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SCIENCE AND THE STATE OF MIND[1]

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YOUR president's invitation to address the American Science Teachers Association both flattered and intimidated me. An economist who has any inkling of what mathematics, astronomy, physics, chemistry and biology in its numerous branches have accomplished is grateful when representatives of these shining disciplines admit him to their company. But he feels that in their company his proper role is that of listener, not of speaker. Your techniques are far more advanced than his, your results are more securely established, you have and you merit higher prestige both in intellectual circles and with the general public. From you an economist should be able to learn much; whether he can make any return in kind is doubtful.

Yet there is a way of conceiving science that rationalizes, and perhaps justifies, both your invitation to speak and my acceptance. Despite the bewildering specialization of scientific inquiries, it is permissible to think of science as a unit. A physicist may not understand the technical papers of a physiologist, and *vice versa;* but the two workers approach their problems in the same spirit. Both workers seek to unite accurate observation of phenomena with systematic analysis of relations; neither expects that his results will be accepted unless they are confirmed by competent investigators who repeat his experiments and check his reasoning; each realizes that what he observes and what he thinks is influenced by a personal equation, but each tries to keep this factor from warping his conclusions more than is inevitable.

In short, we cherish the ideal that all scientific men are single-minded in their search for truth. We expect them to avoid wishful thinking; that is, they must not alter their findings to suit the non-scientific beliefs or longings or dislikes of others or themselves. All of them are supposedly ready to expose

[1] Address given at the luncheon of the American Science Teachers Association, Richmond, Virginia, December 29.

their results to criticisms by their fellows. We admit that it is difficult to live up to this ideal. Probably all of us are conscious of lapses in ourselves from strict scientific integrity, and suspect lapses in others. But we hold to our ideal as the state of mind that is characteristic of scientific work, whether that work is in mathematics or botany, geology or anthropology, chemistry or economics.

Men can treat any subject that excites their curiosity in this single-minded, critical, austere spirit. But some subjects are far easier than others to treat scientifically. These relatively easy subjects were the first ones to be brought within the realm of science, and they are the subjects in which science has made the greatest progress. Euclidean geometry and mechanics may serve as examples. The subjects that are harder to treat single-mindedly, critically and austerely were long dominated by non-scientific types of thinking—by worldly wisdom that scorned theory, by soaring speculation that was impatient of observation, by inner illumination that forbade skepticism. But the cumulative successes won by the scientific spirit in dealing with the easier subjects have embodied men in successive generations to extend the realm of scientific inquiry far beyond its early strongholds. While the older sciences were growing in reach and power, younger sciences were being born and passing through the diseases of infancy. It is as characteristic of the scientific spirit to beget new children as to lavish ever greater care upon the nurture of its elder offspring.

Economics is no longer the youngest child of science, but it is still an infant. Perhaps a century is an appropriate unit in which to reckon the age of a science. In that reckoning economics is barely two, whereas some of the sciences represented here claim to be more than two hundred—they have lost their birth certificates and don't know exactly how old they are. I hasten to add that in so long-lived a family two hundred represents, not decrepitude, but lusty youth.

Of course the very young sciences don't know how to behave as well as their elders. They have to crawl before they can walk, to walk before they can run. They make incoherent noises before they learn to talk intelligently: while they are learning to talk they use a limited vocabulary borrowed from others and not well adapted to their own needs. They are often obstreperous. Their more mature brothers and sisters feel at times like disowning them. But they are legitimate offspring of the same spirit that begot astronomy and mathematics, and if they are true to their begetter they will gradually acquire competence and grace. Yet the road before them is hard; for they are young precisely because the subjects with which they deal present graver difficulties than those with which the elder sciences deal.

We should not forget, however, that the more mature sciences had hard times in their younger ages. They encountered both inner and outer obstacles that they had to surmount by long-continued efforts. Let me recur to the examples of geometry and mechanics. We all know how the later Greek geometers got bemused by hazy speculations concerning the mystical significance of their constructions, and how Galileo's deductions got him persecuted by the church. I take the first to be an example of the inner, and the second to be an example of the outer, difficulties that science encounters in its search for truth—difficulties that assume ever-changing forms as this search is pressed into new territory.

It was pointed out long ago by a great psychologist that we can see the motes in our neighbors' eyes more easily than we can see the beams in our own eyes. Let us take easy things first, and consider some of the external difficulties that laymen put in the way of scientific work to-day.

