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History in the Education of Scientists¹

LADIES and gentlemen, I should like first of all to congratulate the President and Fellows of Harvard College on receiving the gift which makes possible a continuing series of lectures on the history of science. The first lecture was delivered last Spring by the distinguished English historian Herbert Butterfield. I have the honor to be the second lecturer on this new foundation; I hope it will not be considered inappropriate if I not only thank the Harvard authorities for the invitation but salute the donor of the foundation, Mark M. Horblit of the class of 1905. I hardly need say that it is a delight for me to be able to return to Cambridge and once again address a Harvard audience. Those of you who are familiar with my long interest in the history of science will understand what I mean when I say it is a special pleasure for me to be here tonight as the Horblit Lecturer for 1960.

On more than one occasion in the last fifteen years I have ventured to speak about the history of science. I have usually done so in connection with the scientific education of those college students who do not intend to major in one of the fields of the natural sciences. There is no need for me here tonight to do more than repeat my strong conviction that by the use of appropriate 'case histories,' the general student may obtain considerable insight into the ways by which the physicist, the chemist, the biologist, and the astronomer have advanced their respective sciences. For the preparation of such 'case material,' the first requisite is a thorough scholarly investigation of the episode in science on which a case is based. The more rapidly strong departments of the history of science develop in this country, the richer will be the sources from which those who are preparing case histories can obtain the accurate information which they need. There are, of course, other ways in which the history of science may be successfully presented to the general student, just as there are other approaches to fulfilling the

¹Delivered in the Lowell Lecture Hall, Harvard University, 10 February 1960, as the second of the Horblit Lectures on the History of Science, established by Mark M. Horblit, '05; here published with slight revisions. The first Horblit Lecture, 'The History of Science and the Study of History,' by Professor Butterfield, was published in the Autumn 1959 issue of this BULLETIN.

needs of the college student for obtaining a general understanding of the course of development of the natural sciences and the nature of scientific inference. It is not my function on this occasion to pursue this highly important pedagogic topic further. I have been asked to speak to you about the value of the history of science to the serious student of science in a college or an engineering school. In attempting to respond to this challenge, I have been bold enough to enlarge the assigned topic by including a discussion of an educational question which has long intrigued me. What is the value of studying any history, either political, economic, social, or cultural?

Before embarking on what I fear will prove to be an overambitious undertaking, I hope I may be permitted a few words of a personal nature. They will be not unconnected with the general subject of tonight's address, for what I intend to recount very briefly is the history of the history of science at Harvard as I have observed the scene for almost exactly fifty years.

When I entered this college in the fall of 1910, I enrolled for the second half year in a course designated as Chemistry 8, given by Professor Theodore William Richards. This course was an historical introduction to a branch of chemistry which was then relatively new and, for the young men who were exploring it, highly exciting. I refer to physical chemistry. Although Professor Richards had made an international reputation by his refinement of the methods used in determining atomic weights (and was a few years later to receive the Nobel Prize as a consequence of this work), he was deeply and enthusiastically immersed in the new chemistry. But it was only as the second half year was drawing to a close that we arrived in our journey through time at the point where Arrhenius and van't Hoff and Ostwald were making their contributions. In short, it was spring before we began to study physical chemistry. Previous to that, we had been tracing the historical development of chemistry from the alchemists through the iatrochemists to the days of the overthrow of the phlogiston theory by Lavoisier and the firm establishment of the atomic theory by the heroes of the mid-nineteenth century. And I pause to remind the younger chemical members of the audience that in 1911 Arrhenius' ionic theory was relatively new and still being contested by more than one professor of chemistry in the United States.

My interest in the historical development of a science was certainly first aroused by Professor Richards' lectures. As far as I am aware,

no similar course in other scientific fields was offered at Harvard and there were no courses in the history of science in general. I shall return to a consideration of Professor Richards and Chemistry 8 in a few minutes when I consider the possible connection between the history of a science and the training of a research scientist. Let me push on with my account of a bit of Harvard history. One of Professor Richards' students, and later younger colleagues, was Professor Lawrence J. Henderson, biochemist and physiologist of distinction and the first unofficial roving professor in Harvard University. I resist the temptation to recount at length the many imaginative forays of this erstwhile medical student transformed first into a physical chemist, then into an historian and philosopher of science, then into a sociologist and physiologist combined. And for the record, so to speak, I might note that he was largely responsible for the fact that Alfred North Whitehead settled in Cambridge as a Harvard Professor in 1924, after retiring from his position as Professor of Mathematics at the Imperial College of Science and Technology of London. A few years later, Henderson, together with Whitehead, was instrumental in shaping those ideas which President Lowell brought to a focus in establishing the Society of Fellows.

