SCIENCE AND HISTORY

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If we wish to define what science has been and what it has accomplished historically, we find it difficult to formulate a definition which holds for all times and places. The sciences of the bronze-age civilizations differed markedly in character from those of the ancient Greeks, while Greek science possessed only some of the many-sided attributes displayed by science in the modern world. Behind the changing character of science throughout the ages, thee has been an element of continuity, for the men of each period have developed and enlarged some aspect of the science bequeathed to them. Accordingly, we may perhaps say that science is a human activity developing an historically cumulative body of inter-related techniques, empirical knowledge, and theories, referring to the natural world. The American authority upon the history of science, Sarton, indeed considers that in this respect science is 'the only human activity which is truly cumulative and progressive'. But only part of science has been cumulative up to the present time, namely, its practical techniques and its empirical facts and laws. Judged by a long time scale, the theories of science have been ephemeral hitherto. The laws of levers and of the reflection of light, known to the Greeks, have become part of the permanent heritage of science, but the scientific theories of the Greeks are only of historical interest. Similarly, given a continuance of the present tempo of scientific activity, we can hardly suppose that any of the scientific theories of today will remain unmodified for long.

In the civilizations of the bronze age, mathematics and astronomy were largely utilitarian techniques used for keeping accounts, surveying, and calendar making. The sciences then did not differ greatly in character from the arts of the craftsmen, save that they were handed on through a written record, rather than by word of mouth. The ancient Greeks made an important advance in generalizing the discovery that empirically known fact belonging to a particular class could be theoretically demonstrated and shown to hold for all similar cases, as in the examples of the Pythagoras theorem or the laws of levers. The Greeks also used geometry to interpret theoretically their astronomical observations, so that empirical data now began to give a quantitative structure to cosmological theory. However, the dominant world systems of the Greeks were influenced by the conception that the heavenly bodies were superior to the earth, a notion which led them to prefer geocentric systems, notably the homocentric and the epicyclic, both of which, in their final forms, conflicted with facts known in antiquity. Moreoever, the Greeks did not develop a consistent experimental method, though they made experiments on occasion; nor did they extend the application of science to new fields, except possibly military engineering and the making of general world maps.

In the subsequent civilizations of Rome, the Muslim world, and medieval Europe, science did not transcend the bounds set to it in Greek times, and its influence upon those civilizations was not large. During the modern period of history, however, science, and the forces promoting science, have developed an ever-increasing power of historical change. Experimental enquiry, together with the qualitative-inductive, and the quantitative-deductive methods discussed during the early decades of the seventeenth century, gradually found their appropriate place and application in all of the sciences. Applied first to mechanics and astronomy, they elucidated the workings of the solar system, and then to electricity, chemistry, biology, and other sciences, they rendered these subjects in turn more precise and fruitful. Such developments have helped to bring about a profound secularization of the human mind, science assuming, whether by sympathy or antipathy, a more and more important place in all general systems of thought, and, in the industrialized countries, colouring the views generally accepted concerning the nature of the universe and man's place in it. The applications of science too spread beyond the classical bounds of surveying and calendar making, first to navigation, and then to industry, agriculture, and medicine. The changes so wrought have done much to form the character of modern civilization, dissolving old traditions and old ways of life, so that when we speak of modern civilization spreading, say to the orient, we are thinking primarily of the spread of science and its applications.

The long-term consequences of the applications of science were not widely appreciated before the beginning of the present century. James Watt hardly could have foreseen the urban congestion that arose from the adoption of his steam engine in the factories, nor Faraday the relief of that congestion through the rise of the suburbs, which was aided by the application of his electrical researches to problems of public transportation and the transmission of industrial power. The inadvertent nature of the long-term changes brought about by science is perhaps most strikingly illustrated by the fact that they have begun to limit the realization of the values belonging to the period and the society which brought modern science into being. The individualism of men in modern times, and the value accorded to personal endeavour, have provided much of the driving force behind the development of modern science, both directly through the desire to make a personal exploration of nature and indirectly through the connection of science with the movements in which those values found an expression, such as the voyages of geographical discovery, the agrarian and industrial revolutions. But amongst other things, the development of the applications of science has more and more set a limit to the realization of those values. The steam engine, and the new textile machinery, ended the day of the individual hand-loom weaver, and subsequent developments made the technical units of industry even larger, drawing the individual into a composite organization, which circumscribed his activities. The electrical generating station at its inception served a large region, eliminating a number of individual steam engines, and later it was found to be more efficient when operated, as part of a national unit, through grid connections with other stations over a country as a whole. Finally, when atomic energy appeared, it was considered to be a development too precious and powerful for private use, and it has remained a state project in all countries, even in those where the value accorded to private endeavour is most deeply rooted.

