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The History of Science and the Study of History¹

I

ALTHOUGH the world had long known that science and technology were important, it is only recently that these things have taken command of our destiny — that destiny which we had learned from our history books to regard as depending so greatly on the wills of statesmen. Only very recently indeed have we come to be aware of the degree to which, in the future, science is going to be built into the walls of everybody's mind; and only slowly shall we discover what I think we can hardly be said to realize as yet: the tremendous material for the poet, and the tremendous resources for writers of all kinds which exist potentially in the subject matter of the new science, and which will be exploited as the results become more widely communicable.

Even apart from the importance of the actual content of the natural sciences, we have come to be highly conscious of the significance of something which is wider still in its scope — namely, the scientific method. There are some of us who passionately believe that everything — from a buttercup to a poem by Keats, from a scientific discovery to the idea of God — has a quality that, so to speak, escapes the net of either the technical historian or the natural scientist. Those of us who feel most strongly about this point, however, will agree that the scientific method must be applicable to all kinds of subject matter, including even historical data, if only one can find the right way of bringing it into operation. This method must be applicable to the phenomenon of falling in love or to the incidence of the appreciation of Beethoven's music, though we must not pretend that it is capable of explaining everything. And its results seem to overwhelm our expectations — they so often carry us into regions so different from anything that we should have reached by merely speculating on a matter from an armchair.

¹ Delivered in the Allston Burr Lecture Hall, Harvard University, 24 March 1959, as the first of the Horblit Lectures on the History of Science, established by Mark M. Horblit, '05; here published in revised form.

From the seventeenth century, some people were announcing the appearance of a 'scientific method' which, besides revolutionizing the study of the physical universe, would be capable of a certain transposition into the realm of human studies. That scientific method, in one form and another, has already penetrated into our politics and our history, our economics and our anthropology. It does in fact affect the very shape of our thinking, nowadays, no matter what the subject we happen to be thinking about. It affects the very structure of what we in the twentieth century have come to regard as 'common sense.' It would be a mistake, therefore, to imagine that modern science exists in a separate pocket of its own. From the very first it was determined to insinuate itself into all the other parts of human history. From the very first, its exponents felt assured that it would acquire the presidency over everything else.

During the last decade we have come to a new and vivid realization of these things; and this fact is bound to affect our awareness, and to shift our perspective, as we turn to examine the past. It is as though we were now looking at the past from a different platform, so that the light catches different points — or perhaps our eyes are now alert for things which we had hitherto found it easy to overlook. Our view of the past ought never to be governed by our view of the present; but whenever a new generation meets new aspects of life and confronts new types of problems, that generation will make a fresh dip into history, a fresh inquiry into origins and antecedents. When we have made all allowances for the danger of reading the present back into the past, I think it is clear that natural science — and particularly the 'modern science' of the last three centuries — has in fact for a long time been shaping our history more drastically than historians once realized, more drastically than the scientists themselves ever guessed.

One of the safest speculations that we could make today about any branch of scholarship is the judgment that very soon the history of science is going to acquire an importance amongst us incommensurate with anything that it has hitherto possessed. It has become something more than a hobby for the ex-scientist or a harmless occupation for a crank; it is no longer merely an account of one of many human activities like the history of music or the history of cricket — activities which seem to belong rather on the margin of general history. Because it deals with one of the main constituents of the modern world and the modern mind, we cannot construct a respectable history of Europe or a toler-

able survey of western civilization without it. It is going to be as important to us for the understanding of ourselves as Graeco-Roman antiquity was for Europe during a period of over a thousand years.

A student who has chosen to be a natural scientist may be drawn along the lines of his own interests into the field of historical study, through the history of science. Once he has moved in this direction, it often happens that he becomes interested in the outside factors — the non-scientific factors — that have affected scientific development at one moment and another. He finds his attention drawn to industrial questions, to wars, to the general history of thought, or to problems of a sociological kind. Along this route, he sometimes penetrates more deeply into the structure of history than if he were forced to read an ordinary textbook of conventional political narrative. On the other hand, the student of history may be drawn along the lines of his own interests into the very different realm of natural science; and he may pick up the story at an early stage, where the science is less specialized, more closely bound up with the general history of thought. For some of us, in fact, the history of science is likely to be the only gateway to any real knowledge of scientific ideas, the only key to the deeper purposes and the underlying structure of the sciences. It is not clear that any other way of making the sciences available to students of the humanities in our universities can reach the same kind of authenticity. In a world that has so often had to complain of over-specialization, a 'hybrid' subject, like the history of science, may be in a position to perform a significant service in the world of knowledge. And, in any case, curious subtle cross-fertilizations have been known to occur in minds that have familiarized themselves with two different branches of science, or two different kinds of technique.

