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*The Necessity of Freedom for the Free Flowering of Science**

by

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In order that science, as distinct from technology, may flourish it is imperative to have freedom to conduct research and discuss results without dogmatism, to publish, to travel and to attend scientific meetings without state interference.

I WOULD define science as the systematic attempt to understand and comprehend the natural world. It means to enter deeply into the natural world, not just superficially, but to achieve a rational expression in language and mathematical symbolism of the order and beauty of operation that lies behind all natural phenomena. This is the aim of science. Its scope is not just the external world, the scope of science includes ourselves. By that I mean that all aspects of our own experiences of ourselves — our perceptions, imaginations, emotions and actions — everything properly comes into the purview of science.

Now this enterprise of science, is dependent on the imaginative and disciplined activities of unique individuals who ideally form a free and supranational society. This essential feature of science certainly is not fully understood and appreciated by the politicians and the bureau-

* Dunning Trust Lecture, Queen's University, 1968. (Abridged by editor)
I have chosen this title because it is consonant with the magnificent citation for the Dunning Trust Lectures. I do not know of a better citation for any lecture series. "To promote understanding and appreciation of the supreme importance of the dignity, freedom and responsibility of the individual person in human society." Furthermore, it corresponds so well to my vision of what can be claimed to be the greatest spiritual adventure of our present civilization, an adventure that is subsumed in one word, science. In science the freedom and responsibility of the individual scientist are of supreme importance.

crats that operate even the most liberal political systems, and in most countries it is not understood at all. Correspondingly there are not very many countries in the world where science flourishes in a free-flowering manner, as I like to describe it metaphorically.

There are many countries, offering in general, unfavourable conditions, but with isolated growth and flowering, that are dependent upon the courage and genius of one leader and his devoted disciples. As an illustration from the past, I give Ramón y Cajal, who, late last century in Spain (which was completely unfavourable), and with practically no support at all, became the world's greatest neuroanatomist, building up a world-famous school and making a magnificent scientific contribution that to this day we are still so much dependent upon. There has so far been only one Ramón y Cajal in the sciences of the nervous system. He exemplifies a very rare phenomenon; the high level of scientific performance that can be achieved by a genius under unfavourable conditions.

Before I enquire about this extreme diversity between different countries in respect of science, I draw a sharp distinction between science and technology. I am not going to say which has the higher status, but it is necessary to be clear about these two categories, though the same person can be both a scientist and a technologist. He can wear, as it were, different hats for the occasions, but what he does on these two occasions is quite different. There are technologists in many countries, where there are no scientists. In fact all countries have technologists even when they are in the Stone Age. Then they use technology for fashioning stone tools! In Professor Washburn's School of Anthropology in Berkeley, California, the graduate students in Anthropology, as a practical exercise in the archeological laboratory of Dr. Desmond Clarke, spend a whole semester in trying to make a stone tool, using the same tools as Stone Age people had. Professor Washburn tells me that no one so far has succeeded in making a stone tool that is in the class of those made by large brained men some hundreds of thousands of years ago!

The aim of the technologist is to apply scientific knowledge and empirical knowledge in some useful purpose. He may even be designing and constructing scientific equipment. I am a technologist when so engaged. Technologists are responsible for all the marvellous inventions that have transformed the conditions of our life. You only have to think of a spectrum ranging over the revolutions in the means of communication, in the materials for all purposes, in electronics, and all the new discoveries and inventions relating to medical practice, to agriculture and food, to chemical industry, to computers, and so on. This human activity is quite different from science, although it utilizes or even exploits the discoveries of science. Of course, the technologist has to have a wide knowledge, imagination and high intelligence just as does a scientist. I am not underrating the level of his performance, I am just saying that it is different from that of the scientist. The difference lies in the different objectives.

