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Presidential Address

The History of Science in Modern Education

Delivered by DR. H. HAMSHAW THOMAS, M.B.E., F.R.S., *on 3rd May*, 1954.

In considering the subject of my Presidential Address I have felt it my duty to speak of one of the more pressing problems of modern education, which historians of Science may help to solve by their interest and cooperation. The greater part of my life has been spent in trying to educate young scientists at Cambridge, and for some years I have felt that, while we were instructing them in scientific subjects, we were doing little to educate them for life as members of society. More recently this feeling has been intensified by some work in which I have been engaged which involved testing the general intellectual capacity of men and women trained at different universities in different subjects.

Forty years ago or more, students of the Natural Sciences formed a comparatively small part of the student population of our universities; today a very different picture is presented. Men and women studying science, medicine, engineering, technology, and agriculture are in the majority, students of the Arts form only about 43 per cent of the total number of undergraduates. This means that a very large number of people with the best potential intellectual capacity devote themselves each year to scientific or technological studies. Many of them should become leaders in thought and culture, they should play a leading part in society and in politics, they will have to help in guiding our country in the difficult times ahead.

A few years ago the University Grants Committee said in one of their reports, " A University would, in our view, fail of its essential purpose if it did not, by some means or other, contrive to combine its vocational functions with the provision of a broad humanistic culture and a suitably tough intellectual discipline ". It seems to me to be a matter of considerable national importance that our science students should be given that humanistic culture, so that they may become effective and enlightened citizens in the days to come.

Many of those who are in close touch with our students are becoming increasingly uneasy about the results of modern specialization, especially in science. Does this include any real education which will help our pupils to understand their fellow men ? Does it train them to form sound judgments about the things of everyday life ? Does it help them to live more happily in society ? In the United States of America there appears to be some alarm about what has been called the ever widening chasm between the scientist and the public. The man in the street is said to be unable to comprehend the philosophy and aims of the professional scientist, and he, in turn, does not

understand the way in which the ordinary person looks at the world around him. I have talked to university students in England about this subject. Some students of the humanities have complained that they are completely out of touch with the scientists in their own college ; they felt that they had no common interests, and that the science students seldom participated in general conversation. This is regrettable for an important part of university education comes not only from formal teaching but from the informal discussions between fellow students, with different social and educational backgrounds, who are reading different subjects. By sitting round a fire and talking about different topics they gain something of value which could scarcely be obtained in any other way. It may be said that this tendency towards the isolation of the scientist is due to the arts students knowing little or nothing about science, and that the proper remedy is to teach more science to all at school. This, I think, is a very uncertain solution of the difficulty. Even if it were possible to increase greatly the number of good science teachers in our schools, the fact remains that in ordinary life our conversation is very much more concerned with the activities of men than with the world of Nature.

It is perhaps difficult for many of us to realize the intellectual background of most science students of the present day. We were probably given an early classical education, we learnt a good deal about the history of England, and read some English and French literature, besides obtaining our training in mathematics and science. Our present-day students have been specialists since the age of sixteen or earlier : they have a very limited knowledge of the world and of the behaviour of man, derived mainly from newspapers and the cinema screen : they know little real history and are scarcely sensible of their debt to the past. Too often the student has a poor understanding of the meaning of words and of the implications which words can convey, hence he is unable to appreciate poetry and good prose. He is quite at home with formulae and equations, the shorthand of science, but is seldom able to write fluent unabbreviated prose and to express his thoughts in a way that is easily intelligible to others. Even his ability to think logically and to understand the philosophical foundations of his own studies is often weak.

But we must not blame our students for these cultural deficiencies. They all must work extremely hard in endeavouring to learn and remember the vast body of information which is now presented to them, and which they are expected to understand and remember. Every branch of science has progressed enormously during the past fifty years, and the schoolboy of today is taught about subjects which, in my time as an undergraduate were recent discoveries on the confines of knowledge. Moreover, while the field of study has been steadily increasing very little of the older material has been omitted. Our universities seem to take little heed of the fact that the load placed on the science students is becoming, or has become, unbearable, and that this in its turn means a demand for more intensive study at school.