The impact of science on general history — on the over-all development of our civilization — will hardly be detected if the history of science merely exists in its own compartment and is either ignored by historical students or relegated (along with literature and the arts) to a separate supplementary chapter at the end of a volume of political history. The present position of science requires us rather to look once again at the whole of the past — the whole layout of our general history — to discover whether there is anything that we have been omitting from our calculations. It is possible that we are leaving the history of science too much to itself and are failing to examine the displacements that it ought to produce in our picture of Western civilization through-

out the centuries. We should take more notice, perhaps, if we made ourselves aware of the imposing development which was given to the history of science when it was established on its modern footing over fifty years ago.

II

An organic conception of the history of science and a remarkable prevision of the form which the subject was to take in the far future are provided by Francis Bacon in a section of the *Advancement of Learning* which deserves to be noted by all students of historiography. Bacon declared that there were three possible species of what he called Civil History, and that the world already possessed two of them, namely the Ecclesiastical and the kind that deals with Polity. What was lacking was the third species, the History of Learning, without which, he said, 'the history of the world seems to me as the statue of Polyphemus without the eye.' Hitherto there had existed in this field only 'barren narrations' dealing with 'sects, schools, books, authors and successions of events.' Bacon wanted a more organic kind of history which should trace the beginnings and the development of knowledge, the way scholarship migrated from one region to another, the processes which produce at one time a decline, and at another time a revival, of learning. And, he added, 'above all things I wish events to be coupled with their causes.' He wanted to learn how the fortunes of scholarship had been affected by the character of the region in which the study was being carried on — how it had been affected also by the disposition of the people, the state of the country's laws, the influence of the prevailing religion. He wanted historians to discover how far, at a given period, the accidents of history — any kind of incidental circumstances — had been propitious or adverse to the cause of scholarship. He called for an account of the sects and controversies that had arisen in the field of learning; but he also asked that the institutional side of the story — the role of academies, societies, and colleges — should be the subject of inquiry. All this must stand as one of the most significant, and probably one of the most influential, prescriptions ever put forward in regard to the writing of history.

The whole Baconian method, both in its strength and in its weaknesses, may have affected the literary sciences — now stimulating them, now checking them — more than it ever really influenced the study of

the physical sciences. The eighteenth-century *philosophes* transformed the nature of history by requiring that it should show them how mankind, from a comparatively primitive state, had developed to its present civilized condition. In their attempts to answer this question they tried to be scientific, though they were more Baconian, and less in the tradition of Sir Isaac Newton, than many of them apparently imagined. They became greatly concerned at the same time with the cultural side of history, and as the century proceeded they brought to a considerable stage of development the history of the various separate arts and sciences. A great Göttingen figure, Albrecht von Haller, who founded in his university a famous scientific society and a famous learned journal — the *Gelehrte Anzeigen* — produced some studies in the history of science which induced the Göttingen historians to feel that there ought to be a history of every science, including historical science. It was still the tendency, however, to turn such histories into mere accounts of successive great men, whose discoveries appeared to come out of a conjuror's hat, so that there seemed to be nothing which called for historical explanation. It was often even a matter of deliberate policy to leave out of the picture the errors and misfires of the earlier scientists, and to skip over the systems of Ptolemy and Tycho Brahe on the ground that these were mere falsities, mere examples of bad science. The eighteenth century despised the Middle Ages, regarding them as a period of darkness. The history of science was remarkably slow in finding its way out of these particular errors, and, so far as the lower regions of the study are concerned, the errors remained until well into the twentieth century.

George Sarton once declared that the first modern history of science was the *History of the Inductive Sciences*, produced by William Whewell in 1837. Whewell's interests, however, were philosophical rather than historical, and, apart from its amazingly crude treatment of the Middle Ages, his narrative was broken up into separate histories of the various separate branches of science. Sarton says that nothing illustrates better the backwardness of the history of science than the fact that Whewell was still commanding the respect of many thoughtful readers at the beginning of the twentieth century. In France, where Whewell had no influence, the situation was not much better, because there the presiding genius was Auguste Comte, who was equally unsatisfactory as an historian. Yet, at a high level, and in a much more rarefied atmosphere, there had been taking place, in the last quarter of the nineteenth

century, those imposing developments which were to place the whole subject on its modern basis.

