SCIENCE

VOL. 94 FRIDAY, SEPTEMBER 12, 1941 No. 2437

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

THE SCIENCE PRESS

Lancaster, Pa. Garrison, N. Y.

New York City: Grand Central Terminal

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.

SOME SOCIAL IMPLICATIONS OF THE SCIENTIFIC METHOD[1]

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SEVERAL considerations have led me to choose the present title, which I know will appear to many of you, at least at first sight, to be rather inappropriate for presentation before the American Society for Horticultural Science. Among these is the fact that our society is becoming mature. Attendance is now larger and more varied than formerly, and it seems not out of place to consider matters of a general nature rather than to continue the technical discussions of the regular sessions. Not that we should be less zealous of the pursuit of scientific knowledge, but rather that now we have established our position as a first-class scientific society we can pause momentarily and examine our situation with relation not only to other scientific societies, but to the whole field of knowledge as well.

The subject is certainly timely. With most of the world at war or near war it is all too obvious that our control of physical forces has far outstripped the capacity or at least the will of the human race to manage their affairs in a satisfactory way. Such a statement is trite in view of the many efforts now being made to increase the sense of responsibility among the scientists for the social order. This trend has been emphasized recently by the National Research

[1] Address of the president of the American Society for Horticultural Science, presented at the Philadelphia meeting of the society, December 30, 1940.

Council in its consideration of the obligation of the scientists of America to society in general and the defense program in particular.

It is timely also because the method and approach used by many, or should I say most, scholars in studying and attempting to solve the problems of human relationships, including economics, sociology and ethics, are at the present time apparently confused and ineffective. There has not been adequate leadership in these fields at a time when such leadership has been far more important than technological advance and control. Economic bungling of both governmental and private institutions and in industry during the past years of depression has brought out only too clearly the inadequacy of our society to handle the really important problems. It is indicated particularly by the failure among economists to have any answer upon which they can agree and no widely accepted method of approach to economic problems.

Modern ethics also is in a confused state. This was brought out most forcibly in a recent course of lectures on "Ethics and Modern Life," given at Cornell by a leader in that field. The titles of some of the lectures will indicate the confusion of thoughts and ideas that apparently exist. The first title was "The Dilemma of Modern Ethics." The dilemma seemed to be that there is no way by which the problem of human conduct could even be considered. Ideas just don't have any contact with action, and every term that is used is a dilemma in itself. The second lecture was on "The Venture of Moral Philosophy." The venture appeared to be that it was most extraordinary that any one would have the temerity to even try to do anything about conduct. The third lecture had to do with the divergence of theory and practice in which it was again brought out that it is practically impossible to bring ideas to bear upon the world of fact and experience. In the fourth lecture entitled, "The Modern Experiment; Ideas and Immediate Experience," it looked as if the lecturer were going to arrive at something which at least faintly resembled an effective approach to the problem, the scientific approach, if you please. The startling concept was advanced that possibly ideas could be brought to bear upon immediate experience. In the last lecture of the series, however, entitled "The Persistent Tension in Experience and Morals," the idea was given up and it was indicated that the whole matter was in a condition of confusion, futility and conflict. It gave no real hope to the human race for ever doing anything effective in directly meeting their problems in the improvement of social and moral relationships which is so necessary if civilization is to continue. Yet this authority in the field of ethics received nearly $6.00 a minute for bringing his audience to such a state of confusion and impression of futility. The above picture is, of course, overdrawn and can not be used as a basis for generalization. It does, however, contrast rather sharply with the situation where the scientific method is used as a tool in the solution of problems.

It is my belief that the method of science or the scientific approach is useful and effective in interpreting phenomena in all fields of human knowledge and endeavor and will aid in the solution of all problems with which the human race is confronted. It is also my belief that we as scientists have the opportunity, if not even the obligation, of bringing to bear upon the problems of living, both private and public, the method and approach of science. I submit that this method has had an outstanding record of accomplishment in the fields where it has been used and that the extension of its use as a working hypothesis for the solution of all problems is more practical and effective than any approach so far devised.

Before going further it is essential to make clear just what is meant by the scientific method. Here I know that much that is said will seem trite and well known to most or all of you. It is, however, necessary that such a statement be made, otherwise we do not know just what we are talking about.