In the modern world science has led mainly to the secularization of thought and the development of utilitarian applications, but it has had some influence upon human values and standards of judgement. Attempts have been made by a number of scientists, particularly biologists, to derive an ethical code from the theory of evolution, but it is probable that the scientific method has had more influence upon human evaluations than any particular theory. The scientific method relies upon rational arguments rather than emotional appeals, and it suggests that empirical evidence should decide between rival viewpoints, practices which have become perhaps a little more general in personal relationships than they were a century or so ago. It is notable that the practice of settling differences of opinion by duelling began to decline in the early decades of the nineteenth century, 'the scientific century' as the men of the period termed it, and that the decline was most marked amongst the middle classes of Britain and France, the section of the world community which was then the most scientifically minded. The tendency of men imbued with the scientific attitude to adopt a rational and a humanistic point of view is illustrated by the opposition of the British scientsits of the mid-nineteenth century to the policies of Eyre, the governor of Jamaica, who repressed a disturbance there in 1865 in a particularly arbitrary and barbaric fashion. Writing of the incident in his *Life of John Bright*, Trevelyan remarks:

'Except for Tyndal, the men of the finest scientific mind, – Darwin, Huxley, Mill, Leslie Stephen, Sir Charles Lyell, – ranged themselves on the side of law and humanity, whilst those whose cue it sometimes was to complain of the hardness of the scientific attitude to life, – Carlyle, Ruskin, Kingsley, Tennyson, – showed by their own conduct how prone sentimentalists are to inconsiderate worship of brute force and the "strong man".'

Another feature of the scientific method, which perhaps has had some influence upon human evaluations, is its dynamic and inventive quality. The scientific method is essentially a means of discovering new phenomena, and of formulating new theories, so that the sciences constitute ever-expanding systems of knowledge, old theories being overthrown constantly by new ones, so long as that method is practised. The American authority, Sarton, has written in this connection:

'Science always was revolutionary and heterodox; it is its very essence to be so; it ceases to be so only when it is asleep.'

Men with a feeling for this aspect of science tend to be moved by forward-looking values, and to be impatient of institutions which have much inertia. Joseph Priestly, we remember, 'saw reason to embrace what is generally called the heterdox side of almost every question'. Discoursing upon the relations between the Catholic Church and the sciences, Priestly remarked that, in the degree to which the Pope patronized science and polite literature,

'he was cherishing an enemy in disguise. And the English hierarchy (if there be any thing unsound in its constitution) has equal reason to tremble even at an air pump or an electrical machine.'

However, the influence of the scientific method upon the men who espouse it, for the most part, has been small. Scientists generally have adopted the values of the society to which they have belonged, even in the cases where those values have been detrimental to the advance of science, as in Germany under the Third Reich.

Similar considerations hold, to a greater or lesser degree, for the other changes brought about by science, and for the development of science itself. We cannot regard science as an entirely self-moving historical phenomenon, nor as a completely autonomous agent of historical of historical change, even though it has a tradition and a momentum of its own. The development of science has only been one of a number of historical movements that have formed an interconnected complex, in which science until recently has been of minor force. The science of a given age has belonged, not only to its own tradition with its own methods, values, and accumulated knowledge, but also to its own historical period, in which other movements have made their own impact upon it. In comparatively static periods of history, such as the middle ages, science has not displayed a notable development, whilst in expansive periods science has often thrived. Moreover, within a given period, there have been fashions, hesitations, and abrupt changes in the development of science, which do not appear to have been due to internal causes. In the modern period of history we have that curious stagnation of science during the first half of the eighteenth century, which affected chemistry and optics in particular, and electicity to a smaller degree.

