

The scientific temper*

Hermann Bondi

Why is science so universal? Surely the only explanation can be that its methods and outlook correspond to traits shared by all humans, that it is adjusted to a common human characteristic.

It is a great and unexpected honour to have been invited to give this lecture in the memory of a great man, whose name is honoured throughout the world. This memory is so rich, that one can put one's own slant on it and hope that illuminates and adds to it.

My first knowledge of him came to me as a child in Vienna. When our mother fell ill, she engaged a lady as

governess to stimulate and supplement the school education of us children, myself and my sister who was a few years older than myself. We became so fond and keen on this lady that even after our mother returned to health we made sure that she came and spent time with us. She had an avid interest in all aspects of adult education, but her great hero was Gandhi. This was

Hermann Bondi, visiting Raman Professor of the Indian Academy of Sciences, was in Bangalore to deliver the Gandhi Memorial Lecture at the Raman Research Institute. S. Ramaseshan, introducing the lecturer, had this to say:

'Hermann Bondi is one of the most remarkable persons I know. When Bondi's name is mentioned every one thinks of the Steady State Theory of the Universe by Bondi and Gold, – and of Hoyle. For keeping the expanding universe at constant density, what they asked for is not much. Just that space should create a mass equivalent to that of a hydrogen atom in one litre of space every 1/2 a million million years, i.e. 5×10^{11} years.

It is perhaps one of the most beautiful of theories. And yet to my mind it is the classic example that Chandrasekhar and Dirac are probably wrong. They insist that beauty is the ultimate test for truth. This beautiful theory of the steady state of the universe, I think, does not work. Why do I mention Bondi's magnificent failure today? It is to bring out the unforgiving nature of science and that science advances by such mistakes.

But Hermann Bondi has had many many successes. I will mention just two. He took up a problem of what will happen if matter goes on depositing or accreting on to a sphere – as if it were a problem set to undergraduate students. And this paper by Bondi happens to be one of the most quoted papers in astrophysics.



Hermann Bondi will be remembered for his establishing the reality of the gravitational radiation in full General Relativity, the existence of which the Master himself doubted. Einstein wrote to Max Born earlier "I have arrived at the interesting result that gravitational waves do not exist!"

I came to know Hermann Bondi by the slim book he wrote on Cosmology. It reads like a novel. But each sentence was so charged with meaning that I learnt

much of my physics from this remarkable book.

He evolved the clearest way of teaching Special Relativity – the usual method is to expound it using the rigid rod approach. One was uncomfortable and even thought this approach clumsy. When a rigid rod is pushed, the other end moves instantly, i.e. the information is carried to the other end instantaneously. This contradicts the very principle of relativity. Bondi's approach (now called *K* calculus) is simple, logical and without any inconsistency.

After the sixties, Hermann Bondi concentrated on administration and was Chairman of many committees that gave direction to science in the United Kingdom and Europe. One does not know what the good fairy does to make men remarkable administrators and Chairmen. The list of Government Departments and Committees he headed is formidable: Chief Scientific Adviser to the Ministry of Defence, Chief Scientist, Department of Energy, Chairman and Chief Executive, Natural Environmental Research Council. (You should hear him talking with great knowledge about seals and their babies.) He was also Chairman, National Committee for Space, Director General of the European Space Research Organization. (He was perhaps the first to insist that satellites must monitor soil erosion.) The list goes on – and in each field he left an indelible mark.

Hermann Bondi is much interested in the wider implication of science and scientific outlook – as his membership of the Humanist Association and the Science Policy Foundation testify.

I saw this Vienna-born British scientist for the first time in flesh and blood almost 25 years ago. From being my physics teacher by proxy he became a very good friend. Once I went along with my wife to Hermann and Christine's beautiful home near Cambridge to seek his advice. Two more striking things about Hermann Bondi: The first is the absolute clarity with which he expresses himself in the English language. His choice of words and sentence constructions are superb and unmatched.

The other is the fund of humorous stories he has. He is amongst the best raconteurs I have listened to. (We hope we hear some of these. It will be appropriate today as Gandhiji was always so full of fun.)

He was Master of Churchill College in Cambridge for many years. He was truly the Master of many fields he touched – be it fundamental physics, pedagogy, administration, or his concern for human dignity.'

