 45).

It has been said that science is to the modern world what the cathedrals were in the medieval period. Both are manifestations of a certain *Zeitgeist.* There is some truth in this: both are the product of human ingenuity and both manifest an inner beauty and harmony. Both are constructions of the human spirit. But therein the parallel stops. Cathedrals were made mostly by anonymous artists and for the instruction and enjoyment of the people, not to mention the glorification of God. Science, on the other hand, is expected to be valued and appreciated by a few peers, and it is hermetic to the general.

In fact, in spite of a massive effort at popularizing science, most people are interested in it not as a spiritual construction, but rather for the effect it may have on their daily lives through technology. In that sense, science-based technology is much more a characteristic of our time, a popular one at least, than science *per se.*

And it is through technology, or rather its practical results, that the present anti-science movement was born. The first World War was the warning That the most cultured and scientifically most advanced countries in the world should become locked in a conflict wherein the results of the most advanced science-based technology was being used constituted a shock to many intellectuals. But worse was to come. One of the most scientific (and musical, and philosophical, and mathematical minded) of all nations, Germany, was to become involved in a repulsive movement, Nazism, and plunge the world again in a most bloody conflict. The Aryan idea was constructed in the name of science. Toward the end of that conflict, the most awful example of a rapid evolution from a basic laboratory finding (in which my predecessor in this chair, Otto Hahn, played a promient role) took place. I am thinking of the building, under the direction of a distinguished hasic scientist, Robert Oppenheimer, of the atom bomb. ("Scientists have now known sin", he is said to have exclaimed when the first nuclear explosion took place.)

In the sixties, however, after the success of the first Sputnik, there was a rebirth of optimism and the resources for science increased in the developed industrialized countries by leaps and bounds, to the tune of some 15% increment per year. The Vietnam War, with its hombs, its defoliants, its napalm, together with an increasing anguish about population and pollution explosions, was to put a brake to the rather exuberant growth. Anti-science movements, and anti-technology movements are nothing new, as the old Luddist movement is a witness to. But, at least in developed industrialized nations, the movement has taken on a new, intellectual, dimension. True, most of the population in such nations still enjoys the benefits of technology and is in favor of it. A recent study (La Porte and Metlay, 1975) has shown that, at least in California, there was a generalized feeling of approval of technology; disapproval — a rather mild one at that — being voiced mostly by those in the lower economic status and those least conservative in their political outlook. A similar study has not been performed in underdeveloped nations, but I am confident that there, at least in Latin America and within the power structures, enthusiasm is rife for science and technology.

But the anti-science movement must be taken into account, for it is not — far from that — simply a movement of outcasts, young, leftist and discontented. It is a movement which extends from the criticism of the idea of "objectivity" by Theodor Roszak, to the ideas of Paul Feyerabend, which we shall examine briefly now.

Theodor Roszak (1972) has criticized the "validity of the scientific world view, the supremacy of cerebral cognition, the value of technological prowess" (p. 82) and has recognized the existence of a "subversion of the scientific world view" (p. 50) "with its entrenched commitment to an egocentric and cerebral mode of consciousness. In its place, there must be a new culture in which the non-intellective capacities of the personality — those capacities that take fire from visionary splendor and the experience of human communion — become the arbiters of the good, the true, and the beautiful. I think — Roszak proceeds — the cultural disjuncture that generational dissent is opening out between itself and the technocracy is just this great, as great in its implications (though obviously not as yet in historical import) as the cleavage that once ran between Greco-Roman rationality and Christian mystery. To be sure, Western society has, over the past two centuries, incorporated a number of minorities whose antagonism toward the scientific world view has been irreconcilable, and who have held out against the easy assimilation to which the major religious congregations have yielded in their growing desire to seem progressive. Theosophists and fundamentalists, spiritualists and flat-earthers, occultists and satanists ... it is nothing new that there should exist antirationalist elements in our midst. What *is* new is that a radical rejection of science and technological values should appear so close to the center of our society, rather than on the negligible margins" (p. 51).

But science is subject to attacks more subtle than those of the bourgeois young, attacks on the view of its classical Mertonian ethos. The attack on the basic tenet of "organized scepticism", I believe, dates back from the first publication of Thomas Kuhn's great book: *The Structure of Scientific Revolutions*, (p. 160. I quote from the 1970 edition). In his epoch-making book, Kuhn has shown that what he calls most "normal" scientists are committed almost blindly to certain paradigms, which are regarded as proved once and for all, that is a certain view of fundamental scientific truths which suggest fruitful avenues of research and solvable problems or "puzzles", as Kuhn calls them. Speaking of historians of science, Kuhn states, "The more carefully they study, say, Aristotelian dynamics, phlogistic chemistry, or caloric thermodynamics, the more certain they feel that those once current views of nature were, as a whole, neither less scientific nor more the product of human idiosyncrasy than those current today. If these out-of-date beliefs are to be called myths, then myths can be produced by the same sort of methods and held for the same sorts of reasons that now lead to scientific knowledge" (p. 2). Paradigms in science are transmitted through an educational process which is far removed from organized skepticism and close to the dogmatism of, say, certain religions. Until very late in his career, the student is never taught to look at original evidence, much less to read historical scientific sources.

Kuhn still believed, however, in a certain truth with which thought could be matched and which could validate it. Many quotations from his book support this assertion.

It is true that he states (p. 171) "Does it really help to imagine that there is some one full, objective, true account of nature and that the proper measure of scientific achievement is the extent to which it brings us closer to that ultimate goal?", but, in his book, I have counted no less than twelve passages in which he seems to assume that the aim of science is just that: to bring knowledge closer to a certain "truth", which can be known objectively. Thus (p. 27) he speaks of the "immense effort and ingenuity that have been required to bring nature and theory into closer and closer agreement" and (p. 30) of the "immense difficulties often encountered in developing points of contact between a theory and nature". Similar quotations could be multiplied, but suffice it to say that I believe, as I think Kuhn does, that there is such a thing as "truth", an external state of nature, independent of our will or of our desires, which can be known through "objectivity", a certain way of knowing the constraints present in nature observed, and bowing to them without which there would be no science and, in the long run, science would not "work".

This does not mean, of course, that there are not, in science, many elements of a subjective and dogmatic nature, which Kuhn analyzes very properly.

But Kuhn has followers who have gone further than he. These range from Barry Barnes (1974), who in his extreme sociologism, believes that "no arguments will ever be available which could establish a particular epistemology or ontology as ultimately correct. Belief systems cannot be objectively ranked in terms of their proximity to reality or their rationality" and confers the ultimate seal of "truth" simply on the social community of men of science; to Paul Feyerabend, who considers himself in science, not an anarchist but rather a dadaist, whose motto in scientific methodology is "Anything goes".

But the truth is that the run-of-the-mill scientist, at least in developing countries, still sees himself as performing under Mertonian norms. In a survey which we are conducting with Yajaira Freites on the Venezuelan scientific community, Kuhn is practically unknown, much more so Barnes or Feyerabend, and there seems to be generalized belief in the objectivity and reliability of scientific knowledge.

If there is faith and enthusiasm in developing countries towards science, it is perhaps due to the fact that there is so little of it there. It has been said that more than 90% of the research which is being performed in the world comes from developed nations; and indeed that no more than 2% of all research done deals with problems specific to developing countries. If it is true that science contributes to development, this is a grave situation which bears urgent correcting. It is probable that this will not be exactly easy, for it is most likely tied up with a way the world structure functions. Some countries are and have been traditionally providers of raw materials and others, the developed ones, are providers of manufactured goods. The tendency is for this system to perpetuate itself: research is performed in the central countries which need it most to remain competitive and the rest of the countries remain a desert for science.

Science, through its strong and self-perpetuating educational process, and through its visible benefits to mankind, seems to be an irreversible movement. We must continue to cultivate it, in the meantime insuring wisely that it does good and no harm. Although I thoroughly respect the cultivation of excellent basic science, motivated by healthy curiosity alone, I strongly feel that, for most scientific works, especially of the applied type, the basic questions: "For what?" and "For whom?" must be answered before such science is undertaken. There are in our society certain basic injustices which, if possible, science must help at least to mitigate. Development through science and technology must include at least the objectives of eradication of poverty, relative equalization of incomes, full access to productive work, and independence of one's country (Seers, 1972; Roche, 1976).

Whatever the case may be, science is a uniquely twentieth century value, and we are likely to see more rather than less of it in the near and in the distant future. Man should learn to employ his ethical sense to use science wisely and uniquely for the benefit of mankind.

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REMARKS ON SCIENCE AND CIVILIZATION

VICTOR F. WEISSKOPF

I.

Natural science is one of the most important manifestations of contemporary culture but is not generally recognized as such. I believe that the intellectual edifice of modern scientific thought equals in significance the edifices of the Gothic cathedrals of another very different cultural epoch. Yet, to a large extent the cultural and intellectual significance of natural science is not recognized by the general public. Only a small part even of the intellectual public is aware of the tremendous depth and range of modern scientific thought. This deplorable condition is to some extent the fault of the scientists themselves. Very little effort is devoted to the art of presenting the intellectual content of modern science to the educated layman. Success in such endeavor is not rewarded sufficiently; rather it is regarded as a secondary achievement rated much less than original research. Indeed a masterful presentation for laymen is valued much less than a third-rate so-called original research contribution. This is in glaring contrast to the situation in the performing arts.

What is needed here is a re-evaluation of the art of presenting science to the outsider, a talent search and a highly visible recognition for achievement in this field. There exists no journal of science on a serious level that can be read and understood by an intelligent person not trained in the sciences. Of course, science writing on that level is a very arduous task that needs much study, training and a very special talent. Why is so little effort spent and so little recognition given to this cultural endeavor which is so important in a period where the true value of our civilization is questioned and attacked from so many sides?

II.

Natural Science and technology are intimately connected. This was not always so. The history of technology shows that, say, before 1800, technology developed rather independently as a practical art, with little connection to the development of science. Recently, however, the influences from one on the other are enormous. The development of modern technology is unthinkable without the basis of scientific insights and discoveries and the development of modern science is unthinkahle without the support of recent technology, which provides the tools and means for experimentation.

The knowledge accumulated in modern science and technology was a source for power over the natural environment of an unprecedented scale. This power was continuously applied by man in an ever-increasing measure. All forms of power — be it over nature or over people — can be and will he applied for good and for evil purposes and so was the technical power over nature. On one side, the development of enormous energy sources has considerably reduced the human toil in agriculture, construction and transportation; on the other hand, the technical development has produced new means of warfare and exploitation of man by man, vastly superior to anything existing before.

The development of science and technology takes place at an accelerating rate. Methods of research and development are constantly improving, the number of people involved in the process increases steadily, and the activities have spread over the whole of mankind. We have reached a new stage within the second half of this century, both in respect to the spatial and the temporal extent of this development. No longer are human interferences with the natural environment restricted to a few selected places, the changes perpetrated by technology upon nature cover today a significant part of the surface of the globe. Furthermore changes in the environment and of human behavior take place so rapidly that the life style of one generation differs considerably from the previous one. Thus, the experiences of the parents are no longer useful for the solution of the problems of the children; this is a new situation in the history of mankind whose consequences for the fate of future generations cannot be judged. The decreasing value of tradition may produce serious troubles.

III.

The fast spreading use of technology has affected the world by creating a disequilibrium in several respects. These disequilibria are becoming more and more dangerous if nothing is done to redress them. Let me enumerate a few of them.

Science and Technology are the art of the possible. Only those problems are attacked and solved which are believed to be solvable with the available methods and insights. Indeed, the great development of science began only when the interest shifted from general and fundamental questions, such as what is the origin and the end of the Universe, the nature of life, or the structure of matter, to special and directly answerable questions, such as how does an object fall, how do tbe planets move, how does the blood circulate in the body. Of course, it is remarkable that the pursuit of those special questions brought us nearer to the answers to the general questions than we ever were before.

Technology as the art of the possible is one source of disequilibrium today. We are able to walk on the moon but we are not able to construct an electric battery which could serve as power source for the motor car. We are extremely successful in one direction and almost powerless in another. The technical frontiers are pushed forward in the directions where there is a method at hand but not in others where we do not have any solutions. The latter directions often are those that need most progress from the societal point of view. This makes for disequilibrium.

Another perturbing influence comes from the organization of our technical production and its system of cost-accountings. In most cases only the immediate costs of production are considered and not the indirect costs to society which accrue through the pollution of the environment or the long range deterioration of life style. This again produces a disequilibrium by overdeveloping those technical devices that seem economical on a short range and by neglecting developments that in fact are more beneficial to society. The use of the private automobile versus public transportation is a typical example: the immediate cost to the consumer seems to be less for the private car but the long range pollution and congestion problems would probably make public transportation the cheaper solution.