Such happenings indicate that scientific activity has been directed now into one channel, and then into another, and that upon occasion the forces promoting science were relaxed, or even reversed. In a general way, it may perhaps be said that the practical problems of a given historical period have had an influence upon the empirical enquiries undertaken by the scientists of the time, while the intellectual interests of the age have influenced the form in which scientific theories were expressed. Thus the geographical explorations of the sixteenth century stimulated the search for methods of determining the longitude, and promoted the study of astronomical and mechanical problems which such methods entailed. Similarly the theory of natural selection was influenced by the *laissez-faire* current of English thought during the nineteenth century, an influence which Darwin acknowledged indirectly by specifying his debt to the views of Malthus. The division, however, has not been rigid. Practical problems have stimulated the rise of new theories, as in the case of the theory of thermodynamics which arose in part from the study of steam engine problems, while intellectual currents have orientated empirical scientific enquiry into specific channels, as in the case of the romantic and historical German philosophy which promoted the study of embryology amongst the Germans of the late eighteenth and early nineteenth centuries.

In the past the forces promoting the growth of science were not consciously directed, and only the results which those forces produced were immediately apparent. Scientists at the turn of the seventeenth century appreciated 'the present languid state of natural philosophy', though the causes of that state remained obscure. In recent times, however, science has become more consciously and directly orientated into specific fields, the choice of which has passed more and more out of the hands of the scientists themselves. As scientific research grew more complex, the amateur tradition in science declined, and research became professionalized and externally directed, except in the academic sphere, through the setting up of research institutions governed by outside bodies, such as industrial firms and governmental ministries.

These bodies in the main have been concerned primarily with the applications of science, and for a number of decades now they have provided the bulk of the resources devoted to scientific research. At first they sought mainly the improvement of industry, agriculature, and medicine, as illustrated in Britain by the formation of the Department of Scientific and Industrial Research in 1917 and the Agricultural and Medical Research Councils a few years later. Subsequently, however, researches upon subjects of military interest have become more and more stressed. The Civil Estimates, and other publications, indicate that the monetary resources expended by the British government upon military research and development increased sixty-seven-fold, from the year 1936-7 to the year 1950-1, while over the same period the amounts devoted to research and development in the industrial field increased tenfold, in medicine ninefold, and agriculture eightfold. By comparison, government expenditure on the universities, where most of the fundamental scientific research is still carried out, increased nearly sixfold over the same period. These figures are indicative of the general trends within the science of our time, and of the character which applied scientific activity is now assuming, countries which are industrially less advanced perhaps devoting a greater proportion of their resources to industrial research, and the more industrialized states allocating perhaps a greater proportion to researches of a military nature.

Such developments have had their effect upon fundamental science. They have created, for example, a greater demand for atomic scientists, and they have given an impetus to fundamental researches in the particular field of nuclear physics. They have also clothed those researches with a veil of secrecy, which hitherto has been alien to the scientific tradition. Again they have placed greater premiums upon the intellectual conformity of the scientist to the values and viewpoints of the dominant group within the particular society to which he belongs, a trend which has been accompanied by the association of some scientific theories with the one or the other of the two opposing ideologies of the mid-twentieth century.

Throughout history scientific theories have been favoured or opposed, apart from considerations based upon the criteria of the scientific method, according to the degree to which those theories have been congruent, or at variance, with the generally accepted beliefs of their time and place. Such judgements, and the actions based upon them, have been particularly conspicuous during those periods of history when two major movements of comparable strengths have stood in opposition to one another. During the period of the Protestant Reformation and the Catholic Counter-reformation, for example, the Copernican and Prolemaic theories were often judged by criteria which were wholly external to the scientific method. A not dissimilar situation obtained in the mid-twentieth century, though the two movements be secular, and in the 1950s, for example, theories of genetics aroused passions akin to those inflamed by astronomical theories during the sixteenth and seventeenth centuries. It is a measure of the historical importance which science has assumed in modern times, however, that the scientific revolution made little or no contribution to the force of either the Reformation or the Counter-reformation, whilst it is generally recognized in our time that science has become one of the important determinants of the strength of any major historical movement during the twentieth century.

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