One of the greatest obstructions to the history of science at the present day is the fact that so many people, remembering what they were taught in their youth, think that they know the essential story already. It is not sufficiently realized that the great transition, which revolutionized the character of this branch of study and altered the shape of the very landscape, was in its crucial stages just over fifty years ago. It took place in the higher ranges of scholarship, however, and only after nearly half a century did it reach the textbooks and the general public. The chief single instrument of the change was the French writer, Paul Tannery, who, though he had to do his research in his spare time, was described by George Sarton as the first great historian of science. During his lifetime, he was little known in France, where the history of science had come into a state of neglect. Yet he was an important international figure and the specialists in the subject in other countries regarded him as their leader.²

He was not merely a master of research. He belonged to a class of people who have sometimes been very important in the development of historical science. He was one of those scholars who are able to survey their whole field of study with a presidential eye, to make decisions about the larger issues of strategy, and to see the direction in which the entire subject needs to be taken. He thought that the history of

² Paul Tannery (1843-1904), one of the leading French scholars of the nineteenth century, never held a permanent academic post. A graduate of the *École Polytechnique*, he became an administrator in the state *Manufacture des Tabacs*, first in Lille, and later in Bordeaux, Le Havre, Paris, Tonneins (Lot-et-Garonne), Bordeaux, Paris, and Pantin (Seine). Although his literary output would put many an academic scholar to shame, Tannery did all of his research and writing on weekends, holidays, and evenings. His main work lay in the fields of ancient mathematics and astronomy and the sciences of the seventeenth century. He gave a free course of lectures on the history of Greek arithmetic at the Sorbonne in 1884-85 and in 1890-95 replaced Charles Lévêque as professor of Greek and Latin philosophy at the *Collège de France*. In 1903, at the height of his fame, Tannery was chosen by the faculty for the chair of history of science at the *Collège de France*, and his nomination was confirmed by the *Académie des Sciences*; but owing to a variety of political reasons the second candidate, Grégoire Wyruboff, was given the post.

Tannery's major works are his *Pour l'histoire de la science hellène* (1897; rev. ed. 1930), *La géométrie grecque* (1887), and *Recherches sur l'histoire de l'astronomie ancienne* (1893). He edited the writings of Diophantus, Fermat, and Descartes (the last in collaboration with Charles Adam). Most of his articles and his scholarly correspondence have been published in nineteen volumes of *Mémoires scientifiques*, of which the last contains a biography, bibliography, and general index. — [I. B. C.]

pure mathematics had made some progress by the year 1900, and that in recent decades this progress had been crowned by the appearance of a massive work by a German scholar, Moritz Cantor. He thought that the history of astronomy had made considerable advances, because astronomers depended on the observations made by their predecessors — they were compelled to maintain their connection with the past. Apart from these two branches of study, however, and, apart from the considerable progress achieved in the history of both medicine and theoretical mechanics, he regarded the whole subject as being still in a very primitive state.

Tannery's profoundest reason for complaint, however, lay in the fact that, in his view, there existed separate accounts of the development of individual sciences, but these were not embraced in a wider framework, an over-all history of science. It was not merely that he was bitterly dissatisfied with existing textbooks, popularizations, and abridgments; he said that the men who studied the history of a particular science — chemistry or physiology, shall we say — were too content to think of their work as merely an adjunct to that branch of scientific study. They were happy enough if they produced results which were serviceable to the science itself and to its actual practitioners; but those results could never be dovetailed into the kind of history which ordinary historians write; and in any case the history of any single branch of science is inadequate unless it is envisaged within the larger framework of the general history of science. In fact, he said, you might find the gaps in a large-scale history of mathematics by measuring the work against your diagram of the general history of science. By this method, you could discover lacunae that you might not discover in any other way; and these would provide the openings for the next stage in the work of research.