A most pressing example of disequilibrium was caused by the development of medical science. The success of medicine in this century is tremendously impressive. Epidemics are eradicated, child mortality is at a minimum, the average age of persons is more than doubled, pain in most of its forms is virtually abolished. We have succeeded in what one may call "death control" in the sense that modern medicine can avoid death by most diseases before a ripe age. These successes have led to enormous population increases, in particular in the underdeveloped regions. Thus death control produces tragic disequilibria in population numbers if it is not accompanied by an equally effective birth control. Our desperate efforts to feed the populations in the developing countries will come to naught if we fail to keep population numbers down by effective birth control measures. The technical means exist, but not yet the social means to make them effective.

Another eminent source of major disequilibrium is the increasing gap between developed and developing countries. The former suffer from "over-development" in the form of wasteful exploitation of resources in order to fill vastly exaggerated needs for material goods and services, the latter suffer from a severe lack of those goods and services for the majority of the populations. The present social and commercial organization of world trade and of educational facilities exacerbates the situation in most countries of the world. Professor S. Siddiqui deals with this most pressing problem at length at this meeting.

Finally, last but not least, the tragic disequilibrium between high military and low social expenses must be mentioned. Although this discrepancy is as old as history, it is much exacerbated by the development of science and technology which created so many new possibilities to spend money and effort on expensive means of destruction. The situation has become highly paradoxical since the invention of nuclear devices. In contrast to the weapons of the past, these new weapons cannot be used without causing irreparable damage not only to a potential enemy country but to the whole world. Hence, these weapons are made not to be actually applied but only to be used as a threat. Is it not the height of folly and irrationality, when competing nations spend a considerable part of their total production capacities upon fabricating objects which they never intend to use, with the only justification that the other side is equally silly and irresponsible? Unfortunately, just the fact that the nuclear arms race is based upon silliness and irresponsibility is a source of great danger, since we cannot be sure that the responsible arguments against nuclear warfare will be heeded in times of political stress and crisis. A stop to the nuclear arms race and subsequent nuclear disarmament are an absolute necessity and a precondition for the survival of humanity. Much too little is done and we are still much too far from this aim.

IV.

What can be done to redress the tragic dis-equilibria created by Science and Technology? Some of them exist because of unsolved problems of natural science and its applications, and, therefore, their solutions need more concentrated scientific efforts. Others are of social character, caused by political or organizational problems.

The dis-equilibria stemming from the character of science and technology as the art of the possible are of the former type. Here it is necessary to extend the limits of the possible into those directions which are required by the social necessities. Research into electric batteries for motor cars is such an example, research into the nature and consequences of air pollution is another. The development of new energy sources, such as fusion or solar power also belongs to this category. These efforts often require collaboration between different natural sciences.

Most of the dis-equilibria, however, have their origin in the structure of our social organizations. To some extent, they are caused by the lack of corrective mechanisms in our society. A typical example is the short sighted cost-accounting of technical developments. To a large extent, however, these dis-equilibria are based upon a lack of political awareness of the problems and a lack of social morality which would put long range aims of the society as a whole, before short range advantages to certain groups in power. Certainly it would help greatly if all these problems were studied in greater depth by social and political scientists, but a real improvement of the situation can come only from a subtle but thorough change of attitude towards social problems within the broad population. The scientists — natural and social — should play an active role in this change but they can only help if they join with all other parts of society.

We must be aware that science is only a part of our culture, albeit an important one. It is based upon man's curiosity as to how nature and society work. But there are other human urges besides curiosity which are equally important, such as compassion with the fate of our fellow creatures. We will need them all in order to improve the human predicament. Curiosity without compassion is inhuman, compassion without curiosity is ineffective.

IMPERATIVES OF RESEARCH AND DEVELOPMENT IN THE DEVELOPING COUNTRIES

SALIMUZZAMAN SIDDIQUI, F.R.S.

The phenomenal achievements of science and technology in modern times and their impact on every sector of human endeavour have made it imperative for the developing countries to recognise their vital role in the plans of national development. They have also taken account of the fact, that scientific progress involves a highly complex process of phased planning and programming of effort over a wide front. This is so, because education at all levels and researches relating to the various sectors of development do not permit the allocation of priority to any one of them at the expense of the other. With this reservation, however, the greatest stress has got to be laid on raising the standard of education in various scientific disciplines at the universities, without which a secure and solid infra-structure of all future developments in the field of material and cultural endeavours cannot be assured.

In respect of policies pertaining to research and development, one of the most controversial problems is concerned with the allocation of priorities to pure and applied aspects of research at the national level. This is rather odd, because there is obviously such a close interlink between these two aspects of research that they cannot be labelled under rigidly defined categories. It is in fact on this account that whenever this problem comes up for debate at the national or international conferences, it is invariably agreed at the end that no applied research laboratory, if deprived of the atmosphere in which pure research can take root and grow, is likely to develop into an effective centre of research, and that fundamental and applied researches keep on throwing up problems to each other, invigorating and vitalising them both in that process. On the other hand, however, it has to be kept in mind that in the course of the current century, the ivory tower approach of "science for the sake of science" has had to yield to the growing demand of the human situation for its utilitarian orientation, and the national research organisations of a country have, therefore, got to concentrate their research effort on problems which have a direct bearing on the utilisation of the natural resources of the country to their optimum economic advantage.

Leading on from here to the actual promotion of oriented and applied research, it has to be pointed out that science and its applications cannot progress in isolation and that, as already indicated at the outset, their planning has to be closely integrated with the whole wide range of national objectives in the field of education, agricultural productivity and industrial enterprise. It has to be accepted that the determining factor in any scientific undertaking in pure or applied fields, is the status of the educational base in the country, which is linked up with the availability of scientific and technological personnel. It is necessary, therefore, to go in for a massive but carefully phased programme of training, to ensure a gradual build-up of leadership in the various disciplines of scientific research, and technological capabilities.

Another problem that faces the industrial underdeveloped countries relates to the lack of adequate arrangements for the utilization of research results. This makes for a grave and frustrating situation for their national research organisations, because of an increasing insistence that the large funds expended on them should be justified by demonstrable economic returns. Even excluding this compulsion of cost-accounting, applied research appears pointless to scientific workers, if its results are not closely integrated with the relevant sectors of economic development. To cope with the situation, some of the countries have established research utilisation boards, to promote industries hased on research in various applied fields. Due to lack of adequate funds for such a vast undertaking, however, they have not so far been able to make much headway in this direction.

The difficulties that block proper utilisation of research results would appear to be inherent in the mechanics of the first phase of industrialisation in the developing countries. In this phase they generally have to buy foreign technology at a heavy cost as, for instance, was done by the Pakistan Industrial Development Corporation to raise their industrial base. However, it is not fully realised that this cannot be the whole of the answer, and that we must invest and invest heavily in scientific and technological research. This may take a long time to exercise its impact on development; without it, however, it would be impossible to fully harness our human and material resources, and we shall continue to be underdeveloped entities.

Yet another aspect of the situation merits consideration. In the present phase of industrial development, the entrepreneurs of industry settle for "turn-key" jobs, done for them by foreign firms in the manufacture of such well-established commodities as cotton-textiles, jute goods, and petro-chemicals, rather than accepting new processes and products evolved by the research organisations of their own country. Along with this goes the build-up of vested interests, which generally exert a great deal of pressure against the utilisation of researches relating to indigenous resources. Against this background, it may not be inappropriate to cite a few case histories based on my own life-long involvement in this field, to illustrate the difficulties experienced in the correlation of research and development.

As a result of our work on the roots of Rauwolfia serpentina Benth. during the 1930s, about 10 new alkaloids were isolated, and the first paper reporting the ajmaline series of bases was published in 1932 [1]. However, it took nearly 20 years before one of the alkaloids, namely reserpine, was established as a potent drug in the treatment of high blood pressure and mental ailments; and a good deal later ajmaline was increasingly recognised as a drug of choice in the treatment of cardiac arrhythmias of various origins. This long time lag between research and development relating to important therapeutic agents, has been mainly due to lack of adequate facilities with us for inter-disciplinary researches in the field. More recently two therapeutically important nitro derivatives of reserpine have been obtained at our Institute of Chemistry [2], which show the same order of hypotensive activity as reserpine, but are completely free from their undesirable side effects, when administered to experimental animals through the intravenous route. The commercial exploitation of these therapeutic agents is, however, biding time, due to lack of entrepreuner spirit among the industrialists of our underdeveloped country.

A most exciting contribution in the field of alkaloids has recently resulted from years of persistent research efforts of a younger group of scientists of the Institute. It relates to the first synthesis [3] of two dimeric alkaloids occurring in the leaves of *Vinca Rosea*, commonly known in our country as "*sada bahar*" (ever-green). These alkaloids, vinblastine and vincristine, have been found to be extremely useful in the treatment of acute leukaemia in children, cancer of the lymphatic system, cancer of the foetal membrane and many other malignant conditions. Unfortunately, they occur in the plant only in traces, with the result that these life-saving drugs are costing several thousand dollars per gram, posing a serious problem to the pharmaceutical industry, that may be resolved through their synthesis from vindoline and cataranthine, occurring in the leaves in much larger quantities. The problem here again is, whether the commercial benefits of this finding could at least partly accrue to any of the under-developed countries, with the poorly organised condition of their pharmaceutical industry.

I would cite only one more case, to illustrate the handicaps which our scientific organisations have to negotiate in bringing about the utilisation of their research results. Long range studies extending over a period of about 8 years under the Pakistan Council of Scientific and Industrial Research, resulted in a series of chlorinated insecticides based on indigenously available petroleum cuts [4]. Laboratory tests and field trials carried out in association with the Department of Agriculture, have shown them to possess the same order of pesticidal activity as toxaphanes. They further have the advantage of extremely low mammalian toxicity, and also of being heavily synergised by the addition of small quantities of some of the more potent pesticides like endrin and gammaxane. The importance of this development to the agricultural productivity of the country may be gauged from the fact that Pakistan has been annually importing over 10 million dollars worth of pesticides which can take care of barely 10% of its plant protection requirements. Nonetheless, this development has been delayed over the years due to vested interests in the import of insecticides, and due also to a certain lack of faith in indigenous research effort. However, the struggle is on and one may hope that through sheer pressure of the economic situation, these pesticides may eventually be taken up for large scale commercial production.

With reference to these few case histories and the rather expansive observations preceding them, it would appear an obvious demand of the mechanics of R and D, that adequate funds should he provided for them. As to the adequacy of funds in this context, I may point out that the State expenditure on scientific research in the developed countries ranges from 2% to 4% of the G.N.P. As against this, the figure for Pakistan is barely 0.13%, and the position obtaining in the other developing countries, may not he appreciably different.

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DISCUSSIONS

Lépine

Il est essentiel, lorsque nous parlons de science, de distinguer la science et les applications de la science. La science est libératrice tandis que la technologie est contraignante. Si elle allège son travail, en même temps la technologie peut créer chez l'homme de nouveaux besoins et par la même l'amener à un nouvel esclavage. Certes, il est encourageant de voir que par la science les maladies infectieuses disparaissent, on soulage la douleur, la chirurgie fait des progrès, assure les moyens de vie dans l'augmentation de la population, mais en même temps nous constatons — et je trouve dans mon propre pays ce que je vois dans la plupart des pays très évolués — que, par exemple, l'automobile chaque année entraîne deux fois plus de morts que n'importe quelle maladie infectieuse. Que ne ferait-on pas contre une maladie infectieuse qui entraînerait un tel nombre de ces infirmités, de tels désastres? Certes, il est enthousiasmant que le monde entier puisse assister, voir et entendre l'homme marcher sur la lune, montrant ainsi un développement prodigieux de télécommunication, mais nous avons appris que les mêmes techniques mises entre les mains d'un parti politique permettent de dévier la vie de l'homme, de rompre l'intimité de la vie privée, de surveiller, d'espionner les gens, et par la même devenir des agents d'une invasion terrible de la vie privée. Certes, il est passionnant que nous puissions explorer l'espace, mieux connaître l'univers et ses dimensions, et hier soir la conférence du Professeur Dirac nous montrait l'ouverture que ça donne sur l'esprit, mais au même moment nous appercevrons que par l'application de la science les ressources de la terre sont exploitées à un tel point que nous devrons envisager que les sources d'énergie existantes vont être vite épuisées parce qu'on les a gaspillées, et que nous consommons relativement plus d'énergie que nous n'aurions besoin pour vivre simplement. Ainsi, le domaine des se poser finalement au cours de la vie d'un homme. Il faut encore souligner l'importance de mettre la population dans le sciant de la science. C'est une responsabilité des scientifiques.

Et puis enfin il y a un dernier point que je voulais évoquer aussi. C'est que la science a une méthode, que cette méthode rationnelle a un langage qui est universelle. Je crois vraiment que tous les scientifiques sont extrêmement conscients du fait qu'il y a une universalité de la science, universalité avec un dénominateur commun entre tous les scientifiques. Cette méthode, ce langage, créent une fraternité entre les hommes, et on sent chez tous les scientifiques qu'ils comprennent parfaitement bien qu'il y a cette fraternité. La science est un élément de fraternité telle que certains considèrent que la fraternité entre les hommes doit se faire par la science et que, au contraire, les religions sont des causes de difficultés et d'incompréhension entre les hommes. Voilà une tendance qui existe chez certains scientifiques. Bien que je ne suis pas de cet avis-là, j'en suis très conscient. Je pense que la fraternité scientifique internationale pourra jouer un rôle essentiel dans la paix du monde.