Behind the scientific method are a number of basic assumptions which are taken as axiomatic. The first of these is that everything that takes place in the universe as we know it takes place in accordance with natural law. The second is that the human mind is capable of comprehending and understanding this natural law and hence can understand the universe. If this were not true the scientist could not work. What would be the use of spending our time investigating something that we can not understand. Of course, there is much in the universe of which we are not aware, much that our senses do not perceive, but we must assume that all could be perceived and understood if we were given, or if we devised, the proper instruments to perceive. The proof of such assumptions is that they work.

The radio is an obvious case in point. The natural law underlying the development of the radio has always been there. Radio waves, as such, are quite beyond the perception of any of our natural senses. However, by understanding the nature of these waves and how to control them it is possible to translate electric impulses into sound that we can perceive and enjoy. The air at this moment is full of all sorts of programs which, I am thankful to say at the moment, we do not perceive. By bringing in a radio properly tuned we are able immediately to make this apparent silence more audible.

As a further illustration of just what is meant by natural law I might cite the periodic table of atomic

weights as formulated by Mendeleyev in 1869. At that time only 70 elements were known, but on the basis of his hypothesis he postulated that there were 92 and went so far as to describe the properties of some of these that were still unknown. Within a comparatively few years 15 additional ones had been found, and now I believe all have been accounted for. When it was published in the newspaper that element 87 had been discovered it was no surprise. The chemists had known all along that it was there. Another example of what we mean by natural law is the comparatively recent discovery of the planet, Pluto. Astronomers knew by the behavior of other planets that such a planet existed and it only remained for a more powerful telescope to confirm its position. Who would doubt that the laws of astronomy have existed from the first? And so it is with other natural law.

Why many fail to appreciate the implications of the scientific method is that they do not consider natural law of universal application and are inclined to limit its scope to the physical sciences or to those in which material can be accurately weighed or measured. It is here that the greatest progress has been made and it is here that the factors with which the scientist deals are capable of the best controlled manipulation. Lord Kelvin has stated and I quote, "When you can measure what you are speaking about and express it in numbers, you know something about it, but when you can not measure it, when you can not express it in numbers your knowledge is of a meager and unsatisfactory kind: it may be the beginning of knowledge but you have scarcely in your thoughts advanced to the stage of science." This is a very significant statement, and in so far as the material concerned is capable of being measured and expressed in numbers it should apply. But certainly there is no particular virtue in numbers as such, and if the number does not honestly represent what it is supposed to represent it can be more misleading than a statement in words because the number gives an impression of accuracy that does not exist. It is my belief that some economists and biometricians have only confused our knowledge by using and manipulating numbers. Further, what is to be done with that great mass of phenomena which can not be measured and reduced to numbers but which is far more significant and important to human living than anything in the field of the physical sciences?

It might be possible to arbitrarily limit science by definition to those fields in which the material dealt with can be weighed, measured and expressed in numbers. This, however, is an untenable position because what we can measure to-day is far different from what we could measure yesterday and no one can venture what we may be able to measure to-morrow. To set up such an arbitrary limit implies that somewhere in our universe there is a limit beyond which the scientific method does not apply. But there certainly is nothing in the basic assumptions of the scientific approach that would justify setting such limits. These assumptions are simple, namely, that the universe operates according to natural law and we as human beings can understand natural law and hence the universe. To say that this does not have universal application is to say that part of our universe is chaos and without causal relationship between events which take place and the forces and conditions that have brought them about. Personally I know of no scientist or scholar that would admit that such chaos exists anywhere and I insist that it does not.

Because of this concept that nothing is really science unless it deals with things that can be measured and given numerical values there has grown up a sort of hierarchy or aristocracy among the sciences in which the physicists and the chemists hold themselves somewhat aloof from the biologist, the psychologist, the economist and the sociologist, apparently feeling that after all physics and chemistry are the only true sciences and that the others are only pseudo-science. The biologist and the psychologist because they can effectively employ the experimental method in turn are inclined to look down their noses at the social sciences as being on an even lower grade of pseudo-science. This situation has been admirably described by Professor Boynton, of Chicago University, in his chapter on "Knowledge and Wisdom" in a recent book.

