SCIENCE

VOL. 86 FRIDAY, JULY 23, 1937 NO. 2221

SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. MCKEEN CATTELL and published every Friday by

THE SCIENCE PRESS

New York City: Grand Central Terminal

Lancaster, Pa. Garrison, N. Y.

Annual Subscription, $6.00 Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

SCIENCE AND THE SCIENTIFIC ATTITUDE[1]

By Professor ROBERT S. MULLIKEN

UNIVERSITY OF CHICAGO

IN my old home town on the coast of Massachusetts there lived some hundred or hundred and fifty years ago a gentleman who styled himself Lord Timothy Dexter. This self-dubbed nobleman was noted for several exploits, of which I will mention three. Lord Timothy once shipped a cargo of warming pans to the West Indies. This seemed rather a joke to his fellow-townsmen, but, as it happened, the warming pans turned out to be ideal for boiling down sugar-cane juice, and Lord Timothy made his fortune there and then. On a later occasion, this gentleman, fearing that his wife did not love him, pretended to be dead. When she failed to weep at his funeral, he jumped out of the coffin and beat her soundly. Finally, Lord Timothy once wrote a small treatise, entitled "A Pickle for the Knowing Ones." He could spell after a fashion, but he could not punctuate. So, in his text, he put one word right after another, but at the end he included a page of periods, commas and semicolons, with the invitation to his readers to "peper and solt it as they plese." In similar fashion, I come to you now with a discourse that is unseasoned by humor; but I beg you to pepper and salt it to suit your own respective tastes.

Although Lord Timothy was not, strictly speaking, a scientist, he had something of the scientist's experimental and obstinately non-conforming spirit. I think, therefore, that he would not object that I am using him to introduce a speech on science and the scientific attitude. I shall begin with a definition.

The word "science" is derived from the Latin "scientia," which can be translated, roughly, as "knowledge." Present-day science may be defined briefly as *organized* knowledge. More fully, it may

[1] Speech "for the faculty" at trustees' dinner to faculty, University of Chicago, on April 9, 1937.

be described as knowledge found by experiments or observations and organized by rigorous logic under the drive of creative imagination. (In the development of science, the finding and organizing processes continually act and react on each other.)

In my remarks to-night, I should like not so much to emphasize the technique or subject-matter or the well-known material triumphs of science, but rather the scientific attitude, that is, the habit of mind and will characteristic of scientists. Especially I should like to express belief in the great potential value of this attitude for human welfare, including the proper development of education.

The trouble with the world to-day, most scientists believe, is not that there is too much science, but rather that the scientific attitude—the essence of science—is far too little understood and too inadequately applied to human problems. Even among scientists themselves, outside their own specialties, the scientific attitude is far too rare and is never fully developed. Now, you ask, just what *is* this scientific attitude? Briefly, it is an attitude in which supreme value is attached to the idea of objective truth. But science has learned from experience the very great difficulty of finding and of knowing truth and the extreme likelihood of error. Therefore, it combines with its faith a most thoroughgoing skepticism and a tremendous patience and open-mindedness. Dogmatism and wishful thinking are abhorrent to it. Finally, a sense of humor is a useful accompaniment if not a necessary ingredient of the scientific attitude, which otherwise would impose an intolerable strain on human nature.

I should like now to sketch in one or two salient features of the general picture of science and the scientists. Characteristic of science, and at least in part of philosophy too, is a never-ending striving toward a perfection of understanding which, so far at any rate, paradoxically seems to grow more remote as it is approached. Because of this, there becomes imbued in the scientist a willingness to accept science as tentative, ever-changing and always imperfect. This continual striving in the midst of uncertainty runs contrary to the normal human desire for secure knowledge. Yet, for better or for worse, it apparently corresponds to the true nature of life.

Indeed, it is not only professional scientists and philosophers who have felt the futility of being too impatient to solve the riddle of the universe. Thus the poet Keats refers to Shakespeare as a man who was "capable of being in uncertainties, mysteries, doubts, without any irritable reaching after fact and reason." To be sure, the restless striving after new scientific truth seems to be excluded here; but at the same time, the possibility of contentment with imperfect knowledge is well expressed.

There is no doubt that science has changed human ideas very much, and in particular has brought many formerly accepted verities into the rôle of illusions. Frequently it has banished both spirits and hobgoblins together, and, it must be confessed, it has tended thereby to give a certain flatness to things. But after all, if these *were* illusions, that is, if they could not be defended against science, we can not say that science here has destroyed any tangible reality, any objective truth. On the other hand, there are many ideas which the scientist may be inclined to classify as illusions, but to which one must grant at least subjective or poetic or psychological truth. If such ideas or illusions have value for us, it is entirely sensible and scientific that we should keep them, and even that we should search for more and better ones. After all, the pursuit of admitted illusions is nothing new. Illusion is vital in the art of the theater and in many other arts.