LEJEUNE

Je voudrais tout simplement faire remarquer que les deux orateurs précédents ont, simplement, résumé, en partant de la science, ce qui est la nature des hommes. Je m'explique: Monsieur Weisskopf nous a dit — et il a terminé là-dessus — que ce qui était visiblement le moteur principal de la connaissance c'était la curiosité devant la nature et la compassion pour les autres hommes. Il nous a dit en termes très simples ce que Pascal disait: le coeur est la raison.

Il se trouve que quand on écoute Monsieur Roche, on apprend qu'une partie de notre science est fondée sur l'aversion contre l'anthropocentrisme, mais qui donc oserait faire une science qui ne soit pas centrée sur l'homme? Qui donc oserait faire une science qui soit centrée sur le rat et qui fasse une science ratomorphique? Ceci choque la population, qui a beaucoup de bon sens et qui sait très bien que la science ne peut être que anthropomorphique, car nous n'avons qu'un seul outil, qui est la raison, et que la raison nous est donnée par notre nature, et c'est parce que nous avons la nature d'homme que nous possédons cet outil.

Je crois aussi, et j'ai été heureux que ce soit signalé par Monsieur Leprince-Ringuet, que la peur contre la science vient un peu de la gloire que nous tirons de ce terrible et merveilleux esprit prométhéen qui nous a permis de dérober vraiment le feu des étoiles. Nous savons que nous pouvons allumer, à notre tour, notre planète, et ceci est une des peurs, profonde, inconsciente, une suspicion contre la science. Alors cette crainte vient en fait de l'impression que donne la science moderne que nous croyons — nous, les scientifiques — que la raison est toute puissante et qu'elle explique tout.

Personnellement je ne le crois pas. Dans l'évolution des êtres vivants la raison s'est épanouie chez l'homme. C'est vrai. Mais il ne faut pas oublier aussi que le coeur s'est épanoui chez l'homme plus que chez tout autre animal, et la connaissance que nous avons du monde serait complètement amputée si nous ne tenions pas compte de cette obscure bonté qui vient du fond des âmes et qui est inscrite dans chacun de nous. Alors il me semble — et c'est ce que je voulais vous dire en tant que biologiste — que ces discussions si importantes sur la science finissent finalement à constater que nous avons un outil, qui est la raison, mais que cet outil n'est pas la raison de vivre.

Notre raison de vivre se situe à quelque chose de plus profond, qu'on appelle habituellement le coeur, que les neurologistes mettraient dans l'hipothalamus et qui explique pourquoi nous avons tant de peine à ce que tous les deux s'entendent; parce que touchant au plus profond de la vie par les hormones, l'hipothalamus ne sait pas parler, et seul les poètes, les artistes, les mystiques, les amoureux ou les enfants savent le faire parler. La science, elle, est exclusivement corticale — elle a sous commande tout le vocabulaire, mais elle ne comprend pas très bien le langage du coeur. Tant que les scientifiques n'auront pas compris que leur sagesse repose dans l'entente entre le coeur et la raison, ils n'auront pas à s'étonner que la population ne les comprenne pas, car tout homme connaît cette difficulté, inhérente à sa nature, et il s'attend à ce que les savants la connaissent aussi.

HÖRSTADIUS

I hope that I may be allowed to speak about a real danger to science in a developed country, if you allow me to speak of Sweden as a fairly developed country. We have had for 44 years a Social Democrat government. Now in September we had elections and it will be changed. It was planned to create a board above the universities, institutes of technology, etc. This board would consist of one or two professors and the other members would be political members. In the program of the parties of the Left — Socialists and Communists — this board — political board — would decide upon what kind of scientific programs should be allowed and would receive money. That is to say, as far as I understand, that the curiosity of scientists, of basic science, would really be in danger and that this board probably would only support applied science. That is indeed a great danger for the future also in a developed country.

SZENT-GYÖRGYI

My colleague Weisskopf has given a list of disturbed equilibria. I would like to add one more point to the disturbed equilibria. Science has given us enormous power, but has disturbed the equilibrium between doing things and wisdom: what to do and how to do. I would like to support that with one example. In the next year my own country will spend 1.3 times 10 to tenth dollars on instruments of killing, while about half of the children of the world are still starving and cannot develop a good brain because of lack of protein. With that money we could flood the whole world with protein. This is, to a great extent, also responsible for the unpopularity of science, because what the common man sees — what has he got for his money — is the liability or possibility of being killed, or all mankind being wiped out at a moment's notice. That is what we have bought for all that money. So here is a terrible destruction of equilibrium, i.e., this money being spent on killing and destruction while half of the world's children cannot develop a good brain and must remain half animals all their lives. This is a terrible crime. And that is what is happening in one of the most advanced countries. So there is a profundly disturbed equilibrium. What can we do about it?

SEGRE

We are all aware that there are limitations in science, as has been observed by several academicians, especially Professor Weisskopf. Even in mathematics they are far from the certainty we had, for instance, in the last few centuries, when the world dreamed of being able to prove the non-contradictoriness of mathematics. Nowadays we know from the study of logic that it is impossible to find within a theory a satisfactory proof of non-contradictoriness. That can be done only by enlarging the field of study, and this puts mathematics in a quite different position. On the other hand, I think that there are dangers in mixing physics, so to speak, with metaphysics. I think there are restrictions one has to observe. One point raised by Professor Weisskopf is the need for the vulgarization of science. That is a very important point. I suppose that something could be done by this Pontifical Academy in promoting some serious work on vulgarizing certain fields of science. For instance, by establishing that the next Pius XI Medal be awarded to a man or woman who has done significant work in such a field. That would be a real contribution in a new direction, of great importance for the development of science.

FATHER O'CONNELL

I refer to the point that has been raised by Professor Segre. It may seem a side issue, but it is extremely important, as has been emphasized hy other speakers in this discussion: namely, the need to bring to the general public some appreciation of the nature and value and importance of science. Now Professor Weisskopf mentioned the fact that there is no suitable periodical for that purpose, and I fear tbat even a good periodical would not reach a sufficiently wide public. Really one sbould make use of tbe widest means of diffusion possible; that is, tbe media: the daily press, radio and television. I think, for instance, of the articles by Walter Sullivan in the New York Times. If academies could encourage their members to make use of these means of bringing matters to the general public, I think it would be much easier to reach the people.

CHAGAS

Before closing this meeting, I would like to make a few remarks. I come from a country which has an interesting tradition in medicine and has recently made a very great effort to develop science since the establishment of its Research Council in 1952. One of the problems of our scientific collectivity has been, at one point, to fight the econometrics of the government, which is run mostly by economists. However, in the last three years there has been a great improvement in the concept that basic research is also an important component of the development of science in developing countries. This came out by showing positively that without basic science or at least some aspects of basic science — we cannot really conceive of national sovereignty. Its promotion is the only way we can avoid one of the most difficult problems of development at the present time, which has serious political implications, and that is, technological colonialism.

As Roche said, the figures representing the amount of money spent in developed countries for research of interest to developing countries is a very small fraction — about 2 to 3 percent — of the total amount expended. There have been many proposals and many studies — one of the most interesting was made by Sussex University on this subject — but in realistic terms we cannot expect that a substantial number of the scientists in the developed world should have a sort of missionary spirit and devote their time and their funds to problems which are far away from their environment proper. The best results are achieved when the interests of both parties coincide, as for instance in the case of tropical diseases.

Now, I think that in this discussion we left out one of the most dangerous aspects of the present situation in international scientific development, and that is the politicization of science. In every way it is becoming a danger, and I think it is something which has very serious implications. Recently in a meeting of UNESCO Sir Philip Noel-Baker presented the same arguments which were given here by Szent-Györgyi. As a matter of fact, the known amount of money spent yearly on weapons is about 300 billion Dollars. This is the acknowledged figure, but it probably does not correspond to the actual total amount of capital invested in weapons. Now, a simple calculation could show that 10% of that amount, which is about 30 billion Dollars annually, would really alleviate if not solve many of the health, nutritional, housing and transportation problems of the developing countries, especially those countries which are considered now to be in the most primitive stage of development.

I think it was also said here that one of the most important questions is the diffusion, or the popularization, of science. Recently Walter Rosenblith, in a lecture given at the Institute of Biophysics in Rio, pointed out a very interesting fact: if we go to the scientists and ask them what are the three most important discoveries which have been made in the last years, they would certainly say the DNA recombination, the concept of quarks and the displacement of the earth's crust. Not one of these important discoveries has any appeal at the present moment for the people, who still regard antibiotics, the man in the moon, and probably heart transplantation as the great achievements which have been made in science. This shows really an abyss between the scientific world and the person of average education. This is a difficult obstacle to overcome and the use of mass media should, in my opinion, be stressed.

One should point out that the former President of the Accademia dei Nuovi Lincei, which preceded ours, Father Gianfranceschi, was a precursor of this idea of using Radio Vatican to broadcast. Marini-Bettòlo has recently used the Radio Vatican waves for the same purpose, and we hope that this can be followed by other colleagues.

Professor Segre has made a very interesting proposal, which will be studied. With regard to the diffusion of science, I would like to mention the Kalinga Prize, awarded by UNESCO through the initiative and grant of an Indian scientist. It is given every two years to a writer or journalist who has exerted an important role in the diffusion of science; but so far as I know, it is becoming difficult to find good candidates for the prize. The public wants dramatic information and as a consequence many times scientific discoveries are overemphasized, giving the public exaggerated expectations and unrealistic hopes.

I think that what we all here present feel is that without science mankind cannot face the challenges of the future, such as, for example, the demographic explosion, the phenomenon of urbanization, leading to the pollution explosion, and problems of housing, traffic, food, as well as the new diseases which can be the result of new external aggressions (the Arbor-Virus diseases are an example), the psychosomatic diseases, and the neuroses which result from the high population density of new communities.

THE EDUCATION OF A SCIENTIST

A. R. J. P. UBBELOHDE

In deliberating upon possible deficiencies in the current education of scientists, there is always the risk of "overkill", of paying too much attention to his tasks when mature. It is the early stages that matter most, and in these, sound tradition suggests that education should as far as possible be unitary, though leading to multiple options: vocational differentiations should be postponed as long as possible.

This traditional view must nevertheless pay regard to features which are new and prominent in the perspectives of the long world history of education. Education has no real precedents for dealing with at least three major innovations arising from modern science:

1. *Leviathan*: The bulk of scientific knowledge is enormous and is growing continually. This presents major intellectual as well as physical problems, and not only for the specialist in science.

2. *Civitas*: Modern science has become truly world wide in its empire. Exchange about scientific matters between peoples of very different cultures and different intellectual allegiance take place easily, and meet with far fewer obstacles than have ever been met before in exchanges of most other modes of human knowledge. Whilst this situation offers unique opportunities for world collaboration, it must never he forgotten that the depersonalised characteristics of modern science partly account for it. And depersonalised science does not graft very obviously or very naturally

onto every local cultural inheritance, nor onto many traditional patterns of education. Ominous fissures in the unity of human knowledge may result, as well as chasms in human communication.

3. *Material Power*: Applied science is now being used on the largest scale to master material difficulties which heset mankind. Whilst such large scale applications are generally necessary and thus beneficial, they can entrain increased risks of distorting the balance of nature, as well as of enslaving humans through excessive dependence on such aids.

Each of these three features may be examined in turn with special regard to their influence on educational policy. Quite often, of course, their consequences are closely intertwined; this is particularly so for the first two.

Leviathan or the bulk of knowledge

Wonder as an incentive to learning: For alert young humans, interest in the world around them begins very early. A sense of wonder about the World and about the Universe is their birthright. Powerful incentives to make creative responses stem from wonder, these must never be quenched by injudicious or premature exposure to any sheer bulk of knowledge, however important its content may be. Leviathan is nevertheless there, sprawling across the paths of all of us. It must be accepted that for many mature scientists, as well as for most people with other kinds of vocations, career lines are destined to become highly specialised and selective. The great bulk of modern knowledge can thus drive many into that fatal kind of ignorance which arises from specialization in too narrow a line of advancement. Specific educational provisions seem to be needed to mitigate the grave risks involved from extreme specialization; these risks include the quenching of creative responses to new situations, and many other evils as well.