The training now given to students of the Natural Sciences is generally planned, consciously or unconsciously, with a view to the production of professional scientists who will spend their lives at research or teaching. But in fact a considerable number of people do not reach the necessary standard and have to look for other posts. Many men and women in this class have undoubted ability, and might become good administrators, works managers, journalists or business men, if their training were broader and less specialised. Those responsible for the direction of industry very often prefer to choose for managerial work men who have graduated in Arts subjects, or who have not taken a university degree, rather than graduates in science or technology. We have I believe, relatively few trained scientists in Parliament, although one

would think that a scientific education would be an excellent training for the objective examination of public problems and for weighing the evidence from different sources and reaching sound conclusions. There have been scientists in Parliament whose wisdom and knowledge has gained for them a great respect. But while the training of our students is so detached from human affairs they are seldom able or willing to embark on a career outside the limits of their own special subjects. For the same reason they are often unsuited to become really effective teachers in our schools.

The provision of some broad humanistic culture for the majority of our university students is thus of importance, both to the individual and to the community as a whole. We should also consider whether close specialization produces the best scientists. In my view an education that is too specialized rarely produces a really first rate scientist : I know that some of our outstanding men had a very wide early education. The boundaries between the different branches of Natural Science are today so nebulous, physics and chemistry can scarcely be distinguished as separate subjects, biochemistry and biophysics play an ever increasing part in the study of biology. But apart from this consideration, intensive specialization often seems to limit the outlook of the student. When the interest is too closely focused on a small field of natural knowledge, the purely human aspect of science is overlooked. Natural Science is man's quest for an understanding of Nature. Man's curiosity leads him to ask questions and to seek for answers. The initiation of research and the interpretation of results is a personal function, but also is due in large measure to the climate of opinion at the time. Many of our students have little idea of the more general concepts which determine the course of investigation ; they would find it difficult to explain the reasons why they are studying certain aspects of Nature. They are often ready to accept the printed word without criticism, and many of them are known to believe that lectures are a waste of time when text books covering the subject are available. In the past I have found very little interest in the study of the methods of reasoning used in the formulation of hypotheses. My pupils had been taught to rely on mathematical proofs, but were seldom acquainted with any elementary logic or the methods by which a problem can be examined verbally. They were only interested in knowing those generalizations which were at the time most widely accepted, and they seemed often impatient if presented with alternative ideas and told that they must decide which are the most tenable.

We must now consider what can be done to remedy the situation which I have outlined. What modifications can be introduced into our teaching in the universities and schools to give the science students a broader intellectual training? One suggested remedy is the postponement of specialization until the pupils' minds are more mature, and the continuation of a study of a wide range of subjects up to the time of entry into a university. I do not think this a satisfactory solution of the problem. Some specialized study at school is valuable, even for those who will not go to a university ; it can bring a wonderful zest into the intellectual life of many students. It is also necessary for those who look forward to a career in science or in other subjects to have the opportunity of showing that they have the capacity to begin advanced education with good prospects of ultimate success. But when a boy or girl has decided to embark on a particular course of study all intellectual work which does not seem to be directly connected with the chosen field is regarded as a waste of time. The same consideration applies to students at the university, where the first year undergraduate finds much that is new to interest him and occupy his time. The best method is not to impose a compulsory study of subsidiary cultural subjects but to widen our science teaching so that it not

only imparts information about the phenomena of Nature but also deals with the humanistic aspect of natural knowledge. If we can lead students to appreciate the way in which man's concepts of Nature have been built up, telling them of past failures as well as of successes, and revealing the personal characters of some of those who have worked in the search for knowledge, we should make them better scientists and at the same time illustrate the social and human aspects of their studies. All this can be done by the institution of well-planned courses in the history of science.