In all this, Tannery, amongst other things, was laying great stress upon the autonomy of the history of science, which, in his view, could never achieve even its own objects if it were merely subordinate to the practicing scientist. He declared that, as a matter of policy, those who were engaged in this branch of learning should establish their connections with historians rather than with scientists. He himself had helped to transform the study of ancient mathematics partly by applying to the texts the critical techniques of the philologists, which, he said, had hitherto been neglected by the historians of mathematics. He secured that, in 1900 and afterwards, the historians of science should

have their place in the International Congress of Historians; and, when later he had the choice of going over rather to the philosophers, he declared in favor of the historians, because, as he pointed out, it was from these latter that technical assistance was likely to be required.

Like the great German historian, Ranke, who did so much to shape our modern conception of history, Tannery took the line that what he called synthesis must advance along with research, the two perpetually interacting, perpetually enriching one another; and he claimed that, in his day, there was nobody in this whole field of study who shared his point of view. In all that I have described, however, he was confessedly followed by two of the leaders of the subsequent generation, George Sarton and Aldo Mieli. Both these men were initially stimulated by the same dream of a general history of science that should have its own *raison d'être* and should be more than the sum of the histories of all the particular sciences. There came a time when both of these men were jealous to see the history of medicine establishing itself as a separate system, emerging almost as an independent profession, and then claiming something like a presidential position on the ground that it embraced so many different branches of science. When they dreamed of a general history of science, Tannery, Sarton, and Mieli realized that they were reviving an ideal which had been allowed to lapse for half a century — since William Whewell's *History of the Inductive Sciences* and the work of Auguste Comte. They thought that their return to synthesis would infuse fresh blood into the whole subject, bringing it into contact with a broader stream of ideas.

George Sarton later illustrated the point by declaring it fallacious to imagine that the geography of the world was a larger subject than the geography of England. These two subjects, he said, were equally inexhaustible, and the point was that the difference between them was really a difference in kind. He would have held, however, that the student of the geography of England was walking blind if he did not understand where England stood in the geography of the whole world. There is no need to point out that the notion of a general history of science is bound to be of great importance to anybody who is interested in relating this whole field of scholarship to the work of the general historical student. The connection becomes closer still if we remember that, as Sarton said, 'the special histories' — that is to say the histories of particular separate sciences — 'are of necessity more technical, while in the general histories [of science] the humanities and social elements

are much stronger.' Sarton, moreover, emphasized the importance of the influence which the various sciences have had on one another, and the reactions that take place between them.

Tannery is of further importance because he saw what was needed on the organizational side for the promotion of his scholarly purposes. Besides securing the admission of his subject into professional congresses, he called for the establishment of an international journal for the history of science. He failed to achieve this in his own lifetime, however, and here, as in other matters, it was left to his successors, Sarton and Mieli, to attain the objects that he had at heart. Even before the first World War, the international journal was inaugurated; and after that war George Sarton was able to put *Isis* on to its feet, while Aldo Mieli founded the *Archivio di storia della scienza*, a journal which presented articles in a variety of languages. In the meantime Tannery himself had secured a useful organ in France, namely the *Revue de synthèse historique*, which was founded in the year 1900. This review, like the later *American Journal of the History of Ideas*, set out to cater for some of the needs of the history of science. Tannery hoped at one moment to found an international society but came to the conclusion that the time was not yet ripe for this. He saw that it was necessary first of all to secure the wider establishment of teaching in the subject in both schools and universities, and his efforts to extend such teaching are extraordinarily analogous to the efforts which have so often been made during the last ten years. In all this we can see that the career of the amateur, Paul Tannery, marks an important stage in what I might call the professionalizing of the whole subject.

I do not know whether anybody has really examined the curious relations between the history of science on the one hand and the history of medicine on the other. Sometimes they seem to be in competition with one another, as in the 1930's; but sometimes they stand as isolated systems, one university taking up the history of science while another takes up the history of medicine. They overlap, however, and if a single university may have a society for the history of science and also a society for the history of medicine, I notice that a good number of people may be members of both bodies. In England the doctors have often distinguished themselves by their humanistic outlook, and in my own University of Cambridge they played an important part in the development of an interest in the history of science. Their readiness to concern themselves with the human side of their study may have

enabled the history of medicine, at certain times and in certain branches, to develop more rapidly than the history of science as we ordinarily understand it. The same fact may indeed be partly responsible for the way in which the history of medicine was already building up its separate organization while the history of science was still immature. It was earlier in the field with periodicals, societies, international congresses, and effective university teaching. A chair of medical history was founded in Paris at the time of the Revolution, and there was one in the University of Pisa from 1846; while, by the beginning of the twentieth century, regular lectures on the subject were being delivered in many places. It is interesting to note that the work of Tannery in France finds an unusual parallel in the development which took place at a slightly later date in the history of medicine in Germany. The leader of this development, Karl Sudhoff, carried out great researches on Paracelsus, for example, and accumulated a large collection of documents. His career was crowned by the formation of the Leipzig Institute of Medicine in 1906 and by the establishment of a periodical in 1907.