If one thinks of science as a growing tree of knowledge for each one of us, one general prescription is that the young scientist should have preserved for him as many option "buds of growth" as is feasible, to permit later development of patterns of knowledge that are individual. Of course it has long been recognised how dangerous it can be for precocious gifts to flow along too narrow channels. For example, it was this kind of thinking that made the father of Blaise Pascal make his son promise to leave aside his beloved geometry "les ronds et les barres" until such time as the boy had made better progress with his humanities. Science was less complex in the seventeenth century; probably his father's pattern sufficed for the growth of young Pascal. But its lack of subtlety may have generated tensions, too; and in any case the enormous extension of modern science makes it harder now to prescribe measures against premature specialization that are both simple and acceptable.

Our inheritance of knowledge is so great that one needs to consider the evils of specialization even within modern science itself. Evils of hindered access to all the other branches of human knowledge take a different form, and should be examined separately. Broadly, the flux of modern science may, for the present discussion, be divided into two main streams. One of these comprises all forms of physics. In the educational context it is important to stress that physics is not just abstract mathematics, since it involves a bracing experimental experience of nature, as well as its mathematical analytical representation. Abstract mathematical reasoning must, of course, be self consistent to be valid at all; but it is the modern success in achieving remarkable correspondence between reasoning and experience which needs to be stressed educationally. The other main stream of science rationalises experimental experience in various descriptive forms in so-called "laws of nature". No complete analytical mathematical representation has been found and probably cannot be found for these laws, in particular in the life sciences. (Hybrid situations as in molecular biology do not at present extend very far.) With all educationalists, one must accept, as did Etienne Pascal, that a basic function of education must be to enrich later mature growth by restraining any overwhelming preferences at too early a stage. Accordingly in his formative stages, the young scientist should have bivalent access to both kinds of scientific response to experimental experience, that which is mathematical/analytical, and that which is descriptive of living beings.

But what of the humanities? Lack of communication between mature workers in the two main streams of science can cause serious fissures, though this is often known only to those immediately concerned. Much more widely known are the chasms of inadequate communication between mature scientists and those whose primary directions of purpose and action stem from other forms of knowledge.

The civitas of science and the communication of knowledge

To survey the chasms, it is helpful to start with a map of knowledge, even if parts of it are only visionary, like mediaeval maps of the World. One can begin by accepting that all forms of knowledge serve to enrich MAN; they must in a sense all be homocentric. Concerning the unity of all human knowledge, the vision of a hierarchical Kingdom has long inspired Western civilisation, right hack to educational patterns followed by the Greeks. But in our time, it is arguable that the vision of a Republic of knowledge, with its stress upon liberty, equality and fraternity provides a better guide than the hierarchy of a Kingdom, particularly when resolving the all-important prohlems of communication. Whatever the map used, a vision of some viable form of organised relationships between different modes of knowledge seems essential. Mere encyclopaedism is no answer to our modern problems about how to enjoy and how to use all human knowledge effectively. If we think of knowledge as a commonwealth, extreme specialisation can be tolerated at the periphery, but only because of the bulk of modern knowledge. If one maps a homocentric road system, clearly the ring roads are as important as the radial roads to ensure good communication of knowledge.

Greek education (to go back no further) had as one enviable component a training in the arts of eloquence, how to communicate ideas and how to persuade hearers to accept and act upon them willingly. Communication of ideas and objectives across barriers of specialization in modern civilisation urgently demands some more complex equivalent to such training. Without it, acceptance of common purposes is all too often imposed on hearers wbo are servile or indifferent. If man's destiny and nature in a mysterious way is to reflect and focus every aspect of creation in turn, our current role, through lack of intelligible communication, sometimes seems to reflect the communal living and highly specialised functions of termite communities. At human levels there are, of course, many more kinds of specialization than in any termite communities yet discovered. But without a proper vision of the unity of Knowledge, as basis for a map to achieve adequate communication and enjoyment of different forms of knowledge, the rich potentialities of our humanity tend to be replaced by bureaucratic stereotypes of one kind or another.

Whilst a good road system is essential in education, the decision, which ring roads as well as radial roads of communication to establish, in modern attempts to achieve homocentric systems of knowledge that are acceptable, is in some degree a matter of expediency. Quite possibly, different road plans are best suited to different cultures, and to different parts of the world. Philosophers would probably wish to emphasise intellectual patterns and would stress filiations and analogies between different branches of knowledge. Urgent practical demand for easy lateral as well as radial communication between specialists may, however, strengthen incentives to build good ring roads on a more pragmatic plan. Though far from being the only source of pragmatic incentives when formulating educational patterns, a strong driving force clearly stems from the material powers of applied science.

The material powers of applied science

Problems of education in communication between those destined to become specialist leaders in some branch of science, side-by-side with others who will cultivate other specialities, are in fact focussed as well as made more urgent by the enormous material powers made available by application of science. Obviously such applications of science can only succeed through effective collaboration of scientists with other kinds of specialists. This implies appropriate educational patterns and, with regard to many urgent human ills, modern experience increasingly shows that scientific applications that are intended as a remedy can bring consequences which clamour for further remedial measures. Thus bigger and better agricultural crops through the use of insecticides seem an obvious benefit, but they may bring on an aftermath of pollution, and may upset more than one symbiotic balance in nature. Again, replacement of many traditional natural products by machine-made artifacts, as for clothing and housing, promises to relieve extreme poverty, but may also bring gargantuan problems of rubbish disposal. More subtly again, abundantly available mass entertainment in highly sophisticated forms may perhaps provide solace for the greyness of living, but it also may stifle the natural creative responses that remain alive in many quite humble traditional arts and crafts. And so on. As is well known, the balance sheet of good and evil from application of science to meet human needs can, in fact, be extended almost indefinitely.

A common reaction to the consequential evils from brash and unthinking large-scale applications of science, which often seem so beneficial at their outset, is to term "all applications of natural science to meet human needs as ultimately harmful and ultimately even anti-human". Such a nihilistic reaction must be resisted as quite unhelpful and not even meaningful. To undo present large scale applications of science to world problems, even were it possible to go into reverse, would open the door to evils even greater than, say, ecological pollution. We must accept that grave tensions can and do arise even through applications of science which are beneficent in their original aim, but which bring unforeseen consequences in complex human situations. This strengthens the need to attend to careful (which means early) formation of specialists whose skills alone make such large scale operations possible. No real discrimination should or can be made in this situation between specialists whether in science or in other forms of knowledge.

Particularly for leaders, communication and collaboration is an essential precursor to large scale operations. A Platonic Utopia is no longer safe (if it ever was) to educate specialists as a body of men segregated from their fellows, and not themselves expected to control or even properly visualise the consequences of using material powers on a scale that is unfamiliar. Thus, in building ring roads of communication for the modern commonwealth of knowledge it is safe to require education in the social consequences of science as an essential component in the formation of practically all citizens. We may of course stress that education in the natural sciences in either of its main streams should always include some understanding of the social impact of applied science; but we must also stress that other kinds of specialist education need this understanding likewise.

Ethical aspects of applied science

No uses of power can be contemplated without at least considering questions of ethical justification. Since research underpins any multiplication of the power of applied science, some have, therefore, held it necessary to justify ethically even research itself. It may be conceded that even when research has the aim merely to add to knowledge, some ethical constraints seem prudent in certain fields, for example, in genetic engineering. Restrictions on research do, however, raise doubtful issues concerning the integrity and freedom of knowledge. It seems generally unwise to accept such restrictions on research too readily, and not many scientists would view them favourably.

There can be no real doubt, on the other hand, about the need to judge the use of the material powers conferred by science, within a framework of ethics. In recent years, realisation of this need has taken a new turn, and has become very widespread, through increased experience of adverse consequences of applications of science on large scale that were intended to be beneficent. This aspect of the growth of applied science has stimulated ongoing discussion both nationally and internationally. We may assert that education of the modern scientist should certainly include access both to ethical codes and to political aspects of modern uses of applied science, even those that are beneficent in intention. One difficulty is that because the civitas of modern science is so wide, traversing as it does national cultures and different religious motivations, theory and practice of ethical codes in the uses of science tend to be rather pragmatic. Constant efforts at improved common agreement on the issues involved are to be strongly encouraged.

Our present problems are often quite novel, but it is worth noting the perspectives of history when considering ethical codes and ethical sanctions in the uses of scientific power. Two historic areas of debate, each of very long standing importance to mankind, are medicine and war.

In medicine, the so-called "Hippocratic Oath" focusses on ethical principles governing the beneficent uses of scientific knowledge. Its acceptance in the art of healing has been indeed widespread, traversing diverse national cultures, and different religions. But even in these beneficent uses, the material powers now available are grown so great that more extended as well as detailed discussion of modern medical ethics is needed. This has obvious consequences for any plan of education, that of the scientists as well as that of other kinds of specialists.

In warfare, that endemic plague of mankind, uses of science stretch back to proto-history. Numberless instances can be quoted to illustrate the fact that any challenge to national safety from without must raise up a response from applied science, as it does from all the other powers of a nation. There was Archimedes, deep in his studies of Mechanics and Geometry, interrupted and beset by the urgent sollicitations from the defenders of Syracuse, and in response creating all kinds of novel war machines described by Plutarch. There was Leonardo da Vinci, by no means ashamed of his long list of creative skills as a military engineer, including war machines, such as the famous steam cannon. It is notable, however, that Leonardo was so concerned about possible abuses of his invention of a submarine by tyrants, that he took pains not to publish it. There were the reluctant Jesuit scientists in Peking, pressed by the Emperor to help cast improved cannon, when the Empire was threatened by a Manchu invasion. And there are of course innumerable instances of more recent memory, of the powers of science applied to the needs of national defence, as well as of aggression. As is well known, some of these recent responses to urgent needs have been on a scale that is humanly frightening.

In some ways, the stresses and emotions raised by threat of war may confuse the issues, which can be considered more dispassionately in other uses of applied science. It seems particularly important to educate modern scientists in the realisation that science as a mode of knowledge is always an enrichment of mankind; science never is evil of itself, though (like every other power) some of its uses may be lamentable and others simply detestable. Fortunately, the need to work out beneficent applications of science in common on the largest scale, and the need to mitigate any adverse consequences of such applications, are a powerful therapy against the fatal error that scientific knowledge in any way conflicts with, or suppresses the need, to choose between good and evil. For properly educated scientists, science can, however, help to illuminate the choice, and to guide the discussion.

APPENDIX

Four Stages in the Formation of Scientists

In early infancy, encourage scientific responses to curiosity about the natural world; encourage comparative responses along quite different lines to protect multiple growth buds.

1. *Around the Age of Reason*

Encourage the application of simple mathematical reasoning about quantitative experimental information side-by-side with some understanding of the nature and limitations of scientific generalisations in the life sciences.

2. *Around the Age of Education in Ethical Principles*

Encourage understanding of the social consequences on the large scale of applied sciences, in parallel with the deepening of personal ethic. Understanding of religious motivations (historical and personal). Parallel understanding of other modes of mass power in history.

3. *Around the Age Where Original Scientific Work Begins to be Achieved*

Parallels in creative activity of various kinds. Ring roads and bridges of communication across the common separation between mathematical-physical and other approaches to nature. Contrast between the "artisanal aloofness" of the Greeks and the Confucians, and the artist engineers of the Renaissance who were fully committed to applied sciences as a highly esteemed form of creative activity.

4. *Collaboration Between Specialists*

Through the construction of good ring roads and radial roads of communication in the commonwealth of homocentric Knowledge. Discussion of ethical principles and problems in the uses of applied science on the national as well as international scale.

FORMATION OF SCIENTISTS AND TECHNOLOGISTS IN DEVELOPING COUNTRIES

H. R. CROXATTO

I wish to comment briefly on a few points of Prof. Ubbelohde's [1] praiseworthy and inspiring contribution.

But since I have been asked to discuss the education of scientists and technologists in developing countries, I would start by saying that the three major innovations arising from modern science described by Prof. Ubbelohde [1] make even more critical the task of formulating a university policy for science and technology at this very moment in our less developed countries (*). He is right when he says that science has become truly worldwide, but its voice, divided in the dialects of so many disciplines, only reaches the places where the proper specialists dwell. In many cases it does not reach or reaches too late, the developing countries. We must remember that, excluding the last decades, the universities of Latin America were dedicated exclusively to teaching, and the staff was made up of part-time professors.

In the State University of Chile, up to 1930, only few examples of original scientific research work were recorded. In the following decades a great proliferation and expansion of universities took place. In several research areas levels of excellence were

* Obviously there are among these countries great differences in many respects: educational, social, economic levels, etc. I must therefore confine the analysis to those Latin American countries which offer rather uniform or similar social conditions.

reached and more and more full-time investigators became the prominent members of science and professional faculties.

Latin American universities, periodically accused of being either ivory towers for some or the ferment for aggression, political proselitism and nihilism for others, have endured all kinds of crises. The universities have survived the model of co-government and the burning problem of passing from elite to mass-oriented education under the banner: the university for everybody.