Henderson's great contribution to the history of science was in bringing George Sarton to Harvard. This occurred shortly after the outbreak of World War I. He arranged for the support of this great scholar's work through the Carnegie Institution of Washington and later through Harvard University. This is not the time or place for me to attempt even to summarize the history of Professor Sarton's long years at Harvard, his prodigious scholarship, his editorship of *Isis* and *Osiris*, his vain attempts during the depression years to persuade either Harvard or any other university to endow what he considered a minimal department of the history of science. That we are meeting here tonight with a teaching staff in the history of science at Harvard in active service, that a flourishing undergraduate and graduate field of study in history and science has been long characteristic of this University are some of the fruits of George Sarton's long uphill struggle to make the history of science an important part of the American academic scene.

From Professor Sarton I learned, while I was a graduate student in chemistry, the difference between the history of a science (as exemplified by Chemistry 8) and the history of science. To use his own

words, 'The history of science is much more than the juxtaposition of all the histories of the special sciences, for its main purpose is to explain the interrelation of all the sciences, their cooperative efforts, and their common aims and methods.'² And Sarton goes on to say, 'These facts explain the difficulty of making the history of science acceptable to men of science and also the very necessity and urgency of doing so.' And here I am before a Harvard audience tonight, pleading this very cause!

The first time I heard Professor Sarton expound his doctrine privately, he was in his most optimistic mood. I, as a young man, understood him — or perhaps misunderstood him — to say that the future historian of science would write the history of a century solely in cultural terms and largely in terms of the labors of the scientists and scholars. The kings and queens, the politicians, and especially the military campaigns were to be reserved for footnotes, a strong contrast to the usual custom of historians, Sarton pointed out. Orthodox historians might at best insert a footnote to the political history of Great Britain in the eighteenth century to the effect that one Sir Isaac Newton, the Master of the Mint under William III, enunciated his laws of motion and 'explained' the workings of the solar system. He, Sarton, proposed to reverse the scheme!

Writing many years later, after the impact of Nazism, World War II, and the atomic bomb had left their mark on public opinion, Professor Sarton expressed himself more cautiously. He wrote as follows: 'We have recalled at the beginning of this lecture that science is the most powerful agency of change not only in the material world but also in the spiritual one; so powerful indeed, that it is revolutionary. Our *Weltanschauung* changes as our knowledge of the world and of ourselves deepens. The horizon is vaster as we go higher. This is undoubtedly the most significant kind of change occurring in the experience of mankind; the history of civilization should be focussed upon it.'³

Now come the significant sentences: 'At any rate, that is what I have been repeating *ad nauseam* for the last thirty years,' writes Sarton. 'May I confess,' he continues, 'that without having lost any part of my zeal, I am not as full of confidence today as I was before; I have

² George Sarton, *Horus: A Guide to the History of Science* (Waltham, Mass., 1952), p. 51.

³ Quotations in this paragraph and the next from *Horus*, pp. 10-11.

never been very dogmatic (and therefore am a very poor propagandist), but I am less dogmatic now than I ever was. There are other approaches to the past than mine; there may be better ways (at least for other people) of describing the creativeness of the past and of appreciating our heritage from it — such as the history of religions, the history of arts and crafts, the history of philosophy, the history of education, the history of laws and institutions. Each of those histories is an avenue of approach.' Yet, after making this admission, Sarton returns to his original theme — namely, that the only development in human experience which is truly cumulative and progressive is science and says flatly, 'We can hardly speak of progress in the other fields of human endeavor.' And when, as he says, someone taunts him with the question, 'Progress leading to the atomic bomb, what kind of progress is that?' he would be inclined to reply that, 'the history of science is not simply what the title implies, a history of our increasing knowledge of the world and of ourselves; it is a story not only of the spreading light but also of the contracting darkness. It might be conceived as a history of the endless struggle against errors, innocent or wilful, against superstitions and spiritual crimes.' It is the duty of the historian of science, Sarton continues, 'to explain as well as he can the civilizing and liberating power of science, the humanities of science. He must vindicate science from the crimes which have been committed in its name or under its cloak [he makes it plain earlier in the lecture that he has in mind the action of certain German scientists in the Nazi period, the concentration camp atrocities, and not the use of the atomic bomb in warfare]; he must commemorate the great men of the past especially those which have been deprived of their meed; he must justify the man of science in comparison with the saint, the philosopher, the artist or the statesman. Each of these is playing his part, and it would be foolish to insist that this part or that is more important than the others, for all are necessary and none is sufficient.'