The objectives of a man like Paul Tannery could never have been achieved by any scholar single-handed, and, as we have seen, some of them were attained only in the following generation. It is perhaps possible to put one's finger on a certain number of general factors which from the 1890's helped to produce the large-scale developments in the study of the history of science.

The first is a strange one. Lord Acton pointed out that external factors, even factors apparently unconnected with historical scholarship — even, we may add, ideas from intellectual realms which are uncongenial to technical historians — may have an impact on historical study. Towards the end of the nineteenth century it was Auguste Comte who not only inspired Tannery but helped to stimulate in France a revival of interest in the history of science. The influence of Comte lies behind the establishment in 1892 of a chair in the general history of the sciences at the Collège de France — a chair which Tannery, to his great disappointment, just failed to obtain in 1903.

Secondly, the people whom we call 'philosophers of science' have played an important historiographical role because they have been inclined to dig deeper into the thought of ancient scientists, or of writers like Francis Bacon and Descartes. There comes a point at which their own speculation makes them move away from actual history, so that

they become 'unhistorical'; and Tannery, who realized this, told the historians to beware of the 'philosophy of science.' Before the divergence comes, however — before the philosophers of science part from the historians of science — these writers have been able to add depth to the historical side of the work. They have done something to prevent our seeing a man like Galileo too much in terms of our modern mentality. I suppose that Pierre Duhem, a French contemporary of Tannery, can be regarded as emerging from this group.

Thirdly, a tremendous service has been rendered by certain forms of compendium which are almost encyclopaedic in character though they may incorporate researches which are often minute, even antiquarian in spirit. The entire map of the history of science has been transformed by these great works which retrace whole periods, resurrecting hosts of minor people — writers whose very names had been forgotten — and surveying countless scientific treatises that had often been unread for centuries. Future scholars are therefore presented with a preliminary diagram of the whole field and a guide to the literature. Tannery recognized the importance of this kind of work at an early date, and regarded Moritz Cantor's *Geschichte der Mathematik*, which began to come out in 1880, as providing the basis for a new stage in research. By 1906 Pierre Duhem's large study of the predecessors and successors of Leonardo da Vinci had begun to appear; and if this treatise had serious defects, we can say that some of the lines of inquiry which it opened up have been continued down to our time. The successive volumes of George Sarton's *Introduction to the History of Science* belong to the same class of works which are important as instruments for the further development of scholarship, besides being important for the knowledge they actually establish. In some respects Lynn Thorndike's studies of the *History of Magic and Experimental Science* carry on this kind of comprehensive and encyclopaedic work and bring it down to the end of the seventeenth century. Such great treatises almost establish themselves as institutions; and to the external observer they appear to be the end and crown of a long period of progress, which in a sense is what they really are. Like the large-scale *History of Technology* which has recently appeared, they have their special significance, however, when a certain branch of study, though it has made considerable advances, is still somewhat at the pioneering stage. They represent the opening of a new period in which the history

of science collects itself and mobilizes its energies for a more intensive course of research.

Fourthly, Tannery himself, as well as other contemporaries of his, is associated with that publication of seventeenth-century texts and manuscript sources which has continued until our day and has helped to add a new dimension to our study of the Scientific Revolution. The printing of great masses of correspondence has had a special importance since, at that period, so much of the scientific intercommunication, in default of periodicals, depended on letter writing. The total result was an intensification of historical research; and this was accompanied by radical improvements in technical method. The new outlook is illustrated by Tannery's plan of sending appropriate batches of Mersenne's letters to local historical associations, so that the annotation of the obscurer points could be carried out by students with local knowledge.