The University Must Respond to Social Needs

If we consider that the university, during most of its history as a social institution, has responded to society's needs, the discussion about the formation of scientists and technicians should be centered within the frame of the society's requirements. Do the aims of the university converge with those of the society which provides its support? Actually, the society traditionally has been asking the universities for the training of humanists, artists and professionals to build an inspiring and democratic atmosphere and to stimulate imaginative and creative work; but today, in addition, the societal requirements plead for the university to contribute more efficaciously to economic growth and to be more involved in and committed to endeavors which respond to urgent national economic and social needs [2]. In a few words, the university in developing countries, traditionally discipline-oriented, should now undertake interdisciplinary tasks to satisfy the urgent demand for research specialists in the field of science, technology and management in order to accelerate industrialization and promote economic growth and social development of the countries.

Technological Knowledge a Major Factor in Economic and Social Growth

Political unrest and unemployment, combined with inflation, has put the societies of poor countries under very serious pressure. In advanced countries, with the arrival of industrialism science was placed much earlier at the service of production-consumption values. The gap between the industrialized countries and the less developed ones is widening day by day. The latter are excessively dependent on foreign economy and know-how, and the only way to break this servitude is through the proper use of science and technology. Organized knowledge has been recognized to be a major determinant of economic growth and to account for much of the disparity in living standards between developed and developing nations. For many economists there should be an international division of work; on one side the advanced countries which produce manufactured goods, and on the other the developing countries which provide raw materials and basic products.

Efforts should be devoted to creating high scientific and technological capacity as the only way to overcome economic backwardness and provide the benefits of high productivity and services. Although Latin America in most countries has made considerable headway in increasing the number of qualified researchers in basic sciences, the most relevant projects in the various fields have had only meager connection with the most urgent practical needs of the region. Technological or purposeful research has been insignificant.

In Developing Countries the Scientific Community has Been Emarginated

We have repeatedly heard economists and sociologists say that basic scientists, looking outward, are usually deeply engaged in fashionable topics, of interest to the international scientific community, instead of looking inward toward the needs at home. Secluded in their laboratories, they are rather distant from their surroundings, shielded in their right to preserve the legitimate academic freedom to investigate. But again it must be emphasized that 98% of the world investment in R and D is made by the developed countries and the 2%, supported by developing countries, is frequently improperly expended (Sussex Group Survey, 1970) [3]. The ability to originate new technology in these nations, meager as it is, is moreover inefficient in absorbing imported technologies. Among other recent reports, Wade (1975) [4], quoted a disappointing record on technological achievements in 13 developing countries of different continents: the research institutes tend to engage in programs which have no real relevance to industrial needs or problems or to the national plan; the research staff, with no real motivation and incentives, leans toward repetition of the research of their graduate days; interaction with industry and government enterprise is limited and infrequent; the research institute subverts what should be a prime role in the national development plan. On the other hand, the contribution of local industry to technological research is negligible; only very seldom do managers consult indigenous institutes for research or advice to improve their production, and industries are more and more dependent on multinational corporations for technical skills and management.

In Developing Countries the University Must be the Main Buttress of Technological Growth

Since more than 80% of science manpower in our Latin American countries is concentrated in the universities, the remainder in government institutions, bureaucratic organizations and industries, it is easy to infer that the plea for a more direct involvement of science and technology in the national development and more dedication to meaningful research oriented to achieving technological self sufficiency has found its target mainly in the university. Inevitably, it is a new burden and challenge for most of our research communities, which implies critical revision of traditional plans. But let us look at the other side of the medal.

In Developing Countries Bureaucratic Governmental Institutions Tend to Underscore the Potential Value of their own Scientific Community

Boeninger (1976) [5], past Rector of the State University of Santiago-Chile, urgently pleading for the formulation of a policy for scientific development in the universities as part of a vast plan defining and meeting national goals to facilitate the takeoff, is emphatic in declaring: "In fact, to my knowledge, there have never been formulated, either in Chile or in the other Latin American countries, concrete plans for attaining such goals. Neither has any government institution proposed to the universities a sound, coherent, concrete program of action in science and technology, indicating short and long term priorities; and even worse, nothing has ever heen said about its financial support".*

Plans without budget support can only provide political and intellectual satisfaction to the planners, but are quite ineffective. The developing countries expend in research and development only 0.2% of GNP compared with about 3% allocated in advanced countries. Developing countries have no other alternative than to expend much more and to obtain foreign aid, following a well organized and appropriate program for each country. Perhaps the plan for technological research launched by Israel could be a good model. I am not going to discuss the complex problem of how to build a national plan for technology and development in our nations, but it is relevant to analyze what would be the necessary additional contribution that the university can provide. This is a delicate point which deserves very much concern from every member of the university. Any effort towards upgrading technological capabilities is building on sand unless substantial resources or persons, time and money are also devoted to the more subtle, more difficult, but potentially more rewarding task of helping to create self-respecting scientific communities in the country concerned. (Moravcsik and Liman) [7]. Thus, there can be no hesitation. The first task we can expect the university to accomplish, with regard

* This does not exclude the possibility that technologically oriented institutions not ruled by the universities can have a decisive role in the development of special areas (agriculture, mining, etc.).

As an outstanding exception, it is important to mention the national plan launched hy Brazil. Moreover, preoccupations at a government level have taken place in other countries: the dialogue requested by the President of Venezuela, C. P. Perez, in 1975, between scientists and technologists on the one hand, and politicians, industrialists and economists on the other could be cited (M. Roche, 1975) [6]. Also, the Plan Nacional de Desarollo Científico y Tecnológico 1976-80 produced by Conicyt (Chile 1976). This important document was prepared hy government institutions, public research institutes, universities, the Army, the Academy of Science and private organizations.

to general development policy, is to increase its basic research capacity. But in most of our universities the number of investigators is still low, underpaid, in some places with budgetary limitations. They are overburdened by teaching duties, with no incentives or time for public-service research.

However, the principle of autonomy does not liberate the university from its social obligations. If the funds are provided, the university can strengthen its research institutes, expand post-graduate education, train the required personnel in various jobs and fields of specialization and stimulate cooperation with other specialized scientific institutions linked with industries, agriculture, etc. However, any change introduced in the university must preserve its essential critical role, which lies in teaching, fundamental research and the free play of ideas to foresee the future. One of the first decisions to satisfy the urgent demand is to increase its manpower in all the basic areas and branches, particularly in those required for solving relevant social and economic problems. This can be partially attained by repatriating most of the scientists and engineers displaced to the industrialized countries. Although there are several reasons for the brain drain, in general it reflects the fact that the local economy cannot absorb these people. The highest contribution of the university in meeting the challenge would be: 1) expansion of post-graduate education to fill the gap in many deficient areas; 2) offering interdisciplinary, inter-faculty curricula, in order to train students able to tackle a gamut of specialized technological problems. In this particular area Dr. Ubbelohde's proposals are valid for resolving the problem of communication between different modes of knowledge. Of course, application of science can only succeed through effective collaboration of scientists with other kinds of specialists. It is also important to point out that the education of scientists and technologists today requires, much more than ever before, the teaching of the social impact of applied science: that the capacity of the earth to absorb pollution is less than we thought, the dangers of using material powers, or upsetting ecological balance. In a few words, the ethical codes in the use of science.

There are always trans-scientific elements that must be settled by cooperation at all levels of social activity. Several years should be required to achieve these aims, even with foreign aid. The economic planners and the government which makes the expenditure would expect from the university in return, not only trained people, but also a type of research activity with immediate application.

It is possible to envisage that under the pressure of strategic planning, a progressive utilization of its equipment, resources and manpower can take place. Bureaucratic decisions seeking to tune university priorities with those of the national plan could compel basic research to give more support to applied research. This can lead to a dangerous situation which would limit our academic freedom to explore the knowledge frontier and thus erode the essence of university life. Such a risk can be prevented only if the university itself has a decisive and meaningful role in establishing the priorities of the national development plan and if in any policy decision, science has a high voice and is free to criticize as Dr. Chagas [8] has stated.

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DISCUSSION

GENTNER

It is extremely difficult for me to start the discussion on your eminent talk because I agree on all the important points in your deliberations.

The question of education is an old one in human history, but this question has no real precedent in a world such as ours where the bulk of scientific knowledge is growing so fast. We, the older teachers, have to learn every day from our young collaborators about the new discoveries and developments in science. There is insufficient time to read all the publications, even in the narrow field of special interest.

In the chapter entitled "Leviathan or the Bulk of Knowledge", I agree completely with your final statement: Wonder as an incentive to learning and that the young scientist should have bivalent access to experimental experience, that which is mathematical or analytical, and that which is descriptive of living beings. Learning facts out of books to satisfy one's curiosity is not enough; wonder should permanently stay alive.

I now come to the chapter "The Civitas of Science and the Communication of Knowledge". You say, "Greek education had as one enviable component a training in the arts of eloquence" and I understand that we need this today more than ever before in order to have a proper vision of the unity of knowledge.

In this connection, I would say that we are more and more approaching the time of Homer; because we are no longer able to read all the articles and books even in the narrow field of our own research, we invite speakers to tell us the newest research results. We hope to understand more quickly a new theory hy means of discussion rather than by reading all the relevant articles.

Another consequence of this impossibility to read everything is the growing number of meetings, congresses, symposia, etc. In this sense, I would say that the discussions between scientists have increased considerably. A great help in this connection is the acceptance of "Basic English" as the common language.

In speaking about the ethical aspects of applied science, you mention the difficulty of combining theory and practice of ethical codes. Certainly the use of science tends to be more pragmatic. We should certainly do our best to improve the agreement between ethical code and practice, but it is often problematic. Also in medical science, where we have the "Hippocratic Oath", more and more discussions are needed to explain and to agree on modern medical ethics.

In conclusion I would like to point out one main problem which was not mentioned in detail by you. The problem is how to find good schoolteachers, how to select them, and the decision as to what kind of education the schoolteacher himself should have.

Taking a simple example: From my own time in high school I remember — and many of you will do the same — that there are *good* and there are *bad* teachers: Teachers who like to talk and talk, and others who are able to initiate discussion on interesting problems. Our school-time is definitely one of the most important periods of our whole life-time, but the selection of schoolteachers is not the best and should be improved.

Discussion on school reform is taking place everywhere at present, and we in Germany in the last few years have had a real series of orgies of discussion on this prohlem. Long discussions are being held between psychologists and pedagogues, with and without political or religious implications. Finally we have an enormous variety in our school systems. Every young schoolboy can at an early stage choose between very different disciplines — old and modern languages, social sciences, mathematics, physics, ...

But I doubt very much if this kind of great variety in the school system improves education.

Another point is the selection of the schoolteachers and the status they occupy in society. My feeling is that the status of the teacher has become lower and lower; for instance, in the classical period a teacher was responsible for the complete education of a young man.

Now we have schoolteachers with quite a low social status and professors at the university who are of the highest grade but who do not realise their responsibility for teaching, in the sense of educating students. Unfortunately a number of university professors are interested in giving lectures for research students only and are therefore neglecting their educational duties; in other words, students with the aim of becoming teachers are neglected by them.

When I remember my own time at the university as a student of physics, I had the feeling that only the dull and not very original colleagues became schoolteachers. The more able tried to find a position in research institutes of industry or at the university.

The reason for this was that teaching was for most of the students not attractive, also with regard to the salary. This may be different in the field of the humanities, but it is certainly correct in the field of science.

This means, if we are to improve education, we have first to improve the status of teachers in our society and this means to give them a better education.

SEGRE

I would like to make a comment on the paper presented this morning. But I think that the subject, namely the preparation of the scientist, is so important and so broad that it is almost impossible to do justice to it in a few words. As time is short, I would suggest that the talk given this morning and the discussion which may take place now could be the origin of a greater initiative on the part of the Pontifical Academy to study deeply this problem, which is of paramount importance. In this connection I want to mention an initiative by the Accademia dei Lincei quite recently. From the 7th to the 15th of January an international congress took place in Rome, organized by the Lincei, on the integrated teaching of science in the primary school, that is, for the pupils of ages 6 to 12. A report of its proceedings is in the process of being published and will be out in a few months. The Academy will be glad to send a copy to any of you who will ask for it. This international meeting, I think, was a big success, but it is only the starting point of something which could take place later.

Moreover, on December 14th and 15th next, at the Accademia dei Lincei we will have a smaller meeting concerning the preparation of chemists and their position in modern society, with special reference of course to Italy. Again, something with a broader scope could be organized later, perhaps as a cooperative undertaking between the Lincei and the Pontifical Academy.

CHAGAS

To steer the discussion, I would like to call your attention to two points, taking into account my experience in a developing country. In the formation of scientists and technologists we have to consider first the institutions in which they are to be educated and, secondly, the place where they should work. The answer to the first question seems to be an easy one. In either one or the other case, the university is the institution where education should be given even if in some cases special technical institutes may take its place, at least for a certain period of time. In my country, and as I believe in many others, the greatest problem the university teacher has to face is to overcome the unpreparedness with which the student enters the university. However, the university must fulfill its function of developing basic science. This brings out the need to establish a satisfactory relationship between the number of students and of teachers/researchers, in order not to overload the faculty members with teaching. On the other hand, it is at the level of the graduate courses that the scientist begins his real scientific education, supported naturally by his undergraduate performance. It is thus important to establish in a modern way, at the graduate level, a tutor/apprentice relationship corresponding to that which has been so successful in the past. Professor Ubbelohde has brought to our attention the question of an early specialization, and Professor Gentner has also argued this point. As a matter of fact this is due partly to the system of merit evaluation established.