Apparently much of the difficulty is based on the assumption that nothing is truly scientific unless it can be adapted to experimenal treatment in the laboratory. It is true that the experimental method has been identified with science itself from the first and rightly so, and that it is through experimentation that the outstanding advances of the past few decades have been made possible. It is also true that in the fields of knowledge which deal with human relationships and esthetics, experiments of the accepted laboratory type are difficult. This does not mean, however, that the basic principles of the scientific approach do not apply.

To emphasize this universality of natural law, it is useful to consider it as operating in different fields or at different levels. With no attempt at a complete classification we might set up a system something like this. First of all, there would be the physical level which would include physics and chemistry. The fact that chemistry in its last analysis is atomic physics is not important for developing the concept. Next would be the biological level. Here we are dealing with living things, the nature of protoplasm, the

physiology of plants and animals and such matters as health and medicine. Here would be considered all parts of man's nature that had to do with his biology. Psychology has to do with the workings of the mind and might be regarded as a phase of biology or at least to have an intimately associated biological basis. The process of thought is more complex and of a somewhat different nature than the physiological processes of digestion or respiration and for that reason psychology may well be set off from biology as such.

The social level has to do with relations between persons both as individuals and in groups and includes economics, sociology and ethics. We might also speak of an esthetic level or field which has to do with the appreciation of art and literature and poetry. Ethics and esthetics merge directly into what might be termed a spiritual level. In dealing with these upper levels the concept of value comes in. Thus, we speak of economic values, moral values, spiritual values. No attempt is made to give an exact relationship of these. The point to be made is that as we progress from one level to another there is continuity. If we accept evolution as a fact this could not be otherwise.

Also as we progress from one level to another, or from one set of values to another the nature of the natural law that is operating becomes increasingly more complex. It is, however, none-the-less real because it becomes less tangible and more difficult to handle experimentally. To further illustrate the point I am trying to develop it is well to consider some of these levels in more detail. The operation of physical law is obvious and accepted. No scientist has any doubt of its validity and the same is true of natural law in the biological field. This is the level with which the members of this Horticultural Society are primarily concerned. We recognize the application of chemistry and physics to our problems. But here in the biological field a new element that is very important comes in. We are dealing with living matter or protoplasm and its behavior not only as a substance, but as it is integrated in more complex organisms. The distinctive thing about protoplasm, however, is not the presence of certain chemical elements, but rather the integration of these. Of course, the elements which enter into the composition of protoplasm are essential, but merely to mix these in any given proportion is not to have protoplasm. The important thing about this substance is its organization, a thing which we destroy as soon as we try to treat it with chemical or physical techniques. It may be that eventually protoplasm will be partially explained in terms of stereo-chemistry and in last analysis atomic physics will contribute greatly to our understanding of its behavior. This, however, does not invalidate the concept. The important thing with which the biologist deals is protoplasm as such and its behavior as a living integrated functioning entity that is more than the sum of the chemical elements of which it consists.

The question of absorption of water by roots and its movement into the xylem vessels was not explained satisfactorily as long as such movement was regarded as an osmotic phenomenon carried on by purely passive physical forces. It can be explained, however, on the basis of the action of the protoplasm as a living substance which moves salts against a diffusion gradient and secretes them into the vessel in such concentration that water can then move by osmosis. In the process energy is used and work is done and this depends upon the organization and functioning of the protoplasm itself. To be sure physical laws are concerned and none has been violated, though just how they work may not be too clear. The significant fact with which we are dealing, however, is the whole organization of protoplasm and cells and tissues which makes this phenomenon possible.

In the field of horticulture the use of chemical methods has been valuable in some problems. Too often, however, the chemist, particularly if he is not a horticulturist as well, has not contributed to the solution of problems as much as hoped for because of his failure to appreciate the plant as something other than a mass of chemical elements and compounds. As horticulturists we must never lose sight of the plant as a living functioning organism that is more than the sum of the chemical elements of which it is composed. This idea was well expressed by Dr. E. W. Sinnott in his presidential address before the Botanical Society in 1938. It certainly is one that we as horticulturists should not ignore.