In speaking of the history of science I do not mean a mere knowledge of the names and dates associated with discoveries that have stood the test of time. Some teachers of science have regarded that kind of information as comprising the whole substance of our subject. In the first place I should draw no hard and fast line between the history and the philosophy of science. Science is still in essentials Natural Philosophy, though the old name is now seldom used. The present day search for the principles of things can scarcely be understood without reference to its history. Most young scientists need some philosophical training, and we have evidence at Cambridge that many of them find their introduction to philosophy most fascinating. It would perhaps be well if more of their elders engaged in teaching and research paid some attention to the formal analysis of scientific reasoning. One does sometimes meet with writers on biological topics whose work suggests a complete indifference to the principles of logic, but whose arguments are accepted without criticism in an age when few specialists have had a philosophical training, and when non-specialists are unable to understand the language or details of the subject.

It seems to me that the members of this Society should as a duty give careful consideration to the provision of information which will be of use in the preparation of courses of instruction in a history of science that is both comprehensive and philosophical, while closely linked with modern scientific interests. Books and papers of various kinds will be needed when the defects of our present system of education are more widely recognized. Already a number of excellent books are available, but others could well be written for special classes of students. I should like to make some tentative suggestions as to the kinds of teaching which might give our pupils a broader humanistic outlook.

First, we might hope that a general survey of the history of scientific effort would give the student some idea of his own position in the world by reference to the past. The story of the empirical quest for knowledge, extending far back before our era, should not be passed over lightly. The discovery of the methods of extracting metals, of curing hides, of making pottery and raising crops and stock, represent substantial scientific achievements by primitive peoples. Still more remarkable were the abilities shown by the ancient Egyptians in fashioning and using stone on a scale that has never since been equalled, as well as in the construction of buildings, in mechanical problems, in dyeing, weaving, metal and wood working.

A concise account of Greek thought and culture and of the civilization of the Hellenistic age seems essential. In a recent article Dr. Stephen Toulmin, writing of his school days, said, " I blush now to recall what an ass we thought Aristotle, having missed the point of his theory of motion ". It is probable that this represents the attitude of many students today, assuming that they have ever heard of Aristotle. But the world owes so much to the Greeks that one who is ignorant of the main facts about Greek civilization and thought can scarcely claim to be educated. Some teaching about the philosophers, scientists and doctors of classical times would provide a means of introducing

students to the life and thought of the ancients, and of showing how mathematics, mechanics, astronomy, medicine, and systematic scientific thought found their early expression.

The organization of society in Greece and Rome, which is so closely linked with early scientific progress, provides a means by which an outline of the political history of Europe can be approached. I do not suggest the study of more political history than is necessary as a background for the consideration of the progress of civilisation and the movements of thought. Of course, at many points after the 16th century the history of science becomes much linked with political events and can scarcely be understood without reference to them. But battles and treaties, the struggle of men for the domination of governments, and much of the detail usually taught in ordinary courses on history, need little attention. The history of science is essentially the study of the growth of ideas. The successive views on the nature of things, both living and non-living should be followed. The factors which led to the formulation of these views should be examined, and especially the relation between experiments or observations and the opinions current at the time when these or they were made. When possible, the reasons for the persistence of erroneous notions should be sought, as well as the factors which retarded scientific progress. Taking an instance quoted by Raven as an example. Why did John Caius, among some good descriptions of animals, say of an animal from Norway which he called the Hippelaphus :—" in Norway they call it an Elke or Elend, but in this they are plainly mistaken ; for it has not the legs of an Elk since they never bend ". The answer is, as you will know, that Caius implicitly believed the account of the Elk given in Caesar's Gallic War, as having no joints in its legs and being unable to lie down. The complete reliance of educated men on statements about natural objects made by classical authors, which lasted in some cases down to the 18th century, is one of those things which we find very difficult to understand today.

