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SCIENTIFIC METHOD AND SOCIAL RELATIONS[1]

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WITH rare exceptions, society owes a tremendous debt to science. The exceptions are concerned wholly with misapplications of the results of scientific discovery and not with the discoveries themselves.

The immediate task of the worker in pure science, and the term is used with full recognition of the fact that there is no sharp line of demarcation between pure and applied science, is the discovery of new principles, including very broadly in that term fundamental laws, atoms, molecules and their relations to one another and greater refinement of existing knowledge of those subjects. His concern is primarily with the advancement of knowledge *per se,* with satisfying his own curiosity regarding the nature of things, usually with no thought to the practical purposes to which his work may be applied nor to monetary consideration. The worker in applied science, on the other hand, finds himself concerned with application of known principles to the production of commodities which are to be marketed, consequently, also very broadly and with many exceptions his ultimate goal is profit either to himself or to his employer.

The chemist has been able to make a much greater contribution to the welfare of mankind than other scientific men, because his field is fundamental, dealing with matter in its endless variety. Although it is hardly necessary before a group of chemists to mention specifically many of the countless examples where the influence of the chemist is felt either directly or indirectly, some few may be cited in order to indicate the present relation of the chemist to society. These may be grouped broadly into two classes, the first including substances which are utilized directly by the body, such as foods, drugs, cosmetics, etc., and the

[1] Address as retiring chairman of the Chicago Section of The American Chemical Society, September 23, 1932.

second, things which affect the environment, such as structural materials, chemicals, materials used in the manufacture of articles for use or ornamentation, processes, etc.

Foremost in its effect on society would have to be placed the preparation of medicinals for the prevention and cure of disease, including the discovery and manufacture of specifics as well as the isolation or synthesis of glandular secretions. Human reactions are so closely bound up with glandular secretions that it is hardly an exaggeration to say that those reactions themselves may ultimately be resolved along chemical or physico-chemical lines. That, however, is a task for the biochemist of the future.

The chemist's contribution with respect to foods is not mentioned as of primary importance because a bounteous nature provides food for all forms of life without man's assistance. However, there is hardly a food to-day, either raw or prepared, which has not at some stage in its growth or preparation been subjected to some sort of treatment or process dependent upon chemical investigation. One need only mention fertilizers, fungicides, insecticides, preservatives, the analysis of foods for their dietary value, vitamins, etc., to realize the scope of that influence.

On cosmetics, including in that term all toilet articles as well, we need not dwell. They are not an unmixed blessing, although painted in brilliant colors.

With respect to raw materials, not only are natural products made available or improved by chemical treatment, but new ones are continuously being created by the chemist which are better than natural products or are designed for particular purposes which no natural products can fill.

Production costs are lowered by the application of chemical knowledge. In consequence, a vastly wider distribution is possible. Items which formerly were considered luxuries have now become necessities of life. Rarities have become common articles of commerce. Elements and chemicals heretofore unknown have become instruments for the alleviation of suffering or the prolongation of life. It is impossible to estimate what effect just the few generalities which have been mentioned have had on our economic status and habits of life. To mention only a few obvious facts: Hours of labor have decreased in practically one generation from an average of six full days of ten to fourteen hours each to five and a half days of eight hours, and promise to be still further reduced. Crushing human labor in field, factory and home has been relieved by machines. Mobility has greatly increased and intercommunication between nations has attained a facility undreamed of until very recent years. Infant mortality has decreased about one half. The average span of life has increased approximately ten years. To ascribe all this to the chemist is, perhaps, a bit too self-laudatory, but since chemistry is the fundamental science with respect to matter and its manifold transformations, it is entitled to the lion's share of credit, as it must also bear the brunt of responsibility when its findings are misused, particularly so when its disciples, chemists, lend their aid either actively or passively to such misuse. It may be objected that most of these benefits are properly due to development of arts or engineering rather than chemistry, but we can not get away from the fact that fundamentally both engineering and the arts owe their development to the application of chemistry in one form or another.