If, from the later decades of the nineteenth century, there were important changes both in method and in organization, it is also true to say that the actual subject matter of the history of science was being reshaped. As early as 1881 Tannery was inquiring about the sources of Leonardo da Vinci's science, and was tracing his geometry back to the Arabs. Early in the twentieth century he criticized the view that Descartes had been original in one of his mathematical discoveries — the really original element in this particular discovery, he said, went back to Nicolas Oresme in the fourteenth century. It became submerged because it was too advanced for that period. Soon after this, Pierre Duhem traced back to mediaeval scholastic writers some of the ideas of Leonardo da Vinci which had been thought remarkably original. The historians of science had previously been particularly rigid in their insistence on the darkness of the Middle Ages. They had been more emphatic than other kinds of historians in their stress upon the Renaissance, partly because they were less aware of the way in which such historical concepts arise — less aware of the way in which they can be imposed upon the story from outside. Henceforward the historians of science were to qualify very considerably their former conception of the mediaeval world. They were to provide some of the significant material for a modification in the concept of the Renaissance, and they produced some of the severe critics of that concept.

One of the contemporaries of Tannery was the Italian writer, Antonio Favaro, who worked on Galileo's papers and letters, and edited the twenty-volume *Edizione Nazionale* of his writings. Favaro intro-

duces one of his books with the remark that it is unfair, in celebrating the achievements of Galileo, to overlook the men who were defeated in the scientific controversies of the period in question. A number of his other works are specifically devoted to what he calls the minor writers, or to the opponents of Galileo, the friends of Galileo, the correspondents of Galileo. It is hardly necessary to point out how important it is for the reconstruction of the history of scientific discovery to study the writers who grappled with scientific problems but failed, or the less important people who made their small intermediate contributions, bringing their quota towards the final solution. The uncovering of this host of minor people reminds one of the change produced in astronomy by the introduction of the telescope, which brought so many new stars into our vision and altered so greatly the whole map of the heavens. The study of the contributions made by minor scientists enabled the history of science itself to achieve a more organic continuity. As the gaps were filled in, it became possible to trace out continuous lines of development and to examine these analytically — to see the whole long chain of thought which culminated in the modern doctrine of inertia or the Newtonian theory of gravitation. At this point the study of history can become more analytical, because it can take the whole line of development and subject it to a scientific examination, which throws light on the historical process and the genesis of real discovery. We cannot properly measure or appreciate the contribution of Newton until we have set out the history of the development of the gravitational theory down to Newton's time.

By the opening years of the twentieth century, therefore, the history of science had experienced changes which parallel both the Copernican revolution and the discovery of the telescope in astronomy. The immensity of the manuscript sources which began to be available had a significance not dissimilar to that which the opening of the archives had had for the political historians of the nineteenth century. George Sarton held that 'the first satisfactory textbook dealing with the history of science as a whole' was the German work, *Die Naturwissenschaften in ihrer Entwicklung und in ihrem Zusammenhange*, which appeared in four volumes between 1910 and 1913. Even in the later years of his life, Sarton was complaining, however, of the degree to which the condition of this whole branch of study still resembled that which had existed at the beginning of the century. And the truth is that only in very recent years have the discoveries of Tannery's generation and

the enlarged conception of the whole subject filtered down into the lower parts of the system.

III

When we construct a general history of Europe or of Western civilization we do not try to include in it the whole continuous history of France, adding to this the history of Germany, Italy, Russia, and other countries. We might concentrate on France in the period from 1789, because the French Revolution really belongs to universal history. We might turn the limelight on Metternich after 1815 because Metternich is to be regarded as a European (and not merely an Austrian) statesman. Similarly, the general student will hardly expect to be taken through every century of church history, or through all the successive periods in the history of art. He would want rather to know where the church or the painter's studio happened to be making some particular contribution to the world's development. We ought to go to a volume of national history if we want the whole history of France, and to an ecclesiastical history if we want to see the church throughout successive centuries. General history is more than the aggregate of so many national or sectional histories, just as the history of science is more than the sum of the history of the separate sciences. Paul Tannery, who was expounding this point at the same time as Acton (and perhaps more fully), insisted that in a similar way the history of mathematics is more than the sum of the histories of the various parts of mathematics. When we are envisaging the history of Europe or of western civilization, it is natural, therefore, that France and Germany, art and religion, will come to the forefront at different times and then recede into the background.