The last sentence does not bring back to me the George Sarton that I knew when I was young. This is not the voice of the belligerent proponent of the history of science. I can almost hear him say in 1917, 'He must justify the man of science in comparison with the saint, the philosopher, the artist, or the statesman and, in particular, he must justify him in comparison with the statesman with whose activities historians have been far too much concerned!'

I have already taken too much of your time with personal remi-

niscences about the development of the history of science at Harvard. I must now be getting on with my appointed task. But I may point out that not all of what I have thus far presented is irrelevant. Before we can consider the impact of the 'history of science' on the future man of science, the question must be raised: What is meant by the phrase, 'history of science'? A subsidiary question hovers in the background which has often tantalized me — namely, has history, any history, really any meaning?

Sarton's concept of the history of science I hope I have made clear from the quotations I have read from his later writings. That this form of history had meaning was for him a prime article of faith. No doubt of that. How to convey this meaning to those who were not interested in science, however, became an increasingly perplexing problem. It seems to me not unlike the problem faced by an historian of culture in the tradition of Jacob Burckhardt, when confronted with a person insensible to beauty or endowed with only a minimum of aesthetic sensibility. Burckhardt once defined history as 'the record of that which one age finds worthy of note in another.' For him, the focus of his concern was the arts. For Sarton, the center of the stage was occupied by the scientists and scholars. For Burckhardt, it was the record of man's creative activities in art that was significant; for Sarton, the record of scientific advance, of accumulative knowledge. In spite of the difference, the parallel is close.

Tonight, because of the nature of my assignment, I do not have to wrestle with the problem of the significance of the history of science for the non-scientist. I have the reverse undertaking. I must consider the relevance for the practicing scientist of the historical approach to the field of his own activities. On this point Sarton was quite explicit in 1952: 'The main value of the history of science to the philosophically minded scientist, the scientist who wishes to understand the indebtedness of his knowledge, lies in its moderating influence. Retrospective views enable him to keep his balance between dogmatism on the one hand, and scepticism and discouragement on the other. They help him to be patient.'⁴ 'Above all, the history of science teaches humility,' Professor Sarton goes on to say. Now, I would agree but at the same time utter a caution. The research scientist should be humble, but not too humble; he must have faith in the adequacy of his guiding principles (the theoretical framework of his scientific world)

⁴*Horus*, p. 65.

and confidence in *his* ability to advance the frontiers of science. Otherwise he will not be ready to spend freely the enormous amounts of nervous energy required for first-rate work.

It is interesting that nowhere that I can find did Professor Sarton argue that the study of the history of science would make a scientist a better research man. Nor has Sarton's successor here at Harvard, Professor I. B. Cohen, argued to this effect. Rather, in support of the proposition that 'the training of scientists might be immeasurably improved if they were given some background in the history of their subject,' Cohen writes of the importance of seeing that science is more than a collection of facts and that the role of the creative imagination is paramount.⁵ Then he proceeds to point out that 'at the present time it would seem especially necessary for scientists to know something about their historical place in society and the growth of modern culture. Scientists and non-scientists both must recognize that the problems which arise from the interactions of science and society have not originated in the middle of the twentieth century, but have been — in varying degrees — a characteristic feature of the growth of science in modern times. Furthermore, the perspective of the history of scientific ideas can be of immeasurable importance in producing a worth-while critical attitude.' In other words, the importance of the history of science for the serious student of science does not lie in any effect a study of this discipline would have on his powers as a future pioneer, a future investigator. The importance lies in the effect it will have on developing him as a person who views the whole world, including the activity of scientists, with a broad and informed vision.