In the main, the scientific attitude is much the same as the intellectual attitude. It is a mental condition, never completely realized in practice, in which the feelings and emotions are encouraged to help, but not allowed to interfere, with logical thinking. Because of this necessity of holding the emotions in check, and more especially for other less direct reasons, the scientific attitude has had a tendency to discourage emotional and esthetic expression. In particular, industrial mass production, based on scientific discovery, has acted adversely on individual artistic expression in everyday life.

This, however, does not mean that thinking and its daughter, science, are inherently pernicious. It means, rather, that they have become too one-sided in our Occidental civilization, neglecting the emotional part of human nature. It is now time to see what we can do toward remedying this oversight. Indeed, much has already been done in some countries toward restoring the balance between esthetic and material development; and there is much here that we could learn from the Orient. The hard-boiled scientific attitude is inherently quite capable of seeing and objectively investigating the need of human beings for esthetic and emotional expression. Such research would come under psychology and related subjects. To the best of my knowledge, these sciences are making good progress, even though they are still in infancy. In the light of the history of science, I see no reason why they may not eventually make as enormous contributions to the non-material side of the art of living as, for example, the physical sciences have to the material side, if they go about it in the right way.

But what *is* the right way for science to approach new or little-developed fields? It seems to me that it is primarily by bringing to bear the scientific attitude,

in its most general form, and not by trying to transplant special techniques from other fields. Aside from certain very general characteristics, we should be prepared to find that the appropriate techniques may vary enormously from one science to another; and of course they may also vary greatly with the degree of maturity of the science. Undoubtedly, in many instances, techniques similar to those of older sciences may turn out to be appropriate, but it would be unscientific dogmatism to assume this in advance.

Looking back over my own experience, I think it was in a course on quantitative chemical analysis that an appreciation of the scientific method and its rigors began really to take hold of me. Before that, I had been interested in the wonders of science in an irresponsible and second-hand sort of way. But in quantitative analysis, which, by the way, I detested, I was brought face to face with the unpitying relentlessness of nature, in the form of some brute facts of chemical technique. Slipshod work wouldn't do. There were no short cuts to beat clear thinking, careful technique and endless patience. Later on, I found that the same unnatural methods are always required in those activities commonly called "research." Indeed, these same methods are also taught by many forms of human experience and have value in all successful activities. But I believe that these types of behavior, and especially certain further qualities which I will talk about in a moment, are encouraged with particular insistence by scientific work.

The primary objective of science, of course, is to try to find out what *nature* is really like: that is, to distinguish the *actual* universe, including mankind, from all the numberless forms the universe might conceivably have taken. In scientific research, man is engaged in a game with nature. Nature plays this game with a poker face and a certain inexorable humor. Nature calls every bluff—sooner or later. Sometimes she does it directly, sometimes through the work of one's fellow scientists. The embryo scientist soon learns that bluffing is a sheer waste of time and energy in this game.

I think it is right here that we have the most valuable lesson of scientific experience for human welfare in general. In the long run, all human activities are part of a great game with nature, a game in which man makes nature yield the earth's goods to him. Yet men are continually spending a large part of their time in bluffing and fighting one another. Aside from its very real value as part of the fun and spice of life, this kind of activity largely represents time stolen from the game with nature. It results in a low average efficiency and standard of living for the human race as compared with what we could have if we were more scientific.

Let us now return to the scientist trying to discover nature's secrets. He soon finds that only the most persistent, rigorously honest and boldly imaginative effort can win. Nature plays the perfect Sphinx and is completely adamant to every clumsy attempt to force the locks that guard her secrets. Yet to the man who finds the correct combination for one of these, *i.e.*, the truth, she yields without the slightest resistance. Further, the devotee of science, that is, if I may change the metaphor, the man who woos nature for her secrets, must develop enormous *tolerance* in seeking for ideas which may *please* nature, and enormous patience, self-restraint and humility when his ideas over and over again are rejected by nature before he arrives at one to please her. When the scientist does finally find such an idea, there is often something very intimate in his feeling of communion with nature.

It is my belief that experiences such as these should have tremendous value for education, by teaching the scientific attitude or, in other words, the scientific virtues.

It may be that when I say "scientific virtues," many of you will want to substitute the expression "scholarly virtues" or "intellectual virtues." If so, I shall not quarrel with you. When I say scientific virtues, I am merely giving expression to my own outlook, based predominantly on experience in physical science. I leave it to you to judge to what extent the same virtues are common to all learning, or are taught by all experience, and to what extent they may be peculiar to science. Reciprocally, I concede the possibility of non-scientific virtues.

As regards the teaching of the scientific attitude, the first great question is, can it be done with large numbers of people or only with a few? By our usual authoritarian processes of elementary and general education, students commonly lose their native confidence in their own powers of observation and reasoning, and tend to believe only what they read or are told. They generally fail to realize that what they read or hear, in so far as it is true, is based on adventurous contacts of men with nature in the past.