Some historians of science pay little attention to the erroneous hypotheses widely held at certain periods. But for the more mature students the study of theories like that of phlogiston, or of the imponderable fluids may, I think, be very instructive. I often wonder what I should have thought about phlogiston had I been living at the end of the 18th century. A short time ago I was reading the account given by Stephen Hales of his experiments on what he called air, but which were really on the preparation and properties of a variety of gases. Could we have put forward any better explanations than his of the phenomena observed ?

I must not, however, digress from my general theme. Of the general educational value of History there can be no doubt. The modern biological study of organisms in Nature shows clearly how present-day populations owe their existence to events and changes in the past. Scientific thinking should make us more and more conscious of the fact that we cannot understand man, his societies and his social system without reference to history. Most boys and girls are taught some English history at school, but it seldom includes enough social history, or reference to changes in thought and technical skill. Some knowledge of the past and of the ways in which men have acted under different situations is, also, I think, of the greatest value to all of us today when we have to make up our minds on complex problems in both public and private affairs.

This reflection leads to a consideration of what is probably the greatest deficiency in the education of the young scientist. How much does he know of human beings, their motives and desires, their hopes and fears, their affections and hates ? Students of the classics, of literature, history and law become

well aware of the complex nature of human personality and of its wide variety, but the scientist often seems to think that all men in the world have minds that work like his own. He does not realize the power of the more primitive human instincts, of racial and social background, and of early training. He is thus surprised or disappointed when other people do not act in the way in which he thinks they should behave. Some people appear to regard men as they would substances or organisms in an experiment, where an alteration of environmental conditions is expected to produce a predictable response. Human beings, however, seldom react in that way.

We may not be able to give our students very much insight into human personality, but through the history of science we may, at least, make him aware of the different ways in which some people have thought and acted in the past. The story of the lives of well known scientists provides a considerable fund of material from which the development of character and the influence of personality can be illustrated. I think that writers and teachers might well pay more attention to the selection of biographical details to bring out the character, good or bad, strong or weak, of the people they describe. We can find among our records plenty of interesting human stories, showing love and affection, jealousy and hate, perseverance in the face of adversity, triumph and tragedy.

Probably each of us have our favourite anecdotes from the lives of great scientists. From my first book on the history of science, read when I was at school, I have always remembered the story of the devoted help which William Herschel had from his sister; the perseverance in the face of opposition of Galileo and later of Lister; the bitter struggle of Fresnel and Arago with Laplace and Biot; the tragedy of Lavoiser. The story of young Faraday always appeals to young scientists, and many of us have well understood the feelings of young Charles Darwin about Natural History and Geology in the days before he became acquainted with Henslow. I expect that more and better examples of human stories will occur to you.

An entirely different aspect of our problem concerns the training of the young scientist in the use of his native language. So much of his written work is done in the form of tables and diagrams, graphs and formulae, and so little in the form of connected prose, that one hears constant complaints about the inability of the young graduate to express his thoughts in a way that is readily intelligible to others. It may be that similar criticism may be made of the abilities of some Arts students, but today, more than ever, the scientist should be able to express himself in language that can be generally understood. In a recent article on the position in the United States, a well-known scientist considered how the gulf between the scientist on one side and "the hard fisted man of affairs" together "with the non-scientific herd" on the other, may be bridged. He thinks that "it is necessary for the scientist to interpret his work to the layman in terms of concepts and mental constructs rather than in terms of gadgets and applied techniques. This interpretation, however, must be something more than an inculcation of knowledge concerning the new concepts of each new stage in the forward march of science. It is the process of conceptual thinking that must be explained, the scientific habit of mind that must be made attractive". While I do not think that a chasm exists between the scientists and the non-scientific public in England today, there is considerable risk that one may develop in the future. Although we have some first rate scientific journalists and broadcasters, there is also a tendency, not without foundation, to regard the scientist as the back-room boy who knows little of the world around him. This may become more pronounced if our young scientists are unable to tell about their work and ideas in a way

that the ordinary man can understand. To remedy this I can only suggest that our pupils should be encouraged to read more books in good connected prose, like those on history and philosophy, together with some selected works by scientists well known for their prose style; they should be encouraged to try to imitate that style. There is also much to be said for the study of some complete book or paper of outstanding importance, with special reference to the way in which the subject is presented, the evidence brought forward, and the conclusion reached. Darwin's Origin of Species is a book of the kind which I have in mind. I cannot forget the wonderful education and interest which I obtained as an undergraduate from attending what was called Bateson's Bible Class. In this we read the Origin of Species under the guidance of Professor Bateson, who made comments and gave criticisms or further illustration of the points brought forward by the author.