To those unfamiliar with science, it may seem strange that neither of the two historians of science I have just quoted claim that the study of the history of science would sharpen a man's wit as an investigator. I have heard more than one layman argue that it should. Yet Professors Sarton and Cohen do not stand alone. Quite the contrary. I have never heard or read an argument by a competent historian that the study of the past is significant for an investigator, in so far as his functioning as an investigator is concerned. I do not think Professor Richards thought his Chemistry 8 was significant because any of his students would be keener investigators of chemical phenomena later. I

⁵ I. Bernard Cohen, 'Present Status and Needs of the History of Science,' *Proceedings of the American Philosophical Society*, XCIX (1955), 345.

am sure that Professor Henderson held no such view. Indeed, I remember his ridiculing to me a proposition put to him by two well-known scientists in a distant institution who wanted his advice about developing the history of science to the end that the graduate students would learn how to do research by studying the past performance of great scientists. 'Why is the idea ridiculous?' some of you may ask. 'Army commanders for generations have studied the great battles and great campaigns apparently with profit. You, yourself, have advocated the use of "case histories" to acquaint the general student with the ways science has advanced. Are you not inconsistent?'

My reply would be somewhat as follows: The scientific investigator develops his skill as an investigator by a method closely akin to that by which masters of a craft trained apprentices in the past or the painters of the Renaissance developed in the studio of a great master. Continuous experience with experimentation from the advanced laboratory courses to the first independent work has kept the embryo research man in contact with the reality of his business. As compared with what he is learning and has learned in his laboratory, the chemist, physicist, or experimental biologist finds the past has little or nothing to tell him about the methods of research. Unlike the officers who study campaigns in periods of peace to prepare for war, the research worker is never at peace; he is always in the midst of war and learns the intricacies of fighting on the frontiers of knowledge by daily combat, an experience, by the way, which is forever alien to those who are not trained in science. Hence for them I believe a study of past campaigns has value.

I shall press the point no further. Let us agree that the research scientist *qua* investigator has no need of history beyond the knowledge of the immediate background of the field in which he is heavily engaged. (He must make himself familiar with what is often called the literature of the subject, but rarely will he read anything written more than fifty years earlier.) It is as a person who must function outside the laboratory that the scientist has need of an understanding of history. And the time to begin the development of this understanding is while he is still in college. Since the future scientist as an undergraduate is largely motivated by his enthusiasm for the science which he is planning to make his own, his interest in history, with skillful teaching, will develop in the following order: the history of *his* science, the history of modern science in general, the history of science in the

widest sense, the cultural and political history of significant periods first met in connection with the history of science. If you grant, in general terms at least, the validity of my reasoning and its applicability to a good many science majors, the conclusion is obvious. A strong department of the history of science is an essential element in any faculty of arts and sciences which hopes to develop scientific talent effectively.

The need for an initiation into historical understanding during the undergraduate years is much greater today than it was a generation ago. I am referring primarily to students majoring in science, but I think the same statement might apply to all college undergraduates. The enormous expansion of applied science and the intricate connection of science, pure and applied, with government has had as a consequence that few scientists can escape becoming entangled in one way or another with affairs outside of their laboratories. Some have taken over administrative duties, off and on, for brief periods; others have abandoned research work and devoted their entire time and energy to administrative work connected, in one way or another, with science. No need to cite examples; the facts are common knowledge. Every indication points to an expansion of this process of transforming scientists into administrators and statesmen. (I might say 'politicians' except that this word unfortunately has acquired certain unpleasant overtones.) The Ph.D. of today is likely to be the bureaucrat of tomorrow; his locus may be Washington, or a government-supported development undertaking, or an industrial laboratory or plant. (All bureaucrats are by no means government employees.) It is high time we up-graded the word 'bureaucrat' as well as 'politician,' by the way. Our survival as a free society will depend in part on the caliber of men who fill the positions in our industrial and governmental hierarchy. And their caliber, in turn, depends largely on the attitude of the public towards the jobs in question. When men trained in science slip into positions involving political considerations (using the word 'politics' in a good sense), the science they have learned will be of secondary significance. Their former methods of analyzing problems and formulating questions will require considerable transformation. How are they to be prepared for the metamorphosis from a teacher and investigator to a man who must deal with a variety of human problems and be prepared to make quick decisions on the basis of meager information?

Some academic people I know will answer the question I have just raised by recommending that the science concentrator take courses in psychology, sociology, and political science. I should not wish to argue against this recommendation, but I give higher priority to at least one course in political history provided the student approaches down the glide path I previously outlined. He takes the history course because of his interest that has been stimulated, not because the course is a requirement. The difference is very great. It may be that he never finds the time to enroll formally in an orthodox course in history. (The crowding of a future scientist's schedule is notorious.) As a second best, let him audit the course, and, as a third best (which is a close second), let him read on the side the significant books dealing with the period in question. Above all, let us hope he has acquired the habit of reading history and biography, for it is through such reading during his later years that he will acquire from historical study the benefits which I have in mind.