This system, with its excessive stress on the number of papers published, followed by a certain number of distinctions, pushes the graduate student to a high grade of specialization. Entering a graduate course, he has in view the publication of his Master's Degree dissertation and tries as much as possible to become part of a team where he knows his name will quite soon appear in a paper. The teacher/apprentice relationship disappears and the teacher is unable, owing to the competitive type of scientific work which has been created, to give to his student a part of his scientific wisdom.

More dangerous still is the fact that many times, especially in the case of students from developing countries undertaking their work abroad, but also in their homelands, they are used mostly as inexpensive technical manpower. In this case the student becomes a frustrated specialist, or even a complete failure. Now if we take my second point, it seems clear that the major market for basic science graduates in developing countries should be the universities, the vast majority of which at present are understaffed. Applied scientists and technologists should be used in specialized institutes, whose needs should be carefully evaluated before their establishment, but one should not overlook the fact that both applied and technological research should also be undertaken in universities, for otherwise these institutions would completely lose touch with reality.

CROXATTO

The problem of general education is a very important one. Actually I was very busy in Chile trying to improve the science and mathematics situation on the primary and secondary level because I realized that the preparation of students coming to the University was not adequate. We considered that science, as it is taught in the schools, is a form of teaching which concerns itself only with information. The students receive data, sciences are described and taught by teachers in the same way as history. The students are not really involved in science. As somebody pointed out, science is much more than being a substantive, a noun; it is a hirth, an activity. It is something the students should do from the very beginning; they must try to do some research work in order to really learn science. Our reform in trying to change the model of teaching is very successful. Some good has been achieved.

I agree with Dr. Chagas also, that there are other problems involved in the formation of scientists and I would add that one of the main problems, one reason for our backwardness, may be the economic and political instability in our countries. We have seen in the last seven or eight years, a great movement of professors at our universities, leaving the country, thus producing the so-called "brain drain", because of the economic situation we have. This is one of the problems we have to consider too. It is a chronic illness in our country's political unrest.

ROCHE

I wish to speak a bit about the use of memory in science teaching. In my opinion memory is used to a large extent, and it goes with the use of authority. I thought the use of authority, of memory, of teaching by rote was really Iberian, Spanish and Portuguese. But by reading a little bit, and talking to people, I have come to realize that it is really apparently one of the characteristics, one of the many characteristics of under-development. Gunnar Myrdal, in his book on Asia, describes the teaching process and the teaching characteristics in Southeast Asia, and they are absolutely identical with those that we see in Latin America. Speaking with my African friends, I found that they too complain of the use of memory in their teaching. And it is not only in the teaching of science; the teaching of history, the teaching of literature, is very unscholarly too. It is deeply distorted by memory. Now, the teaching of basic science, with the rigor which it implies and the research activities which go along with it, would go a long way towards remedying this sort of thing. Although in the long run it may be that the whole thing is due to the so-called situation of dependence which these countries are accustomed to feel in receiving things from abroad, from other countries. I must say that Thomas Kuhn, again coming back to him, says that teaching by memory is only an absolute characteristic of science itself. Actually, the young pupil is not given orignal experiments to perform, orignal literature to read, until very late in his career, in fact not until he becomes a graduate student. Before that he is taught by memory and he is taught facts generally accepted by the scientific community, which may be true or not. However, the phenomenon which Kuhn describes is very different from what happens in Venezuela. In England, France, the United States, which are the developed countries I happen to know, teaching is very different from the absolutely pure memory method which we still use. In fact, I can document this fairly well, with regard to the type of examinations which are given in Venezuela. What the teacher requires of the student there, as a matter of fact, is that the student give back to him what he has been saying during the classes. I do not know what can be done about this, for a complete change in the social situation would be required. I think this is one of the central problems of the teaching of science and also of other subjects in underdeveloped countries.

LEPRINCE-RINGUET

On a dit beaucoup de choses sur le « teaching », c'est-à-dire sur la formation, sur l'enseignement. Moi, je voudrais donner un avis de mon expérience en France. Dans la préparation à la recherche scientifique il y a une première partie de la formation qui est ce qu'on apprend à l'Université, dans les grandes Écoles, etc., et ça c'est la méthode, c'est la rigueur, l'esprit de rigueur, c'est la méthode rationnelle qui est apprise, qui est enseignée. Cela s'enseigne, cela s'apprend. Et je le vois bien quand les élèves qui sont reçus à l'École Polytechnique ont eu une formation logique, une formation rationnelle, une formation à base mathématique, qui est très solide. Pourtant, ils sont souvent déformés et peu aptes pour la recherche.

Dans la recherche il faut donc un équilibre, une complémentarité, comme dirait notre ami Weisskopf; et bien, je crois que c'est très vrai. On a besoin de cette méthode expérimentale, de cette rigueur, de cet esprit critique, qui se développe d'ailleurs quand on commence à appartenir à un groupe. Mais d'autre part il ne faut pas trop savoir de choses. Je crois qu'il faut laisser l'esprit à la fois avec une fraîcheur, un appétit de connaissance, un goût du risque, un esprit d'artiste, de créateur, car faire de la science sans avoir un esprit de poète, de créateur, c'est devenir fonctionnaire de la science, et il y en a beaucoup, malheureusement, qui ont leurs vues très définies et qui n'ont pas du tout ce sens de la création, du mouvement, le souffle et en même temps l'ardeur qui sont indispensables, pour faire de la recherche.

Je crois qu'il faut que la formation soit diversifiée; il ne faut pas une formation unique. Cela dépend des tempéraments, mais il faut surtout promouvoir — et cela ne s'enseigne pas — l'esprit de création, car on a besoin d'avoir de l'imagination pour faire des appareils nouveaux, des synthèses théoriques, des formalismes pour répondre aux remises en question qui sont la monnaie courante de la science et de la recherche; mais je crois qu'il faut cet équilibre, il faut cette complémentarité. Alors, si le jeune homme ou la jeune fille entre dans un laboratoire après une formation assez équilibrée, en ayant de l'appétit, en entrant dans un bon groupe, — et bien, ça ira, et puis le reste on l'apprend plus tard. Ce n'est pas la peine d'en avoir appris de trop pour commencer de la science; on n'a plus du tout l'envie de découvrir quoi que ce soit quand on en sait trop.

CHAGAS

Merci. Je suis tout à fait de votre avis, et je pense que beaucoup de chercheurs modernes, les jeunes, ont perdu aussi le sens du ludique dans la recherche.

WEISSKOPF

I would just like to mention two rather different experiments that were made at M.I.T. in my own department, on a selective scale. I think they may be of some importance. First of all, one thing which you certainly all have observed, is that most scientists, with a few great exceptions, cannot express themselves very well. That means, to make it plain, that they give bad talks. Of course not at this Academy. But especially the younger generation is less and less aware — not even trained — to express themselves clearly. So what we introduced at M.I.T. is a seminar which was called "How to give a talk". And there each postgraduate student was supposed to give a talk, preferably not about his own field of research, although that was not excluded. Then his talk was criticized, not so much for its content as for the way it was presented. Because I do believe that one understands a topic only if one can present it well. And, if I am really consistent with this principle — which I would like to be — I would say that most of the younger people do not understand the subject they are working on, because they cannot present it well. I think this is a matter of tradition, a matter of creating a style, and I think we all should work at creating this style in science.

Another experiment of a different nature was made in order to broaden the approach toward science. Much has been said about education on the primary and secondary level, but I think on the highest level it is just as bad. For example, at M.I.T. people are educated to be specialists in their own fields but know very little about their neighboring fields. We are now having a course which is called "Atoms, Genes and Stars", which is supposed to give the whole picture, with emphasis on the unity of science, the idea that everything is connected together. Of course this is a difficult enterprise, particularly so because, as it has been said, people are likely to neglect those things which they think may keep them from going ahead in their own specialty.

ROCHE

It is true that there is some rote learning in more developed countries — in the United States or at M.I.T. — but the order of magnitude is much less than it is in the developing countries. You cannot imagine what the use of memory is in our countries. It is absolutely astounding! It is much more than you have in your country. And what you have in your country may be due to the memory which is needed for science per se — I am again quoting Kuhn. I think it is of a completely different order of magnitude.

SIDDIQUI

I shall allow myself just a few words with respect to what you have just now pointed out: early specialization. You have no idea of the extent of this problem as it is seen in the South Asian subcontinent. Now the usual routine is that after ten years of schooling — just ten years of schooling — they start specialization right after matriculation. One set of students takes up zoology, botany, physics, chemsitry and prepares for the medical course, with a further subdivision when they take science and biology. The other group enters the engineering course, taking mathematics, physics and chemistry. So there we find an early specialization at that stage already, the students having an average age of 14 or 15 years. In the continental countries, to specialize you have to be 19 years of age and have 13 years of general schooling, a broad-based general schooling, in which the humanities and an introduction to various fields of science were included. Thus the student can claim something of an intellectual receptive base on which to take advantage of higher education at the university. At the age of 19 you can fairly well choose a subject in which you think you are really interested. This allows for what I have seen very often: that in the course of a university career people change from one subject to another. The lack of a better schooling in our country is the main difficulty; our problem is to develop a better level of higher education. Somehow, however, we cannot get out of this mess. As long as this continues, we are relegated to third raters, and there is no way of getting out of this.

It is a different matter that a few people — no matter what you do with them — come out all right anyway. What matters, however, is the average. Many of the scientists who work in India and in Pakistan and other countries of that area do measure up to the international standards in any field. But the thick middle layer from which leadership emerges and which provides the right type of teamwork, is missing. Then you have a race of pygmies, and I personally feel that the school system is the main reason for this.

What has been said about being able to express oneself is for us a headache ever so much more because we have to acquire command of the English language and at the same time our various national languages, with the result that one cannot express onself well in any language. This is another problem to be overcome.

LA RESPONSABILITE DES SCIENTIFIQUES

LOUIS LEPRINCE-RINGUET

Même si la science est contestée, le scientifique est entouré de considération et de respect par ses compatriotes et pour certains hommes de science, les plus renommés, par les populations situées au delà des frontières de son pays. Einstein, Oppenheimer, Sakharov, en sont d'éclatants exemples. Ce respect est souvent d'autant plus profond que le domaine des recherches est plus difficile à comprendre. Le savant est sensé connaître les secrets de la matière, de l'atome, de la vie, des astres. Il est capable de les utiliser pour le bien ou pour le mal. Bref, on lui prête non seulement une connaissance mais une puissance mystérieuse et parfois magique. Et puis, peu engagés en général dans les âpres luttes politiques, les hommes de science sont estimés pour leur indépendance, surtout s'ils la manifestent de temps en temps vis-à-vis du pouvoir politique. On leur reproche en revanche leur langage ésotérique qui les coupe fréquemment des populations. Cette image de marque, en quoi est-elle valable et quelles responsabilités y sont-elles associées?

Nous savons tous que les hommes de science avancent avec difficulté, patience, que leurs remises en question sont sérieuses et parfois déchirantes, que le caractère répétitif de l'expérimentation incite à une grande prudence dans les comptes-rendus et les informations. J'aime cette boutade: « un savant est un ignorant dont l'ignorance présente quelques lacunes »; c'est bien cela. Les meilleurs de nos physiciens sont incapables de définir une particule, tout se complexifie quand on travaille en profondeur.

Mais il est bien vrai que ce sont les scientifiques qui ont permis la transformation du monde. La découverte du neutron en 1932 a conduit à toutes les applications de la radio-activité artificielle, puis à la fission de l'uranium avec ses deux grandes voies des explosifs et des centrales nucléaires. La découverte de la diffraction des électrons a conduit, après vingt années, à l'utilisation du transistor, qui a transformé l'existence de tous les peuples. Alors, même si les applications se sont effectuées bien après les découvertes, même si elles n'étaient pas perceptibles ou prévisibles pour les savants de la science fondamentale, il est bien normal qu'une responsabilité soit attribuée, par la population qui ignore en général les différences entre découvertes et applications, aux scientifiques de toute nature.

Comment se fait-il que les savants qui se disent tous transnationaux, qui déclarent vouloir abaisser les barrières entre les hommes, qui prétendent que le langage et la méthode scientifique sont des outils universels et favorisent le rapprochement entre les hommes, sont des instruments de fraternisation, comment se fait-il que ces savants soient impliqués dans les explosifs nucléaires, participent à des comités militaires, s'engagent avec le pouvoir pour obtenir des crédits, accroître leur puissance, aident leur pays à trouver de nouvelles utilisations de leur science à des fins de destruction?