The scientist tries to understand or comprehend the natural world as he experiences it using for this purpose hypotheses that are tested under specially designed experimental conditions in which often most elaborate scientific instruments are employed. Yet, in the end, no matter how complex the apparatus is, the information that it delivers has to be looked at and observed by a scientist, who has to take notice of it, and critically examine it in relation to his hypotheses, and maybe reformulate his hypotheses and so on. The essence of what a scientist does is to imagine and explain what lies behind phenomena, in other words to try to comprehend the natural world. On the other hand, the technologist is utilizing the knowledge about the natural world for practical purposes. That statement applies not only for all the practical things that I have spoken about, but it also applies to space travel, which is really technology. It is marvellous engineering, but it is not science. It is space exploration. There may be a little of science in it, but it is not a scientific achievement; it is a tremendous technological achievement utilizing the discoveries of science for its purposes. Another side of technology is of course the threatened horrors of atomic warfare — target-finding missiles with thermo-nuclear war-heads.

It is a tragic mistake that the general public and the political leaders confuse technology with science, there being virtually no appreciation or understanding of science itself. I can give you two examples. The belief that space travel is an advanced form of science can lead to most embarrassing situations. I actually made reference to this misunderstanding in a lecture I gave in Melbourne while the first Sputnik was in orbit unknown to us. Next day I had many interviews with reporters as I was then President of the Australian Academy of Science. A few days later the Soviet Ambassador to Australia asked me why I did not indignantly deny the absurd statements attributed to me. He asked "Do you not recognize that the orbiting of the Sputnik is the greatest scientific event since the discovery of America by Columbus?" To which I replied, not very diplomatically: "Your Excellency, I am greatly surprised that you think the discovery of America had any scientific significance whatsoever!" I received no more invitations to the Soviet Embassy. Only a few days ago (October 1968) it was reported in the *Journal of Scientific Research* that a political leader in emphasizing his support for science had stated "I understand that recently a gap has developed between Soviet and American science. My efforts will be to narrow that gap!" This statement has a most unfortunate implication when one appreciates the very large gap in the inverse sense between the levels of the true science of America and the Soviet!

This is the fate of the most scientifically advanced country today, that its leaders have very largely been misled on what science is, and this defect will be recognized in many of the points that I raise for discussion. Soviet Russia has been credited with high scientific performance because of this misunderstanding. They have been able to peak in a few technologies, space travel and atomic missiles for example, but their performance in almost all aspects of science is quite indifferent. The exceptions are some branches of physics and mathematics. Because they have been credited with great scientific achievement in technology, their Kremlin leaders are quite ignorant of the very special and extraordinary condition that must prevail if there is to be a free-flowering of science.

The mistaken identification of space travel as the most significant science of our day has the further unfortunate consequence that science will be discredited when space travel fails to deliver a continuing stream of startling discoveries. The general public and even the most enlightened political leaders fail to appreciate the extraordinary conditions that must prevail if there is to be a free-flowering of science. It will be my task in this lecture to show that of its very nature the scientific enterprise depends on a very special freedom of the scientific investigator.

Science only came to our western civilization in the 16th and 17th centuries. Before that there were only brief glimpses of it, and since then it has gone on by fits and starts, flourishing and flowering or just wilting. The 17th century was a century of development; the 18th century, much less so; and the last half of the nineteenth century was a period of great achievement that has gone on at an accelerating pace in this century. That brings me to enquire what special conditions are required to produce a rich scientific achievement in any age.

Let me begin by enquiring how a scientist comes to be. That will help to explain how it comes about that some ages and some countries are distinguished by having many scientists and a flourishing science, whereas most fail.

First, our civilization has a naturalistic as opposed to a magical outlook on nature. We do not believe in such influences as the occult, in astrology for example, though of course, there is always a lunatic fringe! Instead the child grows up in an atmosphere in which he learns to believe that there is a rational explanation of everything he experiences. A child will ask questions of his parents or teachers and often they are very good questions. Thus he learns that nature is rational and orderly and capable of being understood. Almost every child in our community grows up in this atmosphere, thinking that even if he cannot understand it, there is at least a good explanation. For example he is offered explanations of the movements of the sun and moon, of the tides, of rainbows, of streams flowing and of the origins of rocks and fossils. The world is orderly and capable of being understood at least in principle. He has an example of what can result from understanding, because we have now progressed so far in science that there have been immense developments in our control of nature, as witnessed by all the wonders of technology, such as machines for every purpose, and the child-like wonders of radio and T.V. The message is certainly compelling to impressionistic youth.