If you have followed me thus far, you will see that a course in the history of science, if properly presented (as I am sure it is at Harvard!), is the essential ingredient of my recommendation. In such a course the student will begin to think in historical terms; in such a course he will begin to have some inkling of the difference between the kinds of evidence that are considered significant by a scientist and the kind employed by historians (an extremely important distinction that has implications for understanding legal proceedings in free societies and rational administrative processes, too). He will, certainly, obtain a wider view of science and of culture; his interests in areas of creative activity outside of science may well be stimulated. Indeed, some would place these possibilities as being the most important potentialities of the study of the history of science by scientists. Thirty years ago, I think I should have held the same opinion. But because of the likelihood, now and in the future, that the scientist will have to be concerned with human problems, I place the emphasis on the use of history as a method of humanizing the laboratory worker. By this I mean the process of making him interested in the vagaries of human nature and concerned with questions involving the individual and society, man's conflicting desires for freedom and for order, for personal glory and for the cooperative teamwork of self-effacing individuals.

I have been assuming that the historian of science, who, among his other academic duties, will have that of enticing the young scientist

from his laboratory to the library, has a deep interest in scientists as human beings. Such an assumption may seem self-evident. Yet it appears to have been challenged by an eminent philosopher of science, Herbert Dingle, of the University of London. In his comments on papers presented by philosophers, sociologists, and historians at a conference held by the American Philosophical Society in 1955, he took exception to the association of the sociology of science with the history and philosophy of science. On that point, I have no opinion one way or the other. But I venture to disagree with what he goes on to say about the nature of the history of science. He writes: 'The association seems to arise from the confusion of science with the scientist. The subject matter of the history of science is science, that of the philosophy of science is science, but that of the "sociology of science" is the scientist.'⁶ To my mind, the separation which is clearly implied between the activities of scientists and the growth of science as accumulated knowledge, if carried out, would leave a barren history of science. And some treatments of the history of science tend in this direction. Summary accounts of the growth of scientific theories, for example, can be written with the names and dates of the scientists relegated to footnotes. This way of handling the history of science has value for the philosopher of science and may lead some students into a concern with the philosophic problems which are basic to all science. (And I do not wish to minimize the importance of such possibilities.) But a course in the history of scientific theory would most emphatically not fulfill the purposes I have in mind when I endorse so heartily the value of the study of history for the future scientist.

At the risk of expanding a footnote into a large segment of a lecture, I must point out a curious episode in the history of the history of science which may have some bearing on Professor Dingle's statement that 'the subject matter of the history of science is science.' In the 1930's many intellectuals who had become converts to the Marx-Lenin doctrines then promulgated as the 'official line' were greatly interested in the history of science. Their writings represent in the extreme form the belief that the history of science is the history of scientists, and to this statement they added a rider which concealed a heavy political potential. The activities of the scientists in the past, according to the official dogma, had been determined by their relation to the current modes of production; since modern science had developed as capitalism

⁶ *Proceedings of the American Philosophical Society*, XCIX, 348.

had developed, science was a product of industrialism; 'pure science' was a bourgeois façade; under capitalism there could be nothing but applied science whatever people might say; and only when Communism triumphed would man's creative activities be truly free. These pronouncements, which were expressed in a particularly crude form by a group of Russian historians of science who visited London in 1935, infuriated many scientists in England and the United States. Indeed, a society was formed to prepare and publish answers to the absurd claim that there never had been such a thing as pure science and to refute the political implications for the future of the Marxists' writings. A few British scientists upheld the Russian view. For a decade a polemic literature developed, which, I must admit, I found quite fascinating reading.

The controversy seems to have subsided, largely because the Marxists have found few followers and the few who are left have greatly modified their position. The marks of the controversy, it seems to me, are still visible, however. The development of scientific theories without any trace of a consideration of their practical utility was underlined by those who attacked the Communist position. Concern with the behavior of scientists as human beings and, above all, concern with their relation to society could be viewed as a dangerous step in the direction of Marxism. I seem to detect such concern in the writings of some philosophers of science. Leaving aside the controversy over the relation of pure and applied science, to which I shall return, it seems to me that one's attitude about the history of science and scientists turns, in part, on a basic philosophic issue. Since the issue also involves one's attitude towards political history, it may not be inappropriate for me to explore it very briefly here tonight.