Pour comprendre et trouver une réponse équitable, je voudrais analyser deux exemples qui me semblent particulièrement frappants. Celui d'Oppenheimer et celui de Sakharov. Comme tout homme, le scientifique appartient à plusieurs communautés; tout d'abord la communauté internationale. La science recherche une vérité universelle, avec des méthodes rationnelles qui sont identiques pour tous les savants quelle que soient leur nationalité, l'ethnie à laquelle ils appartiennent, la religion qu'ils pratiquent. On travaille en science d'une façon internationale, ce qui donne à cette activité une dimension exceptionnelle: c'est l'une des grandeurs de la science. Par l'universalité de son langage elle doit aider à l'établissement de relations plus fraternelles entre les hommes. Ainsi sommes-nous profondément marqués par cette communauté internationale chez les hommes de science. Notre attitude comporte une part d'espérance exaltante.

Mais nous avons également d'autres appartenances. Nous faisons partie d'une famille et aussi d'une nation. Il peut donc y avoir conflit entre « ces territoires ». Ces conflits peuvent même provoquer des drames intérieurs. Nous l'avons vu au grand jour avec le procès d'Oppenheimer, avec l'attitude de Sakharov et aussi avec toutes les remarques qui ont été décrites dans « Bulletin of Atomic Scientists » depuis la Libération. Lorsque les savants venus d'Europe, en général Juïfs, de toute façon anti-fascistes et anti-nazis, se sont retrouvés aux Etats-Unis au début de la guerre, ils ont accepté, alors qu'ils sont essentiellement pacifistes, de s'engager volontairement dans une entreprise qui permettrait, grâce aux découvertes toutes fraîches sur la fission de l'uranium, de trouver des armes pour s'opposer à la victoire du nazisme sur le monde. Ils ont donc proposé au gouvernement américain de s'associer pour un travail de guerre. Il leur a même fallu convaincre le gouvernement américain. On connaît le résultat extraordinaire de cet effort avec les réacteurs de Fermi en 1942 et les premières explosions nucléaires de 1944 et 1945. Lorsque, après la guerre, pendant une période encore tendue de guerre froide, vers 1951, il fut question de faire la bombe H, Oppenheimer, qui était le promoteur de la bombe A, refusa de s'engager dans ce travail, d'où le procès qui lui fut fait et qui finalement l'a usé. En même temps, d'autres physiciens, comme Teller et Wheeler, ont accepté de travailler pour la bombe H pensant que, si l'Amérique était dépassée par l'URSS dans ce domaine, sa civilisation risquerait d'être atteinte. C'est donc un motif de patriotisme national et même de compréhension d'une certaine forme de civilisation qui les a guidés dans leur acceptation.

Pour Sakharov, jeune physicien des rayons cosmiques après la guerre, c'est une pensée nationale qui l'a également orienté vers la bombe atomique. Les Russes étaient en 1945 largement inférieurs aux Américains dans ce domaine. Sakbarov, dans le laboratoire du grand physicien Tamm, a permis à l'URSS d'opérer un redressement spectaculaire avec la bombe H. Le succès de Sahkarov, qui a obtenu la première explosion H avant les Américains, lui a valu le Prix Lénine et toute sorte de distinctions. Il est devenu un grand homme en URSS. Après avoir continué pendant quelque temps il est revenu à la vie civile et maintenant il a pris la tête, d'une façon extrêmement vigoureuse et courageuse, d'une campagne pour montrer le danger de la menace atomique, pour demander la coexistence, pour implorer d'une façon extrêmement vive la liberté d'expression. Dans ses écrits, dont certains d'ailleurs ont été publiés en Russie, on sent à chaque page le désir de compréhension et d'amitié entre les hommes. Voilà donc deux exemples de conflits intérieurs qui déchirent parfois la conscience des scientifiques.

On voit que les problèmes ne sont pas simples: si l'appartenance universelle de l'homme de science le rend violemment hostile à l'établissement de barrières entre les hommes, son appartenance nationale, son patriotisme, peuvent l'orienter vers une conduite opposée qui n'est pas alors une conduite scientifique mais correspond à une attitude politique du moment.

Que penser alors de la responsabilité même du scientifique? Elle va s'exercer de plusieurs façons individuellement ou collectivement. Individuellement, l'homme de science, lorsqu'il perçoit les dangers de certaines applications, doit faire connaître son opinion. Il doit prévenir les milieux gouvernementaux qui très souvent ne lui demandent pas son avis sur les orientations de la science appliquée, en particulier dans le cas de la défense nationale. Il doit également ne jamais hésiter à manifester son opinion par des conférences ou des articles de presse. Cela permettra à ses concitoyens qui ont un respect pour lui, d'être informés et, par leurs manifestations et leurs votes, de peser sur les décisions du pouvoir.

Mais il y a aussi une action plus universelle à développer. Ce genre de responsabilité a été tout-à-fait compris par l'ensemble des physiciens de l'atome et des biologistes. Ils se sont réunis depuis l'après-guerre, en un mouvement, le mouvement Pugwash, pour étudier les conséquences pratiques des grandes découvertes et pour essayer de proposer des solutions aux problèmes qui se posent aux différents Etats et aux difficultés qui peuvent surgir entre les peuples. Ce mouvement a une grande importance. Ses membres se réunissent très souvent soit sur le plan international, soit à l'intérieur même de chaque pays. Ce sont des réunions discrètes de façon que la politique avec tous ses préalables et tous ses faux-semblants ne s'en mêle pas. Ainsi, des réunions internationales de scientifiques peuvent faire avancer des problèmes mondiaux. On peut les étudier dans l'ambiance de la camaraderie, de l'amitié des savants. C'est tout-à-fait différent des réunions politiques où l'honnêteté intellectuelle et la franchise ne sont pas toujours de mise. On peut dire par exemple que lors de la guerre de Corée, le Mouvement Pugwash a agi favorablement pour mettre fin au conflit. De même la réunion amicale des scientifiques Arabes et Israéliens permet également d'étudier et de proposer des solutions raisonnables, étudiées avec le maximum de bonne foi.

Mais les hommes de science continuent et continueront d'effectuer des recherches fondamentales. La recherche elle-même est une des grandes activités de l'esprit humain. Ainsi, au CERN, les études sur les particules de la matière, sur les anti-protons, l'antimatière, ne débouchent actuellement sur rien de pratique. Les physiciens qui travaillent dans ce grand centre sont attachés à leur travail de recherche et l'exécutent avec toute leur intelligence et tout leur coeur. C'est lorsque des choix ultérieurs peuvent orienter des applications que les hommes de science peuvent et doivent intervenir. C'est là que leur responsabilité doit s'exercer à tous les niveaux. La science qui se fait aujourd'hui permettra certainement de résoudre les grands prohlèmes qui atteindront l'humanité de demain et que nous ne pouvons pas encore déceler. Ces applications iront certainement en partie vers l'amélioration de la vie, la médecine, l'écologie, elles rendront possible une meilleure répartition des chances entre les hommes, mais elles peuvent aussi être utilisées pour accroître les barrières entre eux, pour la destruction, pour le malheur de l'humanité. Les savants doivent intervenir de toute leur énergie individuellement et collectivement pour dénoncer les dangers.

RESPONSIBILITIES OF THE SCIENTIST

P. C. C. GARNHAM

I had the honour to address the Academy on April 18th, 1975 on the subject of "Some ethical considerations regarding the use of Man and Primates in Scientific research" (Garnham 1975, *Commentarii*, Vol. 3 No. 8). The paper naturally included a discussion on the responsibility of the investigator and showed that two separate issues were concerned; 1, human experimentation and 2, the use of animals. The former is governed by various ethical codes, stemming from the Hippocratic oath and all ultimately depending on the conduct, etc., of the "technically and morally qualified physician", rather than on lip service to a multitude of rules. Experiments on animals are of an entirely different category, and here the scientist is responsible in two chief ways. He must avoid the infliction of unnecessary pain in terms of the more enlightened anti-vivisectionists, and he should take steps to minimise the use of excessive numbers of animals. There is a real danger that the population of certain species may he so depleted that extinction may occur. Some scientific importers of rare animals realise the threat and try to counteract it hy breeding programmes, hut more evade the responsihility and even circumvent the regulations which forbid the export of such animals from certain countries. Stricter rules and stronger principles are necessary if disaster is to be avoided. I emphasize this point hecause it has not been considered in the present "Symposium".

My remarks now are particularly directed to biologists, but first I should like to mention the immense pride and satisfaction that I have in belonging to this Academy with its unique international character. Everyone feels the same, and has stressed the need for the maintenance of sympathetic companionship within the whole body of scientists. I detect elsewhere a certain bias towards friendship with particular groups and hostility to others based on political or other considerations. Here we are specifically appointed without regard to race, religion or any discrimination other than our science. We should therefore be careful to maintain sympathetic relationships everywhere: with our colleagues in Eastern Europe as well as those in the West; with those in Egypt as much as in Israel; with both South Africans and tropical Africans; and with all shades of opinion in Latin America.

The foregoing is one type of responsibility. There are at least two others. The primary one concerns science itself — the *sine qua non* to which all scientists adhere; i.e. the abstract search for truth and the communication of the results. The second is our responsibility to humanity and here we are faced with the well recognised, even platitudinous, antithesis of research to satisfy curiosity and research to alleviate the human lot. Restriction on certain types of research has been discussed in the symposium, but though a practical issue, it is unlikely to be a consideration of the individual worker who will follow the path wherever it leads. The path may be blocked by the witholding of finance and other lay influences or even by his own conviction of the danger to humanity. These dangers are more likely to be the direct result of the *application* of the fundamental research. It is here particularly that mischief occurs; in the discoveries of the physical sciences (such as Leprince-Ringuet has enumerated) shattering effects may arise; in biology, the changes may be more gradual, but ultimately of greater harm. The human habitat suffers in various ways, e.g. in England a piece of land equal in size to the county of Berkshire is lost to natural usage every five years; the application of pesticides or herbicides may render the country free of a pest, but hundreds of other forms of life may perish as a direct result or in chain reactions. It is the responsibility of the scientist to see that the ecological equilibrium remains largely undisturbed.

The application of the new techniques may be either to counteract sudden disaster or to improve the general use of the land. Our attitude to these two questions is two-fold. The former is often highly successful and is so rapid and efficient, that little permanent damage is done. A sudden resurgence of human sleeping sickness in the African bush may be quickly halted by outside spraying of DDT; an epidemic of human malaria may be suppressed quickly by the use of chloroquine and proguanil and plague disappears rapidly after the application of DDT on the vectors of the infection; the more chronic incidence of Chagas' disease can be controlled by the application of domestic insecticides, but the real answer to this problem is the provision of better houses which would prevent this infestation by the vector of the disease — the triatomid bugs.

The problem of the application of new pesticides is difficult, although in epidemics it is justifiable to forget about long term effects and to concentrate on the immediate saving of lives. But in the more chronic conditions it is necessary to look to the future. The problem is like chess. One must foresee the moves ahead, and construct a strategy, but it is only the Grand Master who sees the likely endings. The use of insecticides for the protection of crops is equally difficult, pollution of the environment is threatened. Each situation has its "Janus-face". The insecticides may become resistant or there may be contamination of the food-chain. The immediate overall improvement may be immense, and a rapid increase of the human population often occurs. The equilibrium is disturbed, and every situation may be different. So the responsibility of the scientist concerns both the first application of these powerful techniques and their after effects.

Finally, the scientist has a responsibility in the laboratory towards his staff. He should hold himself personally accountable for any mishaps which may arise even though he may not have been directly concerned; equally it is his duty to ensure that safety precautions are adequately followed. The actual methods adopted in laboratories obviously vary according to circumstances, but it is probably a good principle that details of most experiments should be discussed by members of the staff, including the technical staff. When human experimentation is involved it is desirable that an independent committee should examine the details of the procedures and express definite approval before the work is started.

DISCUSSION

TUPPY

May I just point out one question which appears to me to be very important nowadays? Obviously there is a genuine scientific responsibility, a responsibility which the scientist has as a scientist, and that is the responsibility to try to achieve the ability to derive conclusions from facts and experience by the use of logic. On the other hand, nowadays more than ever before, scientists are urged to take a political responsibility. Not only do they influence politics by advising but they really become parties in the political game. Scientists are urged — very often by the students — to take sides in conflicts which cannot be decided scientifically. On the one hand it is tempting for the scientist to take a side and thus become part of the political game, of the power game. On the other hand it definitely deteriorates science as such. It is a very bad experience to see how scientists can oppose each other, not on scientific grounds but because they bring into the discussion their personal political views. When science is blamed today for having had very bad consequences for mankind, this has not been so much the consequence of the application of science to urgent problems but rather that scientists have not acted as scientists but as politicians. So one of the most difficult problems is how the scientist should act as an expert in political matters. I feel that he has to separate what he says on a purely scientific basis and what he says as a person, as a citizen, as one who has a certain ideology; and this should certainly help science to achieve its effects.