Secondly, after that initial education, some young people, particularly the inquiring ones, say: "I would like to get an idea of this for myself. It is not enough to be told these things. Can I go on?" So he may elect to do science in the ordinary undergraduate course. Here he gets basic instruction in scientific discoveries and in the laws that scientists have established. However, he does not really understand science at this undergraduate level. I think he is only just learning about science; he is not learning what it is to be a scientist; nor does he learn what motivates a scientist, how a scientist behaves in making discoveries, in fact what is behind the whole process.

Then our embryo scientist may go on at the postgraduate level if he has been successful and done his homework. (In parenthesis I can assure you that I have been through all this myself. I was extremely successful at examinations so that I got a Rhodes scholarship to Oxford, but still I did not know what science was about. I went there and learned. I learned that you do not get clear answers, and there are many arguments, schools of thought, changes of opinion and so on. I began to learn much more when I started out in collaboration with Ragnar Granit to do research with Sir Charles Sherrington.) The kind of thing that is learned in the Ph.D. course is that science has an eternally provisional nature. It is uncertain and so has unlimited possibilities for growth and change. One must cease to believe in ultimate statements which claim to give a finally established truth that should be accepted unquestioningly. Let me repeat that basic scientific ideas, theories, and explanations are always provisional and always subject to change. For example, think what happened to the magnificent Newtonian theory. In this stage, the Ph.D. student gets some routine experience in research. On the whole most postgraduate students are given fairly tidy little jobs that are planned so that the ordinary laboratory equipment can be used. They are supported on all sides by previous scientific investigations, so it is improbable that anything startlingly new will turn up in this research; nevertheless it is worth doing because it fills in gaps and makes the conceptual structure more complete. If our student is lucky, he may come across something that was unexpected. Charles Best at the age of 21 or 22, with Banting discovered the Insulin story, in nearby Toronto. This can happen when he is very young indeed, but it usually does not. However, he will have learned quite a lot about how to do experiments, how to observe and how to handle abnormal observations when they come. There may have been something wrong with the animal, with the equipment, with the substances such as chemical impurities or a thousand and one other things, or there may be the first inkling of a new discovery!

Next if our young scientist is good, he should go further than the Ph.D. level, and in postdoctoral research actually experience creative science both conceptually and experimentally. At this stage it is important to pick the right man to work under. There is no textbook which tells you how to become a scientist. There are lots of books about the methodology of science and also the philosophy of science, but they are mostly wrong and misleading. A scientist has to learn in the old-fashioned way, and be an apprentice. It was just so in Renaissance times if you wanted to be a painter. For example, you would go to the studio of Verocchio, where you learned about pigments, anatomy, perspective, technics of fresco and all those sorts of things, and you were allowed to paint here and there on pictures. Eventually, you might become a Leonardo da Vinci. Leonardo was apprenticed to Verocchio when he was 14 and worked in the studio for six years. This is essentially the way that scientists are made today.

In my experience the relationship in a laboratory cannot appropriately be called a master-pupil relationship. I just work with people. For example, I arrange to do some experiments with them usually on some problem that has arisen in a preceding investigation, but that has not yet been solved. During the experiments we watch the results together and we talk about the literature. We try to interpret what we observe in the experiment, going backwards and forwards about the meaning behind it—"Does that strange phenomena mean anything, or does it have no significance, merely arising on account of defects in the experiment? In that way one's scientific associates can be given an insight into the personal intuitions, hunches, serendipity, which somehow one has learned and which one delights in handing on. Then always in trying to solve one problem we discover new phenomena that raise more problems, some of which we attack in turn and so on.