To a lesser extent our sister science, physics, must share in whatever glory there is, as well as criticism. But since physics has left the earth for parts unknown and many of our leading physicists have gone to the mourner's bench, perhaps it should be left out of consideration entirely where simple human affairs are concerned. Or perhaps chemists should be absolved from responsibility altogether, since the universe has been reduced by physicists to systems of physical waves or metaphysical thought, with a tendency to annihilate matter entirely. The philosopher's stone of the alchemist is still being sought, but under a different guise. The eternal quest for certainty has been resolved by Heisenberg and others into the certainty of uncertainty.

In their respective fields, the biologist, the bacteriologist and every other scientific man, as well as the chemist and physicist, is each making his contribution to the improvement of the condition of mankind. They are making it possible for men to live and enjoy life rather than to simply exist. Whether this condition is actually realized is beside the question. The possibility is there. If it is not realized, it is due to man's stupidity or to the scientific man's failure to follow up his work and see that proper use is made of it.

The day of brilliant individual achievement in scientific work is nearing its end, if indeed it has not already disappeared. The ultimate development of science as well as control of social forces must be sought in collective effort. This apparently is contradicted by the existence of an Einstein, now at the height of his career, but in reality Einstein himself is rather a proof than a denial of its validity. Without the prior work of Minkowski, Fitzgerald, Lorenz, Michelson, Morley and a host of others, there is little doubt that Einstein could not have developed his relativity theories. Einstein is a thinker, a theorist, a scientific philosopher, not an experimenter or laboratory worker. Previous experiments, particularly the failure of one, that of Michelson and Morley, to

detect any motion of the earth relative to the ether, were used by him as bases for his speculations, and in that sense the prior workers were collaborators of his in the development of his theories.

From the standpoint of original, unaided, individual effort the contributions of early scientific men, from Copernicus down to about the middle of the last century, were far more significant than those of later workers. There were more fundamental facts and theories to be disclosed and less prior work upon which to draw. Whitehead, in "Science and The Modern World," points out that Galileo's famous experiment of dropping bodies of different weight from the leaning tower of Pisa could have been performed at any time during the preceding five thousand years, whereas Michelson's interferometer ether drift experiment could not have been made earlier than it was. Neither scientific thought nor apparatus had been developed sufficiently to make even the conception of such an experiment possible.

In this respect the Raman effect is interesting. The scattering of light in a liquid, the illumination of all the water in a vessel, for example, when light strikes the surface, might have been observed at any time, without instruments. The frequency of the scattered radiation could have been measured after Kirchhoff and Bunsen developed the spectroscope about the middle of last century, but it remained for Raman to do this in 1928, when he discovered that it differed from the frequency of the original beam of monochromatic light. Had Bunsen or Kirchhoff made this observation it would merely have been an interesting scientific fact. When Raman announced it, it was literally pounced upon as of tremendous significance. It was soon discovered that the frequency of the secondary radiation was due to the nature of the molecules concerned in the scattering, that the difference in frequencies between definite lines in the scattered and incident light is the same as the frequency of vibrating atoms in the molecule. Consequently, Raman spectra are useful in determining molecular structure as well as for qualitative identification of compounds. The literature to-day is flooded with articles on Raman effect. Raman's discovery is significant only because developments in the conception of atomic and molecular structure in the last few years have made its interpretation and application possible.

Numerous other comparisons might be made, based primarily upon the thought that early experiments were controlled repetitions of common experiences as opposed to modern physical experiments, cosmic in scope or in the field of chemistry and molecular physics, sub-microscopic, wholly dependent upon accepted facts and applications of known methods. A modern paper, even on a comparatively simple item in any experimental science, is always accompanied by a long list of references to the literature, work which is accepted by the writer unless it is his intention to question the validity of the prior work, in which case it is repeated. This acceptance of verified scientific data is quite different from acceptance of social institutions or economic systems, which will be considered later. Obviously, there would be no advance in any science if every worker set out to repeat and confirm in detail for himself each fact upon which his particular work is based. It is difficult to conceive of an isolated fact being discovered to-day which is independent of previous experiments or thought.