Many school and university teachers will have a short reply to what I have been saying. They will point out that young scientists have already more than enough to learn and that they have no time to spare for the kind of instruction I have suggested. This, without doubt, is perfectly true at the present time, but the day must soon come when every British university is forced by the accumulation of knowledge to revise its science teaching and to make radical changes. Those responsible must face the problem of whether teaching or education is to be the first consideration. When this revision comes I hope that it will enable science students to devote some time to the history and philosophy of science throughout their education, so that they may obtain a good measure of humanistic culture, and will not tend to become cut off from the intellectual interests of their fellow students.

This brings me to another aspect of my subject, the value of the history of science to those who are not science specialists. In the past a knowledge of the phenomena of Nature was considered quite unnecessary in the education of those who would not become doctors or science specialists. For a long time the part played by the scientific revolution of the 17th century in altering the currents of man's thought and in improving his material environment, was clear to those who cared to think about it. But it received little attention, and the great improvements in our health, our food, our housing, our transport, and our communications were taken as matters of course. Today most educated people have suddenly awakened to the fact that the discoveries of science have brought about the most profound change in human affairs that the world has yet seen, at least since the discovery of metals. No longer can young people be brought up in complete ignorance of modern science. But this does not mean that they can or should be taught chemistry and physics to enable them to understand the process of atomic disintegration, or learn physiology and genetics for the explanation of blood transfusion. What, I think, is needed is a general picture of how man's knowledge of Nature has come about, and what have been the results of this knowledge. In several schools a successful attempt is being made to inform pupils, by teaching the history of science, of the ways in which discoveries have affected men's lives. The historical approach enables the more important contributions to knowledge to be linked into a connected story. At the same time it enables many inventions and principles to be understood by reference to the way in which they have developed from simple beginnings. Thus the early experiments of Faraday on electromagnetic induction are not difficult to understand, and when these are known the principle of the modern dynamo can be explained. By this mode of study much can be done to show the way in which biological and medical knowledge has altered the lives of the people of the world, and, may I add, the unacknowledged debt of the natives of Asia and Africa to the

labours of European and American scientists. This study will also stress the importance in our lives of vaccination and inoculation, the dangers of bacterial and virus infection, and the value of hygiene. In these days when so many people are terrified by reports of atomic weapons, there is in some minds a feeling that the progress of discovery in the world of Nature is to be regretted ; scientists are only regarded as the authors of horrible contrivances. How important it is to show the manifold ways in which everyone has benefited from the labours of the investigators of Nature.

The members of the British Society for the History of Science may well say that I have been preaching to the converted. I hope that this is so. But I have addressed you today with two objects in view. First, to set out, rather regretfully, the views on modern scientific education of one who has been teaching and examining university students for forty years. It is hoped that this will make our members think more about the subject, and that what I have said may have some influence on a wider public. Many people may disagree with me, some may even become angry, but I trust that they will give more thought to the sad lot of the science student of today, and to how it may be ameliorated.

My second object was to stimulate those who have the knowledge and opportunity to write books and papers on the history of science. If our subject becomes more widely studied, as I am sure it will be in the days to come, those who teach it will require assistance from specialists in many different subjects. We already have some excellent books, but more will be required for a university course extending over three years. Let us go on thinking about what will be needed, and how best to show to students and general readers of all ages and stages that science is not merely the invention of machines and gadgets, but that it is an important branch of human endeavour.