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remarkable, for Vienna was far from the turbulence of British-Indian relations and totally absorbed in its own politics which indeed was of immediate and overwhelming importance as it led to the horrors of the Third Reich and the Second World War. Thanks to this lady, I was immersed, as a boy of 10 or so, in his unique way of bringing morality into politics and making his shining and undeflectable personality an eagerly watched centre of interest for innumerable millions. What a contrast to the violent and doom-laden politics of my home town and its slovenly pessimism!

As a footnote, I might mention that after the war, when all my other friends and relations had emigrated or been murdered or otherwise met their deaths, I made two visits to Vienna for the chief purpose of seeing this lady again in her old age.

Following this modest justification for my standing here, let me turn to the title I have chosen, which admittedly sounds as though it was far more in the spirit of Jawaharlal Nehru than that of Gandhi. Part of my purpose in this talk is to suggest that this contrast is much more apparent than real. It is indeed thanks to Nehru that this splendid reference to 'the scientific temper' occurs in your constitution.

In my view, the most remarkable characteristic of science, even more extraordinary than its achievements, is its universality. Persons can and do contribute to science irrespective of ideology, religion, race, gender or location. I know of no other human enterprise that is so common to the whole world. It is true that under brutal totalitarian regimes there have been short-lived perversions of the universal spirit of science, such as 'Aryan physics' in Hitler's Germany or Lysenko's genetics in the Soviet Union, but these exceptional derailments do not and should not be taken to invalidate the universality of science.

Why is science so universal? Surely the only explanation can be that its methods and outlook correspond to traits shared by all humans, that it is adjusted to a common human characteristic. In my view (and in this I am very much a follower of that great philosopher of science, Karl Popper) this universal characteristic is our fallibility. What science recognizes above all is that depth of conviction and passionate feeling are no guarantee of correctness; nothing that one of us claims can ever be taken for granted. Thus we scientists learn early in our professional careers that we must not take offence if it is felt necessary to repeat our experiment or to go through our calculations with a fine toothcomb. On the contrary, we should take it as a compliment if our work is taken so seriously by others as to merit repetition and detailed analysis. However much we may believe in our results, the outcome of such a repetition may well bring a surprise. But this is part of the process of scientific progress, which tends to be zig-zag. It has rightly been said that science does not advance like a steam roller.

This outlook does affect our professional attitude: To be proved wrong is no disgrace; to be ignored is true failure. Moreover, almost every mistake made has within it the seeds of an advance. Perhaps an example may help. Many years ago a friend and I advanced a theory that if a certain gap in the knowledge of the day hid a particular property, very important consequences we elaborated would follow. This led others to devise most ingenious experiments to fill the gap in knowledge directly. They disproved the existence of this property and thus our theory fell. Though this result was evidently not what I had hoped for, I feel proud of my involvement. As a result of our failed theory having been proposed by us, a gap in knowledge has been closed. My professional standing has also gone up rather than down.

Of course the behaviour of scientists is not always beyond criticism. There is occasional cheating, usually of very short life in a field in which checking and cross-checking is mandatory. A more serious problem is the rule of fashion: if a particular topic attracts some eminent scientists, it becomes popular and soon it is pursued in numerous locations. This gives it momentum: even if the original interest leads to little that is valuable or the benefits of the topic are quickly exhausted, the herd is liable to continue in the same direction whether it is still profitable or not. Thus there is merit in following one of the less popular topics and generally to be honest with oneself if one's choice of subject proves to be unfruitful and to switch to something else. The universality of science does not mean that everyone must chase the same hare at the same time*.

The relation of science to technology is too often misunderstood. It is quite untrue to say that science is pure and primary while technology is dirty and merely derivative. Science is above all an empirical subject; the test of experiment and observation is supreme. But how are experiments and observations performed? Of course by building apparatus that uses the technology of the day. Thus it is advances of technology that lead to more searching experiments that test our theories more thoroughly and reveal previously unimagined insights. In all, this technology is primary and science follows. On other occasions, technology follows science by making good use of novel scientific results. The two are intertwined and it is as foolish to ask which is leading and which is following as it is to ask which came first, the chicken or the egg.

*On one occasion when I arrived at Western Test Range in California to watch the launch of a satellite, I was informed that the management had that day to make the difficult choice of a contractor to maintain all the instruments of the huge base for the next 3 years. When I suggested that surely the obvious choice was the contractor who had carried out the task for the previous 3 years, I was told this was not possible. By law, the contract had to be awarded to a small business. By virtue of this maintenance contract, the current firm had become too big to be classified as a small business.