There was a time when the store of human knowledge was so limited that it was possible for an exceptional individual to be an outstanding authority in many fields. Aristotle, philosopher, naturalist, biologist and scientific man within the limits possible for his time, set a standard for organization of knowledge which compares favorably with current practice, but development of experimental science was retarded for almost 2,000 years by acceptance of his work as finality until the historical revolt of the sixteenth and seventeenth centuries ushered in a new era. A greater figure, perhaps, was Leonardo da Vinci, one of the most brilliant geniuses of all history. His eminence as artist and sculptor during his lifetime was almost equaled by his fame as physician, architect, engineer and inventor. As scientific man and naturalist he was a pioneer antedating Bacon by a hundred years. However, his work, while basically sound, was almost wholly ineffective either in his own day or in influencing subsequent development because the world was not yet ready to proceed along the lines he mapped out, and he founded no "school" to carry out or keep alive his ideas. It is stated that he propounded a theory of tremendous age for the earth as evidenced by fossils, to the faculty of the University of Padua, which was received with respectful reservations as to his sanity.

Since then scientific knowledge has increased by leaps and bounds, until at present there is literally an avalanche of data continuously being ground out in every conceivable branch of science. It is no longer possible to consider the individual sciences as entities. Each has been divided and subdivided and each subdivision still further specialized with decided overlapping into other sciences. Minute fragments of knowledge a few years ago have been and are being expanded into separate branches of science, with these in turn undergoing similar development, each subdivision yielding a whole literature. A book in

three volumes, entitled "Chemical Embryology," was recently announced, consisting of 2,000 pages with 241 of bibliography, listing about 7,000 titles of references. Libraries are being written on atomic and molecular structure and even this highly specialized topic is so vast that it is necessary for a worker to confine himself to one small fraction of the subject if he expects to make any contribution at all. One is reminded of photographs of the heavens which are shown to impress one with the immensity of space. First a portion of the sky is shown as seen by the naked eye. A small square of that, apparently containing only a few stars, is viewed through a telescope and enlarged to the same size as the original picture, and that portion looms up with as many stars as the original. The process is repeated with more powerful telescopes and each time what appeared almost as blank space or nebulous matter is revealed as millions of suns, or other galaxies which await the making of larger telescopes for further resolution. The sciences are in quite the same category. There does not seem to be, at least at present, any limit to the possible development of any science within itself or in combination with other sciences. Advance in science as in invention proceeds in geometric ratio.

This extreme specialization, while highly necessary for progress, presents a serious problem. Few individual scientific men are capable of encompassing their entire special science. Masters in more than one are rarer. A Bertrand Russell is not produced in every generation. As astronomer, physicist and philosopher, his contribution to the science of human relations is proportionate to his mastery of these subjects.

The necessity for close application and extreme specialization has very serious drawbacks with respect to the coordination of the individual scientific man and society. To quote again from Whitehead in his discussion of the professionalizing of knowledge, "It produces minds in a groove. Each profession makes progress, but it is progress in its own groove." He adds: "The leading intellects lack balance. They see this set of circumstances, or that set; but not both sets together. The task of coordination is left to those who lack either the force or the character to succeed in some definite career. In short, the specialized functions of the community are performed better and more progressively, but the generalized direction lacks vision. The progressiveness in detail only adds to the danger produced by the feebleness of coordination." The specialist falls short of effectiveness outside his specialty, because of the circumscribed area in which he is compelled to operate. He is frequently not even concerned with the larger application of his work to the parent science, still less with its application to other sciences, and rarely, if at all, with its possible effect on humanity. Lemon wrote in "The Nature of the World and Man," "The physicist is not concerned with directly benefiting society which perhaps already is in possession of more Godlike powers than it can intelligently use." The million wild horses of Stuart Chase are as nothing compared with the dangerous potentialities of children of the brains of scientific men, abandoned at birth. The need for a coordinator is indicated, or paradoxically, a specialist in generalization. To an extent our pure philosophers and our physicist-philosophers occupy this position, but only in its more speculative aspects. The real need is here and now.

In our industrial research laboratories the problem is solved for particular ends. Research is planned for a definite object, improvement of a process, lowering of cost of production, or development of new products. Should research in "pure" science be required it is usually followed only so far as it has a bearing on the industry.