We need, then, in education, as everywhere in the art of living, to revitalize the spirit of adventure, of inquiry and experiment, the spirit which underlies all creative effort. We need to show students how *really* to take part in the game with nature. We should incite them to learn that nature is real, that nature can be touched and can be dealt with, that nature can be made to help us but can not possibly be bluffed or bribed into doing so. Contact with nature, both physical and intellectual contact, but always vital and creative contact—it is into this that we should try to lead our students.

I shall not have time to deal extensively with the tremendous problem of how this can be done. The main essential seems to be that the student shall be

induced or trained to make his own contacts with nature, and to acquire skill in putting questions directly to nature and in getting answers which he can trust. Such questions may be put in the laboratory, in the arm-chair, in the studio, in the great outdoors or in the haunts of business and industry. The greater the variety of the scenes of action which the student can effectively explore, the broader and better founded should be his resulting generalizations. The scientific or the intellectual attitude comes into being through analytical and dispassionate study of such fields of action, with the help, of course, of thinkers of the past. My confidence in the feasibility of developing the scientific attitude by comparatively simple methods and in many people has recently been strengthened by a scientific colleague, who has told me of a successful experiment he once carried out by conducting an undergraduate course along novel lines of semi-research character.[2]

I should like now to go a little further in reviewing the scientific virtues and in giving some examples of their application. These virtues may conveniently be grouped under the headings of intellectual efficiency, honesty, courage and tolerance. Intellectual efficiency involves the wise use of logic and creative imagination. Honesty, imbued by the struggle with nature, carries with it such things as sincerity, mutual trust, loyalty to truth, impartiality and justice. All these latter characteristics are commonly found in the dealings of scientists with one another on scientific matters. Courage is essential, for a scientist can hardly bring back real prizes from his adventures without the courage of his convictions. Tolerance carries with it many things: respect for facts, including, of course, the facts of human nature; patience, forbearance, self-restraint, suspended judgment, a due humility as to the value of one's own judgment and opinions in relation to those of other people; and, finally, a demand for freedom.

I should like to develop this idea of freedom a little further, since it is a particularly vital one at the present day. Science demands freedom, freedom to conceive and test the most fantastic hypotheses if need be. In the universities, this takes the form of academic freedom, which has been so happily maintained at Chicago. Science, I think, is a natural ally of democracy, and *vice versa,* since democracy gives more freedom than other known forms of government. Science is opposed to repression, dictatorship and all varieties of patent-medicinism in government.

[2] R. W. Gerard, *Jour. Chem. Education,* 8: 1144, 1931. Of course this is not the only effort to introduce research methods into undergraduate work; on the contrary, undergraduate research courses have been provided for some years in certain institutions.

Science itself is by nature utterly conservative, in that it holds tenaciously to all ancient wisdom, so far as this remains true; yet at the same time it is utterly radical, in that it has no inhibitions about examining any new idea, however strange, provided this contains some promise of truth. Science is neither conservative nor radical as a matter of mere habit or sentiment, but only for real reasons. In a similar way, science combines extreme skepticism with a strong faith in its own powers, derived from its past achievements. In the adoption of new ideas, science normally proceeds by evolution, not by revolution; or if at rare intervals there is revolution, it is only through the bloodless triumph of convincing new facts or ideas.

Science, I have suggested, is a natural ally of democracy—more precisely, if I am not mistaken, of that variety known as Jeffersonian democracy. By this I mean a system whose first basic ideal is democracy of *opportunity,* for men and for ideas. This would seek to smooth out differences of opportunity caused by accidents of birth or origin, and it would encourage full and free development of men and their ideas. The second basic principle, really a logical corollary of the first, is an aristocratic one. Namely, since history and common experience show that men differ greatly in their capacities, it would freely concede relatively great opportunity and scope to the *best* men and their ideas; at the same time it would seek to minimize the twin evils of snobbism and class hatred. Roughly speaking, "best" would be estimated here in terms of the interests of the race as a whole. Some such ideal of democracy, it seems to me, springs naturally from the scientific attitude as applied to present-day circumstances; and I believe that a wider diffusion of the scientific attitude would tend to promote such an ideal.

In conclusion, what may we expect of science in the future? It would be unscientific to demand an explicit answer, but I think it is fairly safe to say that the actual future will differ greatly from the pictures of it by contemporary novelists. Scientific history tends toward the generalization that what we can most confidently expect is the unexpected; but further, that this unexpected always increases our power over nature. Since man is part of nature, it is not unreasonable to hope that through science we shall gradually gain increasing power to control the forces of human nature as well as of nature in general for the benefit of mankind. But we can hardly require science to *guarantee* this in advance. As for democracy and civilization, we can not help them by surrendering to the current fashion of passive defeatism. We *can* help them if we are willing to live, in the midst of uncertainty, with the adventurous confidence of hope.