And so it is that at the Renaissance the student of European history will concern himself with classical studies on the one hand, and the Florentine painters on the other hand. When he comes to the Reformation he will turn his attention to religion, and, through a number of intervening stages, he will reach the place at which he must examine the Industrial Revolution. It is better that he should analyze each of these aspects of life, each of these great chapters of universal history, as intensively as possible than that he should mechanically proportion a given unit of his time to a given area of historical events. Moving from art to religion, from economics to diplomacy, he can gain a considerable knowledge of the various ingredients of our civilization. For this reason,

history, as one of the humanities, stands on a broader basis than is sometimes realized.

In the general history that most of us inherited, two epochs were endowed with famous labels: namely, the Renaissance and the Enlightenment. Both labels were meant to signify an awakening of the human intellect, and it was curious that there should have had to be two awakenings, a discovery and then a rediscovery of human reason. The historian's view of the past is liable to be shaped or constricted by the kind of evidence that he happens to be using; and when that evidence was literary and artistic he sometimes used to be unduly under its spell. The Florentine paintings of the fifteenth century meant something to him, and so did the classical learning of the Renaissance. He could take pleasure in Voltaire and Rousseau, the writers of the Age of Reason. It was perhaps unfortunate that at the crucial moment the natural sciences did not interest him.

One would not wish to expel from our historiography either the term 'Renaissance' or that other convenient label, 'the Age of Reason.' The notions involved in these titles have been subjected to serious criticism; but this will only tend to make us more careful about the content that we give to the terms. We shall avoid imagining, for example, that the Renaissance was an actual thing, a cause of causes in history; we shall refrain from assuming that anything has been explained when it has been attributed to the Renaissance. It would be true to say, however, that the history of science has had a dissolvent effect upon that whole schematization of European history which lies behind the use of the labels we are now discussing. We have seen how, over fifty years ago, the origins of modern developments in science were being pushed back, behind Leonardo da Vinci, to the later Middle Ages. All our history becomes more comprehensible when George Sarton draws our attention to still earlier dates which mark the emergence in Europe of algebra, alchemy, and other studies, under the influence of the Arabs. Sarton tells us, indeed, that, from a scientific point of view, the so-called Renaissance of the fifteenth century, far from being an awakening, represented an actual lull. It was an interval between two periods of scientific progress, one before 1400, the other after 1500. Lynn Thorndike suggests that not only in science but in civilization as a whole there was really a falling-off in the period of the Renaissance — a decline from the great activity of the previous centuries. All these views are subject to modification, since historical

discovery never ceases; some of them have already been qualified; and historians of science would not be unanimous on this issue. But it now seems strange that, when our general history was taking shape, the arts and the study of the classics played a decisive part in its construction, while the natural sciences were to a great degree overlooked. Not only historians of science but even also historians of art, like Berenson, have since been prepared to see that the Florentine painters themselves have their part in the history of Western science.

The interest aroused by the French Revolution and the tendency of historians to seek its origins in ideas, and particularly in literary sources, induced historians for over a century to concentrate their attention on the end of the *philosophe* movement. The question of the relation between the philosophic writers and the Revolution remained an important field of controversy until the 1930's. Since that time, however, attention has shifted rather to the beginning of the Age of Reason; and this is illustrated by the work of Paul Hazard on *La crise de la conscience européenne (1680-1715)*, produced over twenty years ago. The increase in the knowledge of civilization in remoter regions of the globe may have assisted the tendency of the later seventeenth century to see the traditions of Christendom as no longer central or in any sense absolute, but as a regional manifestation of a universal tendency. Perhaps there is a trace of what was for those days something like a scientific method in the practice of comparing civilizations and the ability to move towards an attitude of greater relativity. The crucial stages in the general secularization of thought which become evident in these decades may reflect to some degree the influence of the scientific movement on the general outlook of the intelligentsia, though this can hardly be the sole explanation of the decline of religion. The Scientific Revolution, in any case, must stand as a presiding factor in the genesis of the Age of Reason, partly through the widespread resort to types of mechanistic explanation in various fields, partly owing to the publicity given to a 'scientific method' which (as then understood) was regarded as applicable to all realms of inquiry, even human studies — even politics, comparative religion, history, and psychology. In a sense, an attempt was made, furthermore, to transmute the achievement of Sir Isaac Newton into a new world view. The great literary movement in eighteenth-century France has so many roots in the preceding century that the Age of Reason must be regarded as emphasizing the fundamental character and the generic significance of the Scientific Revolution.