Recognition of benefits to be derived from directed research is evidenced by establishment in most countries of institutes, particularly for medical research, and many cooperative institutes of various industries designed for the solution of special problems common to all members of a particular industry. Not only are the advantages of directed research recognized, but it is becoming increasingly evident that many problems require cooperative effort of workers in many branches of science for their ultimate solution. The concluding paragraphs of the report on "The Future Independence and Progress of American Medicine in the Age of Chemistry," in the making of which Dr. Abel and Dr. Stieglitz collaborated with others, are most significant: "The problems of life and health, as safeguarded by medicine, are in their very nature so complex that rapid successful advance demands the *cooperative effort of scientists of the highest type,* each a leader in his field and deeply interested in the correlated fields of science, willing to submerge his talents and his effort in the common problem for the common good."

This is a logical extension of the scientific method to reach a definite goal by concerted effort. Individual effort has thus far failed to produce the desired result in the particular investigations being pursued. Eventually the result might be attained by slow stages through efforts of scattered workers throughout the world, but the probability is that cooperative research will be much quicker if the result is attainable; and who would have the temerity to-day to say that any end consistent with natural laws is not possible of attainment?

Science has no obvious or immediate social obligations similar to those incumbent upon medicine or law. Society expects and receives, to greater or less extent, from these professions something beyond their practice for personal profit. But up to the present society has made no such clear demands upon science, accepting its findings much as it does industrial achievements, with this profound difference—the successful business man is looked up to for advice and guidance in matters quite remote from business, while the scientific man, who by his training should be better qualified, is not consulted, even as to the social uses of the very creations of his particular ability.

There are certain fields in which even scientifically trained persons frequently consider themselves competent judges, notably politics, government, religion, economics and one phase of biology. Their opinions in these matters, excepting those of unbiased specialists, are little more than prejudices. It is no coincidence that the opinions expressed by such persons are usually the prevailing opinions, usually a defense of current institutions, an obeisance to the god of things as they are. J. B. S. Haldane recently said: "A large proportion of mankind, after a more or less human childhood, becomes almost unteachable. They are sure of everything. They know what is right in politics, religion, art and human behavior." Recognition of the part which preconceived notions, prejudices and habits of thought play in human relations would go a long way toward rectifying many of the ills of humanity. General acceptance of this fact by those in position to apply it practically would enable us to make a fresh start in attacking the problems of human relations, freed from the thraldom of custom. It is here that the scientific man can make his greatest contribution.

The scientific method has been variously defined. Perhaps the simplest statement would be that it consists in finding out, by observation, reference to the literature or actual experiment, all ascertainable facts pertaining to a given situation. An indispensable adjunct is the ability to properly interpret the facts after they have been found. Up to the present the method has had little application outside the laboratory. In the larger field of human relations the main reliance has been upon habit and custom, upon a child-like acceptance of the infallibility of methods of past generations, even though those methods were arrived at without scientific analysis of the facts, and, of course, without our present ability to ascertain the facts. It is a most curious inconsistency that the very scientific man who is credited with the basic responsibility for our present state of civilization, at least so far as creature comforts are concerned, should not be thought of by those in power for at least some slight contribution in the matter of social control.

There is much talk in this country now about the advisability of establishing an economic council along the lines of the board appointed during the war. A bill for the creation of such a council was presented in the Senate, which provided that the members shall be selected from organizations representing "the industrial, financial, agricultural, transportation and labor interests of the United States." Surely, on such a council, directly affecting the welfare of every individual in the country, scientific men could make a tremendous contribution. There is not one of these interests or any other interest that is not vitally affected by scientific endeavor, but is there any recognition of this fact? It apparently occurs to no one in authority that, aside from laying the foundation upon which our particular structure rests, the scientific man, by the application of the very method which has enabled him to subdue, or at least modify nature, ought to be able to point a method of approach for the better ordering of man's interrelationships. For, after all, that is the sole purpose in the creation of an economic council.

The scientific man must be largely blamed for this situation, for does he not, outside his laboratory and the productions thereof, himself forsake the scientific method? Thus in the social field we find him in the same category with those who are incapable of forming basically sound opinions. No better example of this can be cited than the deplorable record of scientific men in all the warring countries during the last war. Nothing was done outside their specialties which could have been distinguished from the actions of the most unlearned or unscientific, unless perhaps it was the greater vindictiveness of the scientific man. What more shameful spectacle was witnessed behind the battle-lines than the irrational hatreds exhibited by both individual and organized scientific men in all countries. There is no need to be specific. The shame is on all alike. Instead of being the leaders themselves, which their training should have made them, they permitted themselves to be led, or even driven like sheep, by intellectually inferior politicians and industrialists in every country. And the greater pity is that even now, when more sober judgments prevail, despite profound efforts at greater international understanding and agreement, we still find many scientific men actively opposing such efforts. The reason is easy to find. With respect to his social attitudes, the scientific man is no different than one without his training. In economics it is the same. In a word, in these matters he is no longer the scientific man. He becomes emotionally one of the mass with its prejudices and uncritical acceptance of prevailing ideas.