I might take as an example of external obstacles to scientific work interference with the teaching of biology by those who think their religious beliefs are endangered by what they conceive to be the "doctrine of evolution." But that is too familiar and too obvious an issue to belabor. Nor need I dwell upon the efforts of the present masters of Germany to make science subservient to nationalistic ends. We all look forward to the day when German investigators can rejoin the international army of research workers, and assert again the right to freedom of inquiry and freedom of teaching their predecessors did so much to win for the world. It is better worth while to consider issues on which our minds are not so clear.

In all our schools children are taught American history. Now history may not claim to be a science, but a historian may have a scientific frame of mind. He may be single-minded in his effort to find out what "really happened"; he may be critical in his use of sources; he may strive to avoid wishful thinking. But if some of his conclusions run counter to the patriotic feelings of the parents of school children, he may find his intellectual virtues charged against him as faults. Some people who are ready to admit their own shortcomings feel shocked if their national heroes are represented as fallible. Many who are critical of current developments in our national life like to think of our national past as a record of stern virtues. If they admit that our country has at times gone wrong, they may still hold that patriotism should be inculcated in the rising generation, and that the safest road to that end is to soft-pedal unhappy errors and to stress what they approve. But a man who twists the truth, even for the best of ends, is doing violence to the scientific spirit. Teachers of science have so great a stake in

free inquiry that they should stand shoulder to shoulder with any of their colleagues who may be attacked because their findings are unpalatable to school authorities, to the general public or to special interests.

Similar issues sometimes become acute in teaching children about the way in which our governments, local, state and national, are organized and how they work. The instructor often finds it safer to confine himself to the pretty arrangements of municipal charters and county governments, the state and the federal constitutions. But teaching thus confined is poor preparation for performing the duties of a citizen. The future voter needs to know how aldermen and mayors, members of the legislature, county officials, congressmen and presidents are really chosen, the pressures under which they act and the arts by which political campaigns are conducted. Every alert adult knows that political practice often differs widely from political theory, but many prefer that children be brought up on what ought to be rather than upon what is. No scientifically minded man would advocate courses in muckraking; they would be as one-sided as political platitudes. There is always the possibility that some ardent reformer will try to make his classroom a center of propaganda, and claim to be suffering for righteousness' sake when he is discharged for incompetence or intellectual intemperance. The individual cases that crop up in this connection are often difficult to judge; for political science is one of the youngest children of the scientific spirit, and has as yet accumulated few assured findings. But those who have the will to stand for intellectual honesty can at least tell whether a man under attack has a scientific temper, the ability to observe objectively and to think dispassionately.

It may be agreeable to us as science teachers to dwell only upon obstacles that are put by others in the way of our work. But that would be treachery on our part to the scientific spirit. Our own professions require that we face also the inner obstacles that are raised by our own faults, intellectual and emotional. My impression is that these obstacles within us are more difficult to overcome than the obstacles without. Since the subject is a delicate one, I shall take my own discipline as the first and, you may think, the worst example.

Economics deals with the behavior of men in making a living. In modern times, most men get most of their livings by making and spending money incomes. This is an activity in which practically all adults have to engage, economists among the number. Both in making money and in spending money we have to defend our individual interests against people who would like to pay us less and charge us more than we like. There is a conflict of interests in almost every transaction in which we engage. As individuals we can often do little to defend ourselves against what we deem exploitation, or to exploit others—a term that we seldom apply to our own actions—others may save us the trouble. So we unite with people in positions like our own to form trade unions, trade associations, bondholders' committees, tax-payers' leagues, and the like, and we make the interests of these groups our own.

Thus economists can not be disinterested observers of economic behavior; they are participants in economic struggles. It is therefore far harder for an economist to be a single-minded, critical austere investigator than it is for a man who studies the behavior of gases or electrons or sea-urchins. Even if a man can set aside his individual interests, and there have been economists who have worked hard for policies that would cost them heavily, he can hardly divest himself of the preconceptions and emotional attitudes formed in him before he knew what economics is. Consciously or unconsciously, and the latter is the more insidious bias, he feels an urge for or against certain views. Much of orthodox economic theory is an open or a covert defence of private property and free enterprise in pursuit of profit. Perhaps there is as large a literature that attacks this form of organization under the guise of what purports to be scientific analysis.