The issue, in terms of political history, is the old one of the role of great men. One may ask: 'To what extent did the historical drama unfold uninfluenced by such "accidents of history" as the existence of the heroes and villains of the past?' The more one inclines to the philosophy of Hegel or that of the school which goes under the label of 'historicism,' the less one is interested in 'great men' and the more one believes in a type of historical determinism. Historians who search to find the path mankind has walked through the ages generate confidence in their ability to predict the path mankind is destined to walk in the future. Historical materialism coupled with dialectical materialism represents an extreme example of such confidence. For those who

interpret history in this manner, the delightful and, I believe, rewarding game of speculating on what might have happened in history is out of bounds as a serious undertaking.

I share the view of those who express great skepticism about the ability of philosophers or historians to find any unfolding pattern in the past and am equally skeptical about efforts to predict the future (except for short-range, essentially local predictions). Since it is generally agreed by historians that every generation to some degree rewrites history and, thus, creates its own interpretation of the past, I think it illuminates the problems of the present to discuss such questions as whether there would have been a swing to the left in American politics in the 30's or 40's without a depression, or whether there would have been a Restoration if Cromwell had lived another decade.

The parallel between politics and science is brought out by asking whether our present scientific theories would have the form they now have if certain great scientists had died young, or certain discoveries had been made in a different chronological order. These questions are rarely considered by historians of science, which seems to me a pity. I believe they are neither trivial nor irrelevant. For example, I think a rewarding discussion could be developed around the question: What if Michael Faraday had died before he worked out his idea of lines of force in a medium between magnets? Or one might profitably speculate whether our present terminology and concepts in regard to elements, atomic structure, and the periodic system would have exactly their present form if the methods of accurate determination of atomic weights had been formulated earlier and samples of lead containing lead isotopes had been examined by some meticulous and stubborn chemist. The identity of the combining weight of all samples of an element was one of the foundation stones of the atomic theory for nearly a hundred years. Yet today we know this doctrine to be false. That there is no inherent logical consistency in the order in which experimental discoveries are made is illustrated by Blackett's recent discussion of the history of the discovery of the non-conservation of parity.⁷ If time permitted and my knowledge of the history of nineteenth-century chemistry was what it used to be, I should enjoy trying to give you some 'might have been' accounts of the history of that subject.

⁷ P. M. S. Blackett, 'Non-conservation of Parity,' *American Scientist*, XLVII (1959), 509-514.

The significance attached to the accidental in the history of science depends, as I said earlier, on one's instinctive answer to a basic question. If our present scientific ideas which have stood the test of experiment for several decades are unalterable, as some scientists and philosophers would maintain, then the only conceivable variable is the time that elapsed before the ideas were adopted; their essential form, it would be maintained, is fixed by the structure of the material world. I find myself more and more in opposition to such a view even in the form expressed by Charles S. Peirce, according to whom the 'right' scientific concepts are to be regarded as the limiting cases towards which our scientific developments inevitably tend. I much prefer Professor W. Van Orman Quine's position as I understand it. 'We adopt,' he writes, 'at least insofar as we are reasonable, the simplest conceptual scheme into which the disordered fragments of raw experience can be fitted and arranged.'⁸ This applies to the whole range of experience, from that of common-sense impacts with material objects to the data collected by the chemists and physicists with their ever more complicated apparatus. 'Total science,' writes Quine, 'is like a field of force whose boundary conditions are experience. A conflict with experience at the periphery occasions readjustments in the interior of the field. Truth values have to be redistributed over some of our statements. . . . But the total field is so underdetermined by its boundary conditions, experience, that there is much latitude of choice as to what statements to reëvaluate in the light of any single contrary experience. No particular experiences are linked with any particular statements in the interior of the field, except indirectly through considerations of equilibrium affecting the field as a whole.' And later in the same volume he suggests that it is 'meaningless . . . to inquire into the absolute correctness of a conceptual scheme as a mirror of reality.' To my mind a survey of the history of the physical sciences supports Professor Quine's position. In more than one instance in the last two hundred years, a scheme believed to be the 'mirror of reality' has had to be abandoned. The indivisible atom and the luminiferous ether have shared the fate of the phlogiston theory.