In the last analysis, the matter of social control is the most important task to which any discipline can dedicate itself. However, it is just at this point, when

the method of the scientific man is of such significance, that he apparently forgets his training, accepts without question prevailing opinions and becomes a tool in the hands of others for maintaining the status quo. Had this state of mind obtained with respect to purely scientific matters there certainly would have been no progress. With some exceptions, such as Priestley's opposition to the rejection of the phlogiston theory, or Berzelius' tenacious espousal of dualism, or the arguments against Young's wave theory of light, the scientific attitude is one of continuous inquiry and open-mindedness with respect to change. Newtonian mechanics, firmly intrenched for two hundred years, has been changed. By the accumulation of evidence extending over a half century, sufficient data were amassed so that Einstein in 1905 could definitely state wherein it was insufficient and so modify it as to make it conform to cosmic as well as earthly events. Promptly, a mad scramble was on to verify Einstein. To date this has resulted in his vindication, only to have Einstein himself deny the necessity for one of his earlier assumptions, this also as the result of further experiment. Bohr's atom displaced previous atomic models, was accepted, albeit with many reservations, played its part for a while, finally to yield to newer ideas. Whether or not we shall ever have a picture of the atom which is accepted by all who are competent to judge is at least doubtful in the current state of our knowledge. The point is simply that in scientific work there is no blind adherence to previous conclusions. There is an open-mindedness here, and a readiness to discard outworn vehicles, which oddly enough is not reflected even by the scientific man in human relations. New ideas, customs and even morals are accepted eventually, but these in their turn are clung to just as tenaciously as were the old. There is resistance to change which is thoroughly unscientific.

The kinetic theory of gases postulates molecular immobility at absolute zero. Carrying the idea over, one might say that the absolute zero in intellectual effort is immobility with respect to social institutions, a conviction that the present order is the best of all possible orders, any change in which must be resisted by every available means, even though that order has been distilled from a benighted past. Absurd as this appears in the light of present conditions, it nevertheless is the attitude of a sufficiently powerful number of persons in positions of leadership, either political or economic, to make the application of a scientific method of approach extremely difficult. And yet this is precisely the method of approach that must now be made. More subtle problems, if not more difficult, have to a greater or less extent been successfully attacked by the scientific method. The material is at hand. History, the record of past experiences, needs interpretation in the light of present knowledge. By slow changes, often imperceptible, change does occur —change is perhaps the most constant thing in life— and now, if ever, is the critical time of application of the scientific discipline. Of course, there must be healthy skepticism toward new ideas as well, subjecting such ideas to the same sort of rigorous investigation that characterizes always the scientific attitude.

A great deal has been written recently about the advisability of curtailing scientific effort, on the theory that a holiday in scientific discoveries and their application is desirable so that society can catch up—can overcome the lag between discoveries and their proper uses in the social scheme. Such a discussion is purely academic in this country at the present time. Scientific progress can not be halted nor is it desirable that it should be. The real need is for an extension of the scientific method into fields where it is not now applied, particularly in the fields of economics and human relations. And who should be better qualified to contribute to that extension than the scientific man himself? Usually proposals to alter the present order are met with the statement that you can not change human nature. To accept this is to dehumanize human nature and relegate it to the plane of instinctive behavior of animals and insects. Human nature is human simply because it can be changed. It is changed continuously from babyhood on, and in the past few decades particularly, scientific methods of control, physiological, psychological and the like, have profoundly modified individual behavior. However, our prejudices and inertia to change where social relations are concerned have not been given the same analysis and treatment. Economic "laws" are cited which must not be tampered with, as though these so-called laws were something fundamental in nature like physical laws, instead of being the result of conditions imposed by mankind. Such arguments are used with greater and greater vehemence to-day to prevent any change in a system which periodically blows up and has brought us to our present condition, the seriousness of which most probably has been increased by the fact that the major contribution of science to our economic order has been centered on materialistic advancement almost to the exclusion of directive control. Depressions have occurred at fairly regular intervals for the past hundred years or more. Consequently, it is assumed that it is an economic law in operation. No doubt it is an inevitable result of our system of economics, but wouldn't it be the course of reason to attempt to change that system so that these periodic upheavals would be impossible? Instead, we wait for something to happen—nobody knows what—and eventually prosperity must return,