In biological problems, particularly in studying the physiology of plants and animals we continually use the scientific approach at least in our basic concepts and attitudes. We assume that what we observe is going on according to natural law and that we can understand it. We are so sure of this that when apparent exceptions occur we merely conclude that our conception of the natural law that is operating is wrong and that we must search further to find out what is basically involved. This approach which we all use has been adopted because of the fact that in general it works, or at least works much better than any other approach which has been devised.

An example of the use of this approach might make our meaning more clear. Some weeks ago in the greenhouse at Cornell a chrysanthemum plant normally with dark bronze flowers was observed in which a part of the flower heads were light yellow, a part dark bronze and in some heads the florets were dark in the lower part of the head and light in the upper.

The question arose immediately as to the cause of this difference in color. Because of the position of the flowers, it was evident that bud mutation was not the answer. The difference in color was apparently related to the proximity to a steam pipe. Such an observation immediately suggested the possible effect of heat upon the color of the flowers in question. This, of course, is tied up with the nature of the coloring matter concerned. Knowing that the color was anthocyanin and that this is a derivative of sugar, immediately the problem becomes related to the sugar supply available for the production of this coloring matter. Increase in temperature is, of course, related to respiration so that the possible explanation might be that the color pigment was absent from the flowers next to the steam pipe because of the loss of sugar through increased respiration. Another relationship indicated in the heads with dark florets below and the light above was the effect of the progressive shortening of day length in relation to carbohydrate manufacture. Heads that had color in the basal florets might have developed relatively earlier during longer days than those in the center. Under such conditions the sugar supply available at the time the florets were forming might be the controlling factor in determining the color. Doubtless other factors were also operating, and in any case these hypotheses would have to be proved experimentally before acceptance.

This example merely illustrates the scientific approach to a problem. First, we ask the question, "What is it that has happened and what are the materials involved?" Next, "What are the factors operating that might bring about the changes which we have observed?" Then, "What are the natural laws which are operating in controlling these factors?" It is my contention that this method of approach is valuable in approaching any problem.

At the psychological level we are dealing with something a little different from that found at the lower levels. Here again there is increased complexity. Nevertheless there is continuity in the natural law operating in the psychological field throughout the animal kingdom. There is no break between man and the other animals. The psychologists, of course, or at least many of them, have recognized this and have adopted the scientific method. Certainly there would be no logic in working with rats, dogs or pigs if this continuity did not exist. The natural law underlying psychological behavior seems to be relatively well understood compared to such understanding in the fields of economics and ethics. At least it is being made of practical use on a wide scale. We have only to mention such terms as "child training," "high pressure salesmanship," "propaganda" and the like to show this to be a fact. The astounding effectiveness of the Hitler régime is based largely on the control of some psychological factors. We can only hope that his knowledge is inadequate to carry out his plans in their entirety. Certainly neither the effect of bombing upon the British morale nor the imprisonment of the German clergy in concentration camps has worked out as was planned and indicates a lack of understanding of the psychology of these people.

Here again in the psychological field we are dealing with natural law that is unlike physical law and unlike most of the natural law in the biological field also. We are concerned with human response. Attempts are made to reduce human behavior to terms of endocrine secretions, blood pressure and similar factors. To get any significance out of human relationships, however, it is futile to reduce human behavior to such terms. The minute we try to break down a human reaction in terms of solutions and secretions the thing itself is lost. It is like trying to find out the nature of protoplasm by subjecting it to chemical analysis. As soon as it is manipulated with chemical techniques the significant thing about it no longer exists. For example, take the behavior of an affectionate child toward its father. On meeting after a separation, at the first sight of the parent the child comes running to him with every expression of eagerness and joy. Such actions are doubtless associated with various physical and chemical stimulations and electrical phenomena of one kind or another. However, these are not the significant things about it. The significant fact with which we are dealing is the whole complex phenomenon in its entirety.

In the field of economics the situation becomes even more involved and complex because we are considering not the psychology of an individual but the behavior of groups of individuals with regard to other groups and are also concerned with their relationship to various materials and commodities. Yet there is no question but in this field there are laws which operate in spite of Federal Farm Board legislation and the Agricultural Adjustment Administration or any other governmental organization. It seems to me evident that much of the difficulty of the past years during the depression is due to the fact that many economists do not use the scientific approach to their problems. Although some of them do use this approach there is such disagreement as to valid methods that great confusion has resulted. It is also entirely possible if not altogether probable that some of the so-called natural laws which have been thought to operate in the economic field are not valid. This does not mean, however, that such law is wanting and that it may not be discovered if studied in an effective manner.