LÉPINE

Le problème de la responsabilité de l'homme de science est important, et pourtant ceux qui cherchent la vérité ont été confrontés avec des problèmes de conscience et avec des dilemmes. Sans remonter jusqu'au procès Socrate, ou aux difficultés qu'Atchimède a connues avec le Tyran de Syracuse, ou aux mécomptes qu'a connus Galileo Galilei, il faut rappeler que Pasteur lui-même a connu de telles angoisses et il les a résumées dans une phrase célèbre lorsqu'il a dit: « La science n'a pas de Patrie, mais les savants en ont une ». Je voudrais élargir cette notion, ou, si vous voulez, la généraliser dans une paraphrase qui consisterait à dire que « la science n'est pas en soi morale, mais les savants doivent obéir à une morale ». Et ici nous retrouvons ces notions d'éthique qui ont déjà été évoquées ce matin, car c'est bien au nom de l'éthique, représentée par la morale chrétienne, avant tout pour nous, que l'opinion humaine dans le monde a condamné les expériences sur l'homme comme celles qui étaient pratiquées dans le camps nazis pendant la guerre. Par conséquent, là encore, je crois que nous sortons du domaine scientifique pour entrer dans le domaine de la morale, auquel nous n'échappons pas.

Le deuxième point que je voudrais mentionner, c'est que Leprince-Ringuet a très justement fait remarquer que le savant a une responsabilité et même plus, une obligation vis-à-vis des mass-media actuels, en participant à l'information. C'est très important. Les savants ont donc le devoir d'informer, et non seulement le désir de donner une information juste, exacte, loyale, sur les faits scientifiques tels qu'ils se présentent. Mais il y a un autre avantage que j'ai souvent remarqué moi-même, et c'est qu'un exposé honnêtement fait d'une question scientifique est plus que toute autre chose capable de faire naître des vocations chez ceux qui les entendent et qui comprennent quel peut être le rôle de la science. Et par conséquent, là le savant a une haute responsabilité, qui n'est pas strictement d'ordre moral, mais qui est celle de susciter, de provoquer, de faire venir les vocations de ceux qui, après lui, continueront l'oeuvre scientifique.

SZENT-GYÖRGYI

I just want to put before you the result of certain calculations I made two years ago — and which Dr. Weisskopf made also. Since we owe everything that we have — almost everything — to basic research, I calculated how much money mankind has spent on basic research since Adam and Eve, and I came to the result that it was half as much as the Pentagon — that means the American Army — spends on instruments of killing in one year. Half as much! Two years ago I was so frightened by this result that I did not publish it, but Dr. Weisskopf repeated the same calculations at the same time, and he found I was wrong, it was only one-third of what the Pentagon spends in one year. I got so frightened — well — this is just simple fact.

I would like to offer my apologies, I made a mistake this morning. I said the American Army is spending 130 billion Dollars in one year. I made one rough mistake: it was not 130 billion Dollars, but 1,300 billion Dollars. I just made a little mistake! I am completely unable to understand that, except with one theory expressed by Bernard Shaw, who said that "if there is life on other planets or stars, they certainly use our globe".

WEISSKOPF

I would only like to make a few remarks. One is about the responsibility of scientists in respect to basic research. It is of course extremely hard to apply to the scientific community the principle usually requested by the public, namely, to make only those researches or those discoveries which are good and not bad, and prevent or in fact even refuse to work on those things that will have evil consequences. Now it is clear to all scientists that this is in itself an impossibility, that when research starts, when it is basic research, it is quite impossible to know what will come out of it. When Einstein discovered in 1905 that energy and mass are equivalent, how could one know? But I would even go further. I do believe that any fundamental basic discovery can of course be used for both good and evil, but that the sum total is mostly good. Indeed it is hard for me to conceive of any fundamental discovery in science that is all evil. Unfortunately, however, the belief that some or perhaps most fundamental discoveries are evil is very widespread among the public; and there are many who feel that scientists who discover a formula like "energy equals the product of mass multiplied by the square of light speed" should actually burn that formula and prevent it from being known. This is not an exaggeration. People do believe this, and I do think it would be useful if one would, even in a more systematic way than has been done so far, analyze and show that indeed the fundamental discoveries including Einstein's discovery have done much more good than harm, if one analyzes all the consequences. This was one remark I wanted to make.

The second remark is only a very short one and has to do with Dr. Szent-Györgyi's remark about the costs of armament. The figure he has written down is only for the American expenditures. If you add it all up, for all the world you would have to multiply this figure by at least a factor of three.

CHAGAS

A question students ask very frequently is the following: What do you think a man should do who has discovered in basic science something which is important, but can produce damage to mankind? Your comments, Dr. Weisskopf, are a good answer to the question.

UBBELOHDE

I would suggest that one bad use does not make the totality of uses, and I thought the point Weisskopf was making — correct me if I am wrong — was that there are always nine good uses to one bad, with which I agree entirely. I think this is the human situation, the human tragedy. I think this is here now entirely agreed. There is no such thing as bad science; there are of course bad uses of science.

SIDDIQUI

Many of the speakers have referred to the population explosion. One of the delegates — I believe he was from Bangkok — at the closing session of the U. N. Conference held in 1963, ultimately succeeded in dealing with this point exactly, in a paper which he had prepared after a great deal of study of the statistics. His finding was that the world population increased during the agricultural period of humanity at a very slow pace, but that after industrialization started the curve went up very steeply. Then, with industrialization the standard of living increases up to a certain point and then it flattens out again. The best method for improving the situation in less developed countries would he to telescope the early stages of industrialization to the developing countries. The only way I see that this can be done is by following the wishes expressed by Professor Szent-Györgyi.

SELA

I would like first to make a brief comment on the need the biologists have to learn from the mistakes referred to before. This concerns especially the problem of genetic engineering and manipulation. I think that most of the biologists feel convinced that they took the right road. However, when we look at what happened last year in the Boston area, and particularly at Cambridge, one must wonder. The scientist who really wanted to prevent that genetic engineering should become a political issue paved the way to what is now outside of scientific logic. I am referring to those who were extremely careful and prudent, and convinced their colleagues to accept the unilateral moratorium on genetic engineering research. They were painted as villains and had to fight with the Cambridge Aldermen, the politicians, and alas! scientists also, who, for political reasons — which have very little to do with science — were trying to profit from the issue. This is a case from which we can learn and draw conclusions. It is my feeling that if scientists would be left alone, they would know how to distinguish between what could be dangerous and what not. In the case of DNA recombination, we find a positive side of caution by the scientist. However, public opinion just accepted the wrong way. Maybe it is correct to say that once the scientist goes public he has to be very clear and simple so that his real objectives are not misrepresented by public opinion.

I want to make another comment and extrapolate what Szent-Györgyi and Weisskopf have said, on a global scale. I cannot help thinking of my own country and our expenditures on defense, and how lovely it would be to give all this up. As a matter of fact, I think we would be in spendid economic shape if we would do it. On the other hand, the one point to which I would like to hear an answer from Professor Szent-Györgyi is this: Can one do this unilaterally? Because you referred only to one country in the world. Do you think that if the United States alone would give up armament and all the rest of the world would arm, this would result in a better life?

UBBELOHDE

I honestly do think that the judgment of Philip Noel-Baker would make me more than highly suspicious as a compatriot. I mean the figures are there of course. But I think this is beyond scientific discussion. We know these facts and we are going to be attracted into just what we are taught to avoid, which is a political opinion on a matter that is not strict science. I entirely support what has been said by Weisskopf and by Sela. You must go on with science for its own sake regardless of whether knowledge may have some evil applications. But we can be attracted into political half-truths as easily as anyone else. Nothing protects us from it.

Chagas

As I pointed out this morning, what Sir Philip Noel-Baker is suggesting — and I think he can really be considered a champion of the cause — is a reduction of 10% in the amount of money spent every year for weapons. This means a reduction from 300 billion dollars a year to 270 billion dollars; and he has shown us that those 30 billion dollars could really do a lot for developing countries.

I think that the important question here is to know exactly what should be the attitude or the behavior of a scientist when he knows that, for instance, the publication of his fundamental work may lead other people to use it in what we are calling a bad way.

Lejeune

Je désire d'abord dire que je suis d'accord avec le Professeur Ubbelohde, et citer simplement ce que disaient autrefois les chinois — je parle d'une Chine très ancienne — quand on demandait à un simple paysan: « Est-ce que vous faites de la politique? » et le paysan répondait: « Sûrement pas; je paye assez cher des fonctionnaires pour ça ». Il me semble que nous, les scientifiques, nous sommes un peu dans le cas du paysan chinois d'autrefois. Ce que nous pouvons dire, et même ce que nous pouvons penser, n'a pas autant d'importance que nous le croyons sur le cours des actions humaines, et surtout n'est pas compris dans le sens où nous l'entendons. Vous avez posé, M. Chagas, à M. Weisskopf une question très claire. Vous avez demandé si, ayant fait une découverte fondamentale dont il sache que l'usage puisse être mauvais, il aurait enterré cette découverte. Je voudrais raconter très simplement ce qui m'est arrivé personnellement.

Ce n'est pas une découverte fondamentale, mais quand j'ai découvert le chromosome surnuméraire chez les enfants trisomiques 21, ceci était le signe d'une maladie. A l'heure actuelle, avec l'amniosynthèse, dans certains pays, ceci a été pris pour un signe de mort, et ces enfants dans des pays autrement civilisés, parce qu'on décèle en eux un chromosome en trop, sont tués à quatre ou cinq mois d'âge, dans la ventre de leur mère.

Je peux donc répondre à votre question, car je me souviens de cette histoire et je dirais que si c'était à refaire je republierais tout de suite, parce que de toute façon la vérité éclate un jour ou l'autre, et il est absolument illusoire de s'imaginer que l'on détient pendant un instant un savoir qui nous appartient. C'est enfantin. Mais ce n'est pas seulement pour ça; c'est parce que je crois que la responsabilité vraie et la seule qui soit à notre mesure, comme scientifiques, c'est d'utiliser l'information sans la déformer. Et je m'explique à propos de ce que je connais de l'histoire des enfants qui sont atteints dans ce que l'homme a de plus précieux, à savoir, dans leur intelligence. Il fallait, bien sûr, publier la cause de leur maladie; ce qui fait le drame actuel n'est pas qu'on sache les reconnaître, mais c'est qu'on ne sache pas les guérir. Autrement dit, il faut d'abord publier la cause et courrir tout de suite pour essayer de trouver le remède, et c'est là qu'est notre vraie responsabilité. Toute découverte est vraiment comme un fruit qui pousse sur l'arbre de la science, qui est finalement bien l'arbre du bien et du mal. Ce que nous avons comme seule responsabilité ce n'est pas de déterminer la qualité des fruits — c'est impossible pour l'homme — mais c'est de montrer aux autres hommes à cueillir les fruits qui sont bons. C'est là que notre responsabilité est en jeu.

LÉPINE

Ce n'est pas la peine de rappeler ici que lorsque Adam et Eve ont mordu dans le fruit de l'arbre de la science, ils ne savaient certainement pas les conséquences qui seraient tirées de leur acte ou qui interviendrait par la suite. Donc le problème n'est pas nouveau.

LEPRINCE-RINGUET

Quand on dit « une découverte va servir pour le bien ou pour le mal », c'est extrêmement aléatoire, illusoire, de dire « le bien ou le mal »; c'est très difficile à définir. Si vous prenez un petit peu de barbiturique, vous dormirez bien, mais si vous en prenez toute une boite, vous allez mourir. Par conséquent, la même découverte utilisée par la même personne peut lui servir pour son bien ou pour son mal; de même les rayonnements. Les rayons X, vous pouvez vous en servir pour le bien, pour votre bien, mais si vous en abusez ou irradiez certaines régions, et bien, vous en servirez pour le mal et vous finirez par en mourir. C'est très difficile, je dirais même pour le cas d'une découverte pratique, définie, de dire, « Cela va servir pour le bien ou pour le mal ».

CHAGAS

Je pense que maintenant nous allons suspendre la séance. J'aimerais dire seulement, en tant que Président de l'Académie, que je suis très heureux de ce commencement que nous avons eu et qui est né d'une suggestion du Professeur Ubbelohde. Evidemment, le sujet était très vaste; c'était la première fois qu'on se réunissait pour prendre un sujet commun comme débat. Cette expérience n'aura pas été peut-être un succès total, mais a été tout de même une réussite, et je crois que c'est pour nous une leçon dont nous devrons profiter pour notre prochaine séance. Je vous remercie vivement du travail, de l'attention, de l'intérêt, de l'enthousiasme, dirais-je, que vous avez donné à notre débat, et en vous remerciant vivement, je voudrais encore vous dire, puisque c'est le dernier moment que j'ai, que j'aimerais beaucoup recevoir le plus souvent possible vos opinions, vos conseils, vos réflexions sur la façon de poursuivre notre activité. Merci beaucoup.

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