Science is an art. It is an art because it has to be learned in this strange manner. It is a way of looking at things, of seeing behind them, a way of imagining. Creative imagination is required, and in this kind of association in a laboratory there is one of the most satisfying experiences in human living, a real delight in the exchange of ideas. However it can be very tough at times; you fight about meanings and ideas, but it is not a one-way action. I can learn, and in recent years I have learned a great deal from what you would call my junior colleagues. I have been wrong in my explanations and of course eventually recognized that I was wrong. That is the way it goes. Sometimes, they are wrong too! It is this disputation backwards and forwards which is the essence of science, and it is in this way that you can create a scientist. There is the exception, like Ramón y Cajal, who created himself, but this is asking too much, even for the extraordinary person. I feel then, that scientists are a band of adventurers exploring the unknown.

You do experiments and you can have a very good idea of what to expect from your past experience, and your expectations may be fulfilled. Usually, however, there is something else coming in, some worrying phenomenon and for a while, you take no notice of it. You even try to look aside when it appears! But it keeps on reappearing, so you recognize that "here is something that nature is trying to tell me." This is essentially the way in which I have made discoveries. They arose from the happenings that I was not expecting, where eventually I was tuned in enough to listen to what nature was trying to tell me. The good students and the good research workers are those who can recognize and appreciate the significance of the unexpected. Those that you discourage and tell to devote themselves to practical affairs are those who, when asked how they got on with an experiment, say that they were terribly disappointed because what you had predicted had not happened. They did not recognize that, when confronted by the unexpected, you really should be alerted; and this is what a good scientist has to learn. This is what he should learn in a good environment.

But after much experience I have to admit that there is also a perversity in some students that lowers one's assessment of their quality as potential scientists. As one learns from one's own hard experience, wisdom and judgement are required in the interpersonal relations that are so important in the creation of a good scientist. It is good to be motivated by ambition, but those dominated by ambition become impossible colleagues, and even their scientific integrity may suffer. The overly ambitious irritate by their arrogant posturing and display.

And now comes the final stage of being able to lead an adventure and to have students in this enterprise. After two or three years post-doctoral experience working under good conditions some young scientists can venture on their own and succeed. It is most encouraging when you find that your research associates develop in this way from strength to strength, making remarkable discoveries. I had with me for some years in Canberra, Dr. Masao Ito who went back to Tokyo to develop his own research group. They performed experiments on neural pathways from the cerebellum that led to ideas which I could not possibly believe when I first heard them. They were so original that I just rejected them, but eventually I had to realize that this was a new and quite fundamental discovery. I regard it as a great success, when your students graduate to such an amazing scientific performance.

Now I come to what science is. Hitherto I have been trying to give you a feeling of the free society in which a scientist is created. It is neither a dogmatic society nor an authoritarian society. It is a free society of people adventuring into the unknown. Following Sir Karl Popper I can state that in science what we do essentially is have ideas and hunches going quite beyond anything that is yet established as a result of experimental investigation. These ideas or hypotheses offer challenges which become formulated as predictions capable of experimental tests. Scientific hypotheses should be defined so closely that they challenge attack. One of the best compliments you can be paid is that someone spends days and even years trying to disprove some hypothesis that you have proposed. You have challenged them and maybe they will disprove you, but this is science. It is a scientific success to have disproved a good theory. Science advances in this way, refining and clarifying ideas by rigorous testing. As a result, a hypothesis can be said to be corroborated, but it should never be claimed that it has been proven true. Ultimate truth is still beyond that. No scientific hypothesis or theory today can be claimed to be completely true in itself. We must say it is the best we can do. You have an example of this in Newtonian Mechanics, which for more than 200 years was regarded as the ultimate truth, but now of course, is only a good approximation. This is what will happen to all our theories of today. Many of us scientists have become very wise about this, but non-scientists do not understand it at all; they think that science gives truth, and that, they think, is the great virtue of science. This is also believed by most scientists today. That is the trouble. They believe in a false philosophy because they have been badly brought up theoretically. As long as they have been well brought up in the "practice" of science, they can get along quite well, doing things correctly, but misunderstanding the essential nature of scientific investigation. They believe with Bacon and that science consists in observing nature, and when you get enough of these observations, you then extract from them a pure distilled truth.