Both science and technology require human cooperation. The work of a scientist is useless unless and until it has been communicated to other scientists and been understood by them. Thus that most singularly human of our abilities, language, is essential for science*. Whether we do enough to develop the communication skills of young members of our profession is perhaps debatable, but it is as essential for the effectiveness of their work as scientific knowledge is.

At this stage, I want to pause to describe, in the light of what I have said, my interpretation of the phrase 'scientific temper'. It certainly does not mean that everybody should be a scientist. It does not even mean that everybody should have a modicum of scientific knowledge. It is the methods and outlook of science that it refers to.

First, it must mean that we favour human cooperation and linkages without setting to them any boundaries of race, religion, nationality, ideology or gender. Secondly, it must imply that we are humble even about our deepest convictions and offer them for checking by others wherever this is feasible. Thirdly, it should make us similarly sceptical of what others try to force down our throats. Cooperation cannot and should not be based on unsubstantiated claims, particularly where this might imply hostility to others. Fourthly, we have to cultivate an enquiring mind. To summarize, we have to live with uncertainty.

This deep and fundamental uncertainty is basic to the human condition. It requires a very adult outlook to be ready to accept this uncertainty and yet to take necessary decisions. Such an attitude is fundamentally human and is what 'the scientific temper' means to me.

Of course this is not a prescription for perfection. Competition is an unavoidable and even essential aspect of any effort involving numerous people. We all know that competition in any enterprise can take very ugly forms. This applies in science and perhaps even more in technology. Yet there is a good deal of evidence that abolishing competition leads to worse faults and that we should accept it as basically human, while doing all we can to diminish its nastier manifestations.

It may well be asked what good science and technology have done to the human species. Even a professional scientist like myself cannot brush aside such a sceptical attitude, least of all on an occasion in honour of perhaps the greatest of all such sceptics. My response comes in two parts. First, I want to stress the spiritual quality of all we have learned. The Copernican system and Darwinian evolution have profoundly altered our outlook on the place of us humans in the universe, a

change that I regard very much as a change for the better and rightly humbles us.

To come more to my areas of science and technology, the universe has been found to be an infinitely grander (and perhaps more mysterious) place than was ever imagined before, while the technology of space has been triumphant and chastening at the same time in a previously undreamt of way. I agree with Bronowski's description of science as our greatest spiritual adventure.

But secondly, what about the strikingly Gandhian criticism that the acquisitions so characteristic of modern life do nothing for the human being as a thinking and feeling individual? Gandhi himself showed that much of what we think is necessary or at least desirable can be done without, though most of us, unlike himself, would find it aggravating, to say the least, to be deprived of our material comforts. Yet he demonstrated convincingly that they are not essential to our inherent humanity. On the other hand I think that in some respects our modern industrial and technological civilization has led to a profound change for the better.

The first and, I think, most important of these is the reduction in child mortality which has been substantial throughout almost the whole of the world and particularly so in the industrialized countries. The grief of a parent for a dead child is a primitive and most powerful human emotion. It is not part of the veneer of civilization, but deep and intrinsic. To have materially reduced the number of such tragedies is no mean achievement of our century. It cannot be belittled as purely relativist. Moreover, it is a result of a large number of aspects of our civilization and indeed of its whole outlook which at its best can be described as 'the scientific temper'. Clean water, better nutrition, more knowledgeable and healthier mothers, better housing, preventive medicine have all contributed mightily to this highly desirable result.

Like all human achievements, it has a negative aspect too: Until parents everywhere appreciate that their children are very likely to survive to adulthood, many will continue to overinsure by having unnecessarily large families. Until the reduction in child mortality is universally understood, this will add to the worrying growth in our numbers. But this is probably a purely temporary difficulty that should not stop us rejoicing over the progress achieved and fostering its further advance.

Another change that our civilization has brought about is the greatly increased mobility of people. In as far as it makes us more aware of the variety of our species and brings us to understand better the strength and significance of common humanity, this is to be greatly welcomed. However, it also has negative aspects such as increased tensions and the slackening of family bonds. Moreover, it raises ethical questions we have barely begun to understand. Yet on balance, I have little doubt that in making us less parochial, the increased mobility

*A man went into a pet shop wanting to buy a particularly intelligent parrot. After taking great care to choose such a bird, the pet shop owner sold it to him. Two weeks later this man returned to the shop and very angrily complained that the parrot, in spite of its supposed intelligence, had not said a word in all that time. 'Ah yes' said the pet shop owner 'this one is a thinker, not a talker'.