In our personal relations with others natural law is

operating, also. The so-called laws of friendship have a very real meaning. It must be perfectly obvious to all of you that certain reactions in other people will follow certain courses of action on your part. It is quite possible to make another angry or to arouse many other positive or negative reactions at will.

The field of ethics has to do with personal conduct as related to what is right or wrong. Here, conduct must be judged in the light of the society in which it occurs. A thing is good or bad, moral or immoral, only when related to some specific situation or environment. Still there is no chaos, though some would say that there was. I recall hearing a famous criminal lawyer discussing this matter before a gathering of college students at Wesleyan University, Connecticut. The whole effect of his talk was to leave the students with the idea that there was no basis for judging conduct as moral or immoral, good or bad, and the general concept was that society had no right or justification in punishing criminals for what they do because it had no valid standards of what is right or wrong. It would seem to me that this conception was contrary to fact at least in so far as holding that there was no way to determine what was right or wrong. In this day and age and in our society a person of good moral character is a perfectly definite sort of person. We know what to expect in the way of behavior from such an individual. Each one of us has friends about whom we would not believe a report of their having done an immoral or disgraceful act. On the other hand, we may also have acquaintances about which such reports would be accepted as the thing to be expected. A possible concept of ethics might be stated after this fashion—Behavior is right or ethical if it is in accordance with natural law operating in a constructive manner. This has to do only with human behavior, as there is no ethics in the field of physics and chemistry.

In considering any behavior the level of the natural law that is operating must be considered. A thing may be right at one level and wrong at another. Certain behavior for example may be quite moral on the biological level with no immoral social implications whatever in a society like that of the early Polynesians, whereas the same course of action might be highly immoral in our own society judged on the basis of its biological, economic or social significance.

It is not my purpose to discuss ethics further than to point out the fact that natural law is operating in this field also. It is my firm belief that there is a fundamental and universal law governing human conduct under which human beings can achieve the best possible and most satisfying relationships. This has to do with many things that are known and recognized. The qualities of honesty, loyalty, truth, decency, kindness, unselfishness and the like are constructive in their effect upon individual and social life and in the long run will make for a better society than their destructive counterparts. It is obvious that if individuals and nations conducted themselves along these constructive lines the chaos which now confronts the civilized world would not exist. The point is emphasized here that any problem of ethics can be approached effectively by using essentially what we understand as the scientific method. It is granted without argument that our knowledge of natural law is incomplete, particularly at the economic, social, ethical and spiritual levels and that the technique of the chemistry laboratory can not be carried over directly into the field of sociology and ethics. Not so long ago, however, chemical and physical laws were also unknown. Certainly no scientist can take the position that anything will be impossible in the future in the way of understanding and in controlling our universe. Further and more important, I would maintain that the scientific method is the most effective approach we have in dealing with our problems of whatever sort and can be taken as a working hypothesis upon which we can base our activities. At least, until we find a better one it will go far in giving meaning to our universe in fields where otherwise chaos and confusion exist.

I hope that I am not being misunderstood. It is the farthest from my desire to advocate that the members of this society become less zealous in doing effective work in the science of horticultural research. Rather, it is to point out that we as scientists should realize more fully that in the scientific method we have an extraordinarily effective technique that can be brought to bear upon the problems outside the field of the physical and biological sciences. Further it is our opportunity and obligation to take some responsibility for the social and political order in which we work and which makes our work possible at all. With such a broad concept of responsibility the scientist would not abandon the scientific method when he closes the door of his laboratory each day, but would carry the same critical and dynamic approach with him wherever he goes.

In these troublous times when four fifths of the nation paused to hear President Roosevelt's statement of the crisis with which we are confronted, we as scientists are in a favored position to be of outstanding service. We, more than any other group, have the approach that will be most effective in meeting the problems raised by events as they come, provided, of course, that we realize at least some of the social implications of the scientific method.