Paraphrasing a passage in the presidential address that Edwin G. Conklin delivered before the American Association last year, let me say that science is concerned to show only what is true and what is false. By so doing it is of inestimable value in helping men to decide what is good for them and what is bad. But science itself does not pronounce practical or esthetic or moral judgments. The investigator who tries to persuade men that they should choose one course of action rather than another may be drawing sensible conclusions from his scientific findings, but he is certainly not doing scientific work when he does so. The investigator who consciously or unconsciously allows his preferences to shape or color his scientific findings is offending the scientific spirit. He may make contributions to our knowledge of what is true and what is false in the course of his analysis; but that will be a fortunate accident. Perhaps some attacks upon and defences of forms of economic organization are meritorious performances from other view-points; but they are not scientific, and whatever analysis of economic processes is incidental to them must be suspect. For the man who has a cause at heart, however fine that cause may be, is likely to prove a biased observer and a sophisticated reasoner. Economists find it peculiarly difficult to preserve a scientific frame of mind just because they deal with issues about which they and their fellows feel intensely.

Not to leave the impression that economists alone face inner obstacles when they try to do scientific work, let me recall a few derangements from which most of us suffer in some degree. We have our personal likes and dislikes that make it hard for us to assess impartially the scientific contributions of our fellow workers. Often these emotional aberrations take the still more irrational form of living or disliking large groups of people whom we don't know but about whom we imagine things. Who among us maintains a strictly scientific attitude toward what is called the race issue, either in the form that is acute in Germany or in the form that is acute in the United States? To be more offensively personal, is there any one so free from vanity that he can be strictly scientific about critical appraisals of his own work? And on a higher level, are not most of us conscious of an unreasoned predilection for certain types of scientific inquiry balanced by an equally unreasoned tendency to depreciate the value of other types?

I should hesitate to talk in this vein to any company not composed of scientific investigators. Just because other groups would probably have more biases per gram of gray matter than can be found in this room at present, it would be futile to dwell upon their intellectual limitations. Little but annoyance could result. But we who profess to follow the scientific ideal can face even our own deficiencies and lapses from grace in a scientific spirit. And the firmer our scientific temperaments, the readier we are to overcome so far as human nature allows the inner obstacles to scientific work.

We have, indeed, a high calling, and much depends upon how we acquit ourselves. Progress in human well-being is conditioned by progress in discovery in both the natural and the social sciences. Scientific discoveries are made by gifted individuals; but these individuals have to be conditioned for their work, and this conditioning is a social process. Even more patently, the application of scientific discoveries to human uses, good or bad, is work in which thousands share. Many citizens of the future have their most vivifying contacts with science through us. We do not expect to make many of them scientific lights, but we do expect to give most of them some impression not only of what science has accomplished but also of the spirit in which scientific men work, thus to influence their future attitudes toward science, and to promote the social processes that favor scientific discoveries and their applications. The most effective way to exercise this influence upon others is to cultivate the scientific spirit in ourselves.

SCIENTIFIC EVENTS

THE NEW GEOLOGICAL GLOBE AT THE SOUTH KENSINGTON GEOLOGICAL MUSEUM

IT is reported in the London *Times* that a geological globe, 5 feet 11 inches in diameter and electrically rotated at the rate of one revolution in 2½ minutes, was formally set in operation at the Geological Museum, South Kensington, on October 10, by Sir Frank Smith, secretary of the Department of Scientific and Industrial Research. This globe, which is believed to be the largest yet prepared to show both surface relief and the distribution of geological formations, was modelled by C. d'O. Pilkington Jackson and was colored by the museum staff, the painting being carried out by Mr. C. Keefe under the direction of Mr. A. J. Butler.

The scale adopted is approximately 1 in 7,000,000, or one inch to 112 miles. Mountain heights are exaggerated 20 times, and one of the most striking impressions which the new globe creates, according to the *Times,* is that of the comparative insignificance of even the loftiest mountains, for in spite of this exaggeration the summit of Everest projects scarcely more than an inch above sea-level. The globe rotates on its polar axis nearly 600 times as fast as does the earth, but the actual speed of a point on the surface of the earth is about 12,000 times that of the corresponding point on the model.

The various rocks of the earth's surface are shown by a graded series of colors, ranging from deep purple for the oldest rocks, formed perhaps 1,000,000,000 years ago, through shades of blue, green and yellow to a flesh-pink for the large areas covered by deposits laid down during and since the Ice Age. The igneous rocks are colored scarlet and orange. Ice-caps, rivers and lakes are also marked.

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