Historians in recent decades have realized more and more that the things they associated with the mediaeval world did not by any means disappear at a touch of the wand in the period of the Renaissance. Historians of science themselves have helped to show that religious preoccupations, the scholastic philosophy, the veneration for the ancients, and the submissiveness to the notion of authority as such were a prevailing feature of the seventeenth century itself. If anything, it was the Scientific Revolution which discredited the authority of the past — of both classical antiquity and the Middle Ages — undermining even the traditional concept of authority. In other words, we have tended on the one hand to attribute to the Renaissance of the fifteenth and sixteenth centuries many things which belong rather to the seventeenth century. We have tended to impute at the same time to the Age of Reason a wealth of changes that are to be traced rather to the earlier scientific movement. Here are two great sets of changes the better part of which ought to be bunched together in one place; and the place to which they belong is the point at which, in modern times, the natural sciences make their great impact on general history. The moment belongs to universal history, for whereas the Renaissance and Reformation must mean nothing to the Oriental peoples in general, the Scientific Revolution is an event that must come home to every Chinese or Indian who is in touch with modern science and technology.

This historical moment has even an enhanced importance for us when we remember how difficult it is to analyze away the originality of the achievement which it signalizes. The science of ancient China seems to have excelled anything that existed in Europe at the time; but I gather that there was never any sign of a transformation of Chinese science — any hint of a future possible development — comparable with that of the West in the seventeenth century. Something new happened in seventeenth-century Europe to alter the nature of science itself, to transform its role and position in the world, and to make it an unprecedented thing — unprecedented as a factor producing dynamic change throughout the centuries of subsequent history. Something excitingly new was happening in the seventeenth century — something not to be accounted for by the process of tracing it back to the Renaissance, or to the mediaeval Arabs, or to the ancient Greeks. In a sense, no revolution was ever more consciously planned in advance than the Scientific Revolution, for men wrote books about the need for it before it was achieved, and they made remarkable predictions concerning

the wealth of consequences that were bound to follow from it after it had come. Yet it is clear from these very works that the authors of them had little idea of what the revolution would be like — they were feeling their way to something, without really knowing what it was. Even while they were looking for it, calling for it, they could not identify it and could not tell where the key to it might lie. Substantially, we may say that the seventeenth century produced a new thing, not digging it out of the past, but working away until the thing precipitated itself out of their own wrestlings with experience. It is doubtful whether anything else so original as this ever happened in all the rest of European history, unless it is perhaps the comparable development of historical science and historical consciousness in the nineteenth century. This latter, also, is a thing which cannot be explained by examining antecedents; it was born in a similar way out of men's own wrestlings with experience. Compared with this, the Renaissance (though it not only resurrected classical antiquity but revived something of the ancient spirit) possessed a more limited kind of originality — recombining the old ingredients but not adding a new ingredient of its own.

The Scientific Revolution of the seventeenth century, like the later development of evolutionary ideas (which appear in the eighteenth century as well as the nineteenth), has its repercussions in many fields and helps in general to produce a new way of looking at things. We can track down the influence of the new scientific knowledge, and the results of the new consciousness of the scientific method, on all branches of life and thought from the closing decades of the seventeenth century. Fontenelle in his *Eloges* showed how the new scientific outlook led to a more conscious resort to inductive methods in both politics and economics. A modern writer has tried to show the effect of the scientific movement on the organization of government under Louis XIV. The supporters of that movement insisted all the time on the effect that it could produce on industry, agrarian life, shipping, warfare, engineering, and scholarship. The English supporters of the scientific movement were ready to call for the development of a more utilitarian prose style and the creation of a universal language. In fact, the compound changes associated with the Scientific Revolution produced a palpable change in the actual workings of the historical process. In the closing decades of the seventeenth century men are beginning to be aware that the world does not remain constantly the same. No longer do they feel themselves to be acting out their lives on a stage where conditions in

general are apparently unchanging, save that one state may be rising while another falls. There emerges that controversy which was to change the whole character of historiography itself — the controversy which hammered out the modern idea of progress.

Since the Scientific Revolution is a turning-point not merely in European history but in world history — since Sir Isaac Newton is the starting-point of a new age not merely for us but also for the Indians and the Chinese — this chapter of history merits all the analysis that we have been accustomed to give to the Renaissance and the Reformation. Its antecedents and its consequences are a matter for the general historian.

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