If one takes the position that, for the future impact of any new discovery, scientists have a choice as to which parts of the entire field are to be readjusted, then the same would seem to be true as regards

⁸Quotations to end of paragraph from Willard Van Orman Quine, *From a Logical Point of View* (Cambridge, Mass., 1953), pp. 16, 42-43, 79.

the past. Therefore, to some degree science, as we now have it, does not represent a stage in the unveiling of the one and only correct pattern of nature, a mirror of reality. On the contrary, the fabric of science is man made and carries all through it marks characteristic of the weavers; in part, it represents the accidents of history as to the way the weavings have been patched together. The significance of regarding science as a reflection, in part at least, of the genius of great scientists is brought out clearly by Professor Cohen in his truly great book on Franklin and Newton. Without entering into the ontological question I have just discussed, he considers the statement attributed to Einstein that the calculus would have been invented if Newton or Leibniz had never lived, but that without Beethoven the C Minor Symphony would never have been composed.⁹ As Professor Cohen says, this proposition needs many qualifications. He points to Faraday and his 'lines of force' and goes on to write, 'The historian, furthermore, cannot help exploring problems of personality whenever he studies the lifetime program of research of any scientist.' The entire volume is evidence that this Harvard historian regards the history of science quite as much the history of scientists as the history of scientific theories.

The enthusiastic young scientist who has become interested in the study of the history of science need take only a short step in order to study the history of politics, or 'history,' as the word is used nine times out of ten in discussions of books and lectures. But why should he take the step? I have already indicated the nature of my answer by indicating the significance of a knowledge of history for the scientist turned administrator. It is not the memory of dates, names, events that is important, but an understanding of what a study of the past, or rather an interpretation of the past, can and cannot reveal. First of all, it is obvious that the present functioning of any social institution and the limits of possible variability for the future can only be assessed in terms of the history of the institution. Thus a scientist who becomes the president of a university with which he is totally unfamiliar would be well advised to take time off to read up on the history of the institution and the community it serves. If he has had the proper introduction to history, he will have some notion of evaluating the evidence presented by various documents which readily come to hand. I suggest he would be well advised to know something about the his-

⁹I. Bernard Cohen, *Franklin and Newton* (Philadelphia, 1956), p. 43.

tory of universities in general, if possible concentrating on one or more episodes where there was a violent collision of academic vested interests; if possible the writings of apologists for both sides of the controversy should be studied. On the basis of the record of the past, he can form his own estimation as to what recent changes seem likely to be reversible (like prohibition) or irreversible (like our laws prohibiting child labor).

The scientist who turns administrator is more likely than not to become involved in two types of questions which are a product of the mid-twentieth century. I refer to the organized activity of scientists and the relation of pure science to applied science. It is frequently asserted that the day of the solitary inventor or the isolated professor who singlehanded makes a great discovery has gone. As a generalization this is probably correct. The number and size of research teams have increased. Furthermore, science has long since become an organized activity which, through meetings and publications, prescribes definite limits to the activities of the members of the guild. The mores of scientists determine the meaning of such phrases as 'fraudulent,' 'highly significant,' 'not worthy of serious consideration,' or 'revolutionary.' The way science has become organized in the last one hundred and fifty years in different nations and the relation of government to organized science are worth an administrator's careful consideration. The process has not ceased; many of the factors which shaped the present are still operating. Those who desire a particular turn of events for the future are apt to base their argument on history. The validity of the case can only be assessed by a person who understands something of the nature of historical evidence and is prepared himself to examine the record.

The Marxist arguments about the matter of pure science were based on distorted interpretations of the history of science. But the problem to which they addressed themselves still remains. Either organized society (government) or an organized segment of society (an industrial company or a philanthropic institution) or both are now involved in almost every research undertaking. The results that flow from the laboratories daily affect the production of material objects in a multitude of ways. The interconnections between industry, universities, and government in the United States are multiple and sometimes tangled; information flows in many directions. Can the concepts 'pure science' and 'applied science' have the same meaning today as

they had at the turn of the century? I doubt it. To my mind a more fruitful line of analysis of a complex social problem is to discover the degree to which an original young scientist finds himself committed to a program whose outline is determined by considerations other than those that flow from his own imagination. Rather than talk about the need for supporting pure research, I should stress the importance of aiding the investigator quite apart from his program.