There are many other strange beliefs associated with this so-called inductive theory of science. It is erroneous, because you are just misleading yourself if you think that observations in themselves have scientific significance. In fact you only observe special happenings because you have some ideas about what to look at. A scientist does not just make observations, he makes observations within the special framework of a theory which gives him highly specific information about what to look for. It is also a mistake to believe that nature cannot lie, and if you listen with an unbiased mind to what nature has to tell you in response to your questioning experiments, and write it down, then you have a truth. The whole point about it is that nature would only give you the most confused stories — nothing at all scientific, just myriads of happenings. Instead, a scientist has to develop from his hypotheses specific experimental situations by which they can be subjected to crucial tests. By experiments that are well designed and carried out he is asking carefully framed questions of nature, and discovering how his hypotheses stand up to this experimental scrutiny. That is the way scientific investigation is carried out. In contrast many of the so-called scientific publications are just compilations of observations often made with the most sophisticated and expensive equipment but lacking any scientific meaning.

It is important to appreciate that inevitably we have tensions between innovations and the orthodoxy of the Establishment. A scientist must be an innovator. Previously I mentioned Masao Ito, who discovered something quite unexpected, fundamental and new, and my reaction had immediately been to reject it, and say something was the matter with his measurement of time, or his electrodes were not properly recording, or something like that, yet eventually I had to recognize his discovery.

How then do we manage to progress in science? Well, a scientist does some experiments, and gets a lot of results. He writes an account of his problem, his results and a discussion of the results. He sends his paper to a journal, or he could publish a book. The ordinary way is that he goes through the mill of presenting his data to a scientific journal. The journal has editors whose task is to criticize and evaluate the work, and also to make suggestions about changes that should be made if it is to be accepted for publication. If you are unable to get your paper past the referees of one journal, you can try others in succession until one will take it, and as far as I can see almost everything gets printed eventually! Often papers have to be modified and usually referees give good advice for revision.

Once the paper is printed, the next stage the scientist has to go through in his testing is that it is read, and sometimes by experts in the field. If you are an expert in the field, at first you look it through very cursorily and see if it is worth reading and secondly you decide how much time you should spend with it. Sometimes, you read and re-read it, making copious comments often in the margins, and sometimes it just disappears from your mind and even from the literature. Some papers have an extraordinary short "half time." I am told that there is an organization in America that for Presidents of Universities and such like will carry out investigations on any named person to find out how fast his papers disappear from the quotational literature! Sometimes it is too revealing. It is all done on computers within a day or so, and at a price you can get the answers for all candidates applying for a job! Frequently before or during the course of publication the scientific results and ideas are presented verbally at some scientific meeting, where the author has the opportunity of defending himself against criticism or of further explaining his results.

The next stage may be even more remarkable. You may find people not only quoting your paper, but also accepting it so that they base their own experiments upon it, or they may even write textbooks or monographs with the paper occupying a key role. This is the ultimate success. However, don't be misled by that. It still could be wrong, and probably is at least in part wrong. It takes longer to get something out of textbooks than it does to put it in. But even after this success stage it still remains open to attack — which may either be directly in new experimental developments or it may be when it is found to be inconsistent with quite other investigations. And so the scientific process goes on — an interplay of conjectures and refutations, as described by Sir Karl Popper.

I think it is very important that we should cherish and appreciate the operational aspects of scientific societies and journals. The tradition is that the scientific societies do not intrude on the scientific freedom of their members. You have to realize that as august a body as the Royal Society of London does not adjudicate as to whether any particular scientific statement or hypothesis is true or false. Its members can do as they like, but it is the tradition that as a society it never adjudicates. The same would be true for the National Academy of Sciences, and so on.