how or why we do not know, when all the hardships and heartaches of the depression will be forgotten, the obvious lessons as well, only to go through precisely the same ordeal when the next collapse occurs. This is sheer stupidity. It is just as stupid as though the cylinder head of an engine were to blow off periodically, and each time it is put back exactly as it was before without attempting to find out the cause, whether more bolts were required or different material or a better method of combustion, or different fuel, or perhaps the whole engine needed redesigning.

The condition in which the world finds itself to-day requires more than the some sort of blind faith that has served in the past. Our industrialists have failed us; our bankers and banking system have proved woefully inadequate; our statesmen and politicians have failed utterly, if they have not indeed wilfully underestimated the magnitude of the disaster. In the face of one of the most serious economic breakdowns the world has ever known, prohibition is the greatest concern of our two major political parties. It would be amusing were it not so tragic. Even our profit system, that much-vaunted motivating force, the alleged life blood of the capitalistic system, has failed to prevent this calamity. No subtle operation of "economic laws" is going to evolve order out of the chaos in which we to-day find ourselves. Much less can we expect them to effect any modification in the underlying causes of our present condition. Whatever is done must be done by deliberate thinking and planning for a more rational, equitable and secure ordering of society. And to whom shall we look for guidance? Ordinary prudence would say most certainly not to the same sources, industrialists, capitalists or statesmen who have so clearly demonstrated their ineffectiveness. Neither can we expect our scientific men, acting as individuals, uncritically accepting the present order as finality, to be of much assistance. Nor is it very likely that a Moses or a Messiah will suddenly arise in our midst. It is rather a method than a superman that is required. As previously stated, that method is the scientific method, used with such remarkable success in the laboratory, which must somehow be applied to economics, government, international relations and human affairs in general. And it is to our leading scientific men in all branches, including the social sciences, working cooperatively, that we must look for the application of that method.

To summarize briefly the points which I have attempted to make:

(1) The extreme specialization required in order to make any contribution to a particular science has resulted in a lack of coordination between scientific discoveries and their social uses.

(2) The accumulation of scientific information is so vast that it is impossible for a single individual to encompass any one science *in toto*.

(3) Reliance upon the findings of prior workers in a particular field is essential to progress. Even the work of an Einstein can not be considered individualistic, since it rests upon the discoveries of many past or contemporaneous scientists.

(4) It is recognized in some fields, particularly in medical research and in certain industries, that many problems require the cooperative effort of workers in several branches of science for their ultimate solution.

(5) The scientific method which has resulted in such strides in all branches of science and which promises so much more when used cooperatively, should be applied to human relations, national and international.

(6) In our present social order, the greatest progress has been made in materialistic development through technological applications of scientific data, but in human relations there has not been the slightest employment of the scientific method. Instead there has been stubborn resistance to change which is thoroughly unscientific.

(7) The scientific man, best fitted by training and experience, should lead the way in the extension of the scientific method to human relations and help direct the cooperative effort for the solution of the problems involved. Preconceived ideas and prejudices must be discarded. Human relations must be studied in the same manner as physical problems. Open-mindedness must prevail. In the light of the findings, a better order of living than obtains to-day will result.

THE AGE OF METEOR CRATER

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THE noted astronomer, Arrhenius, is said to have declared that Meteor Crater is the most interesting spot on earth. Although others may not concur in that opinion, it is certainly a fact that Meteor Crater[1] has aroused the wonder and interest of the many who have visited it, and has already called forth more than thirty-five papers describing its peculiarities and explaining its origin. Having spent a few days examining the crater in the spring of 1930, I venture

[1] Situated on the plateau of northern Arizona, about 20 miles west of Winslow. Also called Coon Butte.