In presenting illustrations as to the kind of problems a scientific administrator faces, I find I have wandered far from the subject of this lecture. And I have not yet touched on the most important point, for over and above a knowledge of the history of an institution, or a department of government, or an industry, or a scientific discipline, the administrator must hope to be aware of the way human beings behave under a variety of conditions. And it is to enrich his knowledge of human nature that I recommend the study in depth of some rather turbulent period of history. The time must be sufficiently distant for the records to be available and for the controversies to have been sifted over by professional historians. Biographies and autobiographies are particularly to be recommended. The period should not be too remote, lest the records be insufficient, and the complex of social forces too unrelated to the present. The Cromwellian period in English history and the period of the United States from the War of Independence to 1812 are two which I personally have found continually rewarding. Saints and sinners, rascals, fools, and heroes (if you like to paint your history in strong colors) crowd upon the canvas. Their modern counterparts are to be found whenever the scientist starts to make decisions, or influence people outside of the laboratory or his family circle.

What I have been trying to say was far better expressed by Thomas Jefferson. Writing in his *Notes on Virginia* (1781-82) about his educational proposals, he discusses the education which was to be supplied by the state for *all* the young people with the aim of rendering the people 'the safe . . . guardians of their own liberty.' 'For this purpose,' he declares, 'the reading in the first stage, where *they* will receive their whole education, is proposed, as has been said, to be chiefly historical. History by apprising them of the past will enable them to judge of the future; it will avail them of the experience of other times and other nations; it will qualify them as judges of the actions and designs of men; it will enable them to know ambition under

every disguise it may assume; and knowing it, to defeat its views.' ¹⁰ When Jefferson wrote these words, he could hardly have foreseen the active part he was to play in American politics. Is it too much to assume that some of his adroitness as a politician and his vision as a statesman came from his having taken his own advice about reading history?

Now in conclusion let me make it plain that I am well aware that historians have many important functions to perform other than that of starting young students of science on a career of reading history as an avocation. The serious student of history may take a different attitude towards his field of scholarship from the very limited one I am presenting. The historian may believe that his reconstructions of the past have meaning. I shall intrude my skepticism as to history on the grand scale no further. I am also aware that the historian of science has other tasks than that of stimulating the scientist to try to understand how historians go about their work. The history of science since, say, 1500 is the portion that is relevant for the purposes I have been discussing. But there is a vast history of science stretching back to Greece and Egypt and including, of course, the Islamic world that can be rewardingly explored by historians of science. The results throw much light on the cultural and social history of the first millennium and a half of the Christian era. And I remind you I stated at the outset I was not considering tonight the value of the history of science for the large number of college students who have no intention of becoming scientists. I have touched only briefly on the connection of the history of science and the philosophy of science, and perhaps left the impression of a certain lack of enthusiasm for the latter. If so, I have erred. One of the reasons why a university should be proud of having a powerful history of science group is because such a group can, under favorable circumstances, profoundly affect the philosopher's approach to science, and the intellectual traffic between historian and philosopher can, and often is, a heavy traffic on a two-way street.

My arguments for the study of history may seem to historians too restricted; they may seem conservative and even unscientific. For I do not suggest that the student of history will, by virtue of his studies, be able to foretell the future or find a clue to the meaning of human life. Let me conclude by quoting from a seventeenth-century scholar,

¹⁰ Quoted from a copy of the first edition, Paris, 1784-85, p. 273, in the Harvard College Library.

and let it be noted that he, like Jefferson, wrote before Hegel unleashed his ideas and Karl Marx's revision of Hegel made the Communists certain history was on their side. John Selden in 1618, in his *Historie of Titbes*, wrote as follows: 'For, as on the one side, it cannot be doubted but that the too studious Affectation of bare and sterile *Antiquitie*, which is nothing els but to be exceeding busie about nothing, may soon descend to a Dotage; so on the other, the Neglect or only vulgar regard of the fruitfull and precious part of it, which gines necessarie light to the *Present* in matter of *State, Law, Historie*, and the *vnderstanding of good Autors*, is but preferring that kind of Ignorant Infancie, which our short life alone allows vs, before the many ages of former Experience and Obseruation, which may so accumulat yeers to vs as if we had liud euen from the beginning of Time.'¹¹ The study of history may so accumulate years to us as though we had lived even from the beginning of time. On what better note can I conclude this lecture on history in the education of scientists?

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¹¹London, 1618, dedication to Sir Robert Cotton; quoted from a copy in the Harvard College Library.

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