Scientific orthodoxy thus is not maintained by some formal establishment. It is dependent in a strange manner on the informal and often unorganized discussions between small groups of scientists. That's how science goes on. Scientific meetings are often most valuable in the opportunity they give for free informal discussion between the programme items or even during the items, because except at very small and specialized symposia, absenteeism is much practised — often to advantage!

Scientists can be very hard in their criticism of each other, but they also, of course, match that with generosity and admiration. The level of performance is always being assessed and judgement may often appear to be uncharitable. Accusations, however, are rarely made that a scientist lacks integrity. Criticism is not made on those terms. Rather it is that he is misguided and has mistaken ideas.

Now I come to freedom. I have talked about science and the atmosphere in which it is conducted, now I ask: how does freedom fit in with this? Why is freedom, as we define it, so necessary? Its necessity comes from this tension between the two different themes of science. On the one hand there is the freedom to adventure ideologically and imaginatively and so to have the opportunity to experience new visions in the understanding of nature. All scientists, except those conditioned by their political masters, will believe that freedom is necessary for this. There must not be some imposed dogmatism limiting what can be done or expressed in science, as for example happened to Galileo. On the other hand, I have referred to this critical and even repressive activity, the general authority that is exercised by the scientific community with its scientific societies and informal groups. They function as arbiters, but are not properly or even deliberately constituted for this purpose. There is on-going discussion and criticism all the time by scientists whenever they meet. It is the tension between these two opposite poles of scientific activity, on the one hand freedom to adventure, and on the other critical restraint and even repression that gives science its amazing strength and success. Scientists may develop and express mistaken ideas, but experimental refutation soon prevails.

I think the safeguards against arbitrary action are given because in a free society the community of scientists does not act as a single dogmatic authority. Instead there can be many authorities, often advocating different and even opposing schools of thought. There will be many mistakes, but usually they are not fatal to any individual. And there is no rigid dogmatism is most fields. Thus freedom of scientific exploration is safeguarded fairly adequately. In the free countries of the West there is also freedom to travel from one country to another for scientific meetings and for scientific training. In fact it is greatly encouraged by generous financial provisions.

If the young scientist we have been imagining has ideas that do not fit in with those of the professor he is working under, he is free to move to another place where the scientific ideas are more consonant with his own. He can move because he has freedom to travel which is very important, and also because there are always places for dedicated scientists. This is why a free society is so important. Even within most laboratories there is much room for differences of opinion and even for a generous tolerance of dissent.

I had a young scientist from a satellite country working with me some years ago. He appreciated our free society very much and after some months of observing and thinking he said, "I think I now know the difference between the East in Physiology and the West in Physiology. In the East, I was taught that you had to get some ideas which were orthodox and official and you had to do experiments so as to support and confirm these ideas. Here I find out what you are doing is: firstly you have some general ideas that lead to experiments, then you seem to listen to what nature is trying to tell you, so that you can develop better ideas." That, of course, is what science essentially is. . .

In Washington on August 25, 1968, at the 24th International Congress of Physiological Sciences, I met some Czech scientists and heard from them what a terrible blow had been delivered to their country by the Soviet invasion some 5 days earlier. From January they had had freedom after 20 years of oppression by their Stalinist masters. The point about freedom is that you never really appreciate it properly until you have lost it and then regained it. This was their great illuminating experience. They spoke with great emotion how they felt that an eternal spring had come to them. They said, "In the excitement — even intoxication of the new-found freedom — we felt a new life had come to us in the creative, the scientific, and the artistic world. This life was welling up in the creative work in Czechoslovakia in those marvellous eight months." Then it was quashed. The general assembly at the opening of the Congress went on as a very formal affair with perhaps 4,000 people present and with a full array of the Establishment up on the dais. As we anticipated, the Establishment adopted the secure and comfortable position of making not the slightest reference to this tragedy for the large delegation of Czechs attending the Congress for fear that the Russian delegation might feel embarrassed!

With help from some of my colleagues who shared my views, a microphone was secured before the meeting assembled and was placed just below the dais, and it was arranged for it to be turned on at the right moment. Just at the end of the final welcoming speeches, before the closing speech by the President, I walked up quickly and made the following brief statement:

> Freedom of body and spirit is essential for the growth and free-flowering of science to which we are all dedicated. We, participants in the 24th International Congress of the Physiological Sciences, detest and abhor the perfidy and treachery by which the Soviet Union and its satellites have brutally attempted to quench the newly relit torch of freedom in Czechoslovakia.

This was at least a help to the 49 Czech scientists there, and I felt that something like this was required. It received a fine ovation from the gathering and has been greatly appreciated by the Czechs, as I have often heard from them, but it was much resented by the Establishment who regarded my intervention as a political contamination in what should be a purely scientific occasion, and an insult to the 46 Russians present.

In retrospect I have no regrets. The subsequent months have clearly demonstrated that the Russian invasion was ordered by the Kremlin in order to quench by brutal power the freedom that could be a threat to their tyranny. All other stated pretexts are now known to be lies. One is reminded of their blatant lies at the time of the Cuban crisis. At the same time as the Congress in Washington there was in Siena an International Congress on the History of Medicine and I have heard from Professor Gibson, Professor of History of Medicine in Vancouver, that the situation was quite different. The Italians gave an immense reception for the Czechs. When the Czech delegate at the end spoke, everybody stood up and applauded for over five minutes without stopping. Then the Soviet delegate was asked to speak, but he couldn't be found. This example from the recent tragic history of Czechoslovakia emphasizes the necessity for the eternal struggle for freedom, else our future society will be dehumanized to the level of insect societies, as portrayed in Orwell's *Nineteen Eighty Four*. Not only will science and art cease to exist, they will never be known to have existed. This struggle for the freedom to tell the truth is being fought out in Czechoslovakia today. Jan Palach's self-inflicted martyrdom as a human torch bears witness to the toughness and intensity of the battle for freedom against totalitarian repression.

In conclusion I would like to give you three quotations that I think are closely related to the theme of my discourse. The first is from the eminent scientist-philosopher, Michael Polanyi, who has been in the forefront of the battle for freedom and science for many decades. I am happy to acknowledge that I have tried to express many of his ideas in this talk. I now quote from his book *Science, Faith and Society* (University of Chicago Press, p. 62.)

> There is one feature which, judging from the eternal life of science we may expect to be essential to it. That is freedom. If the way in which truth is found *in* science is any guide as to how truth is to be found *about* science, the society in which this process can be properly conducted must be based on freedom; discussion about science must be free.

The second quotation is from a recent article of mine that owes much to my mentors, Michael Polanyi and Karl Popper:

> Science is shot through with values — ethics in our efforts to arrive at truth and aesthetics in our conceptual imagination and in the appreciation of our hypotheses. If we can give to people an understanding of science as a very human endeavour to understand nature, and to present in all humility the best of our feeble efforts to do so, then sciences will

> be appreciated as a great and noble human achievement, whereas, instead, it is in danger of becoming some great monster feared and worshipped by man and carrying with it the threat to destroy man.

(*Perspectives in Biology and Medicine*, v. 12 (1968), pp. 61-68.
I finish with a quotation from Sir Karl Popper:

> What we should do, I suggest, is to admit that all knowledge is human, that it is mixed with our errors,, our prejudices, our dreams and our hopes, that all we can do is to grope for truth, even though it is beyond our reach. We may admit that our groping is often inspired, but we must be on our guard against the belief, however deeply felt, that there is no authority beyond the reach of criticism to be found within the whole province of our knowledge, however far it may have penetrated into the unknown. Then we can retain without danger the idea that truth is beyond human authority. And we must retain it. For, without this idea, there can be no objective standards of inquiry; no criticism of our conjectures; no groping for the unknown; no quest for knowledge.

(*Conjectures and Refutations*, New York, p. 29-30).

This quotation gives you then some feeling about science and the kind of society and the kind of individual persons that are required to be scientists. My belief is that the concepts I have presented concerning science and scientists are very much in accord with the citation for the Dunning Trust Lectures.