When a physicist talks like this, he is often told by friends with a philosophic turn of mind that physicists have found nothing new. I can not accept this. I am sure that when the first circumnavigators of the world returned from their voyage they were told by friends that some Greek philosopher, who lived in ? B. C. had held that the world was round and that they might have spared their trouble. The world is either round or flat, and endless discussion might have been carried on for ages between opposing schools who held the one view or the other. The real contribution to settling the problem was made by the circumnavigators. The achievement in physics which I have tried to outline is like a circumnavigation of the physical world. There will be no end to further exploration, but we realize for the first time certain bounds within which it must take place, just as we now know that geographical exploration must take place over the surface of a globe and not upon an infinite plane.

To summarize, let me try to explain by an analogy the position in which we find ourselves as students of the mechanism of nature. You know those large glass-paned floors which often form the pavement of an upper room or of the street, which are such that any one in a lower room can look upwards and see the footsteps of people passing above. Let us suppose a physicist placed in such a lower room, and that his sole means of observing what was going on above was by observation of the feet of the passers by, and of anything else in contact with this glass floor. He could learn a great deal and would be able to formulate laws. He would observe that footsteps did not suddenly disappear into space—the indestructibility of matter. He would observe that the footsteps always passed around objects and not through them—the impenetrability of matter. Starting in one direction they on the average pursue the same direction, though fluctuations from the average are evident. Sometimes a foot slips; such a phenomenon is generally followed by violent movements of the feet and their disappearance altogether, followed by the appearance in their place of an object of roundish outline—a kind of radio-active transformation. The laws governing a crowd of footsteps all moving in one direction would be more exact than those applying to a single individual. Yet he could never predict exactly what they would do.

We may make our analogy a closer one by supposing that we can only tell where the footsteps are, not by looking at them, but by reaching up and tweaking their toes. A light tweak has little effect on their movements, but leaves us uncertain of their exact position. A heavy pinch tells us exactly where they are, but causes them to swerve from their course in an erratic way which we can not predict. To see where they have got to, we must pinch again, and this introduces a new element of uncertainty into the future, though it tells us what has happened in the past. The physicist might be tempted to say that an element of blind chance enters into the behavior of all he observes, upsetting his precise calculations. We know that he would be wrong. The objects above exist in a third dimension of which he is unaware.

Is not this precisely our position as regards the physical world? The same element of uncertainty enters into all our physical calculations, and does so not because our instruments are imperfect, but because of the very nature of physical laws. We must think of the physical world around us as the footprints of something which exists in other dimensions as well, which has other qualities which are not physical and which no physical apparatus, however delicate, can measure.

It seems to me that this is the contribution which recent developments of the physical sciences makes to human knowledge. Nothing can exceed our instinctive horror of the finite, our revulsion at the idea of being entrapped in a mechanical web. Science now suggests the way of escape from a dilemma, for which its own logical pursuit has been largely responsible.

THE SUPREME INTELLECTUAL OBLIGATION[1]

By Professor JOHN DEWEY

THE scientific worker faces a dilemma. The nature of his calling necessitates a very considerable remoteness from immediate social activities and interests. His vocation is absorbing in its demands upon time, energy and thought. As men were told to enter their closets to pray, so the scientific man has to enter the seclusion of the laboratory, museum and study. He has, as it is, more than enough distractions to contend with, especially if, as so often happens, he is also a teacher and has administrative and committee duties. Moreover, the field of knowledge can not be attacked *en masse*. It must be broken up into problems, and, as a rule, detailed aspects and phases of these problems must be discriminated into still lesser elements. A certain degree of specialization is a necessity of

[1] The undersigned served as a committee to make the plans for a dinner held in the honor of Dr. J. McKeen Cattell, at the University Club, Boston, Wednesday evening, December 27, 1933. At that time an address was given by Dr. John Dewey. The committee has requested SCIENCE to publish Dr. Dewey's address.

OTIS W. CALDWELL
BURTON E. LIVINGSTON
HENRY B. WARD

scientific advance. With every increase of specialization, remoteness from common and public affairs also increases. Division of labor is as much a necessity of investigation into the secrets of nature and of man as it is of industry.

Nor does aloofness reach an end in this point. The language in use for common communication does not fit the needs of statement of scientific inquiries and results. It was developed for other purposes than that of accurate and precise exposition of science, and is totally unfitted to set forth comprehensive generalizations in exact form. The result is that the scientist speaks what for the mass of men is an unknown tongue, one that requires much more training to acquire than any living speech or than any dead language. He can speak directly about his own affairs and problems only to a comparatively small circle of the initiated.

These considerations define one horn of the dilemma. The other horn is constituted by the fact that the scientist lives in the same world with others, and a world that is being made over by the fruits of his labors. There is hardly a single detail of our common and collective life, whether in transportation of persons and goods, in modes of communication, in household appliances and conveniences, in medicine, in agriculture and all the varied forms of productive industry, that is not what it is to-day because of what science has discovered. The scientist may be aloof in his work and language, but the results of his work pervade and permeate, they determine, every aspect of social life. The inventor, the engineer and the business man are unremittingly occupied with translating what is discovered in the laboratory into applications of utensil, device, tool and machine, which have largely revolutionized the conduct of life in the home, the farm and amusement as well as industry. I could easily spend many times my allotted time in a partial cataloging of things unknown fifty years ago that are now everyday necessities.

These consequences of science extend their influence far beyond what anthropologists call material culture. They affect institutions and great modes of interest and activity. We have broken with the intellectual traditions of the past and the mass of men have not had the nature of the change interpreted to them, although science set the terms on which men associate together. They transform life in ways that have created social problems of such vastness and complexity that the human mind stands bewildered. The intellect is at present subdued by the results of its own intellectual victories. It has become a commonplace to refer to consequences of chemistry in its application to warfare. High explosives, with their allies of steel and airplane derived from physics, are capable of destroying every city on the face of the earth, and we are even threatened with bacterial warfare. If the problems of peace and war have assumed a new and unprecedented form—which, alas, the nations are meeting for the most part only by increased expenditures for armament—it is because of applications of scientific knowledge.

I have selected but one aspect of the question. The economic problem which weighs so heavily upon us to-day affords another illustration of the new social impact of science. Here too it is a commonplace that mankind in advanced industrial countries and especially in the United States confronts the paradox of want in the midst of plenty. It is science which, through technological applications, has produced the potentiality of plenty, of ease and security, for all, while lagging legal and political institutions, unaffected as yet by the advance of science into their domain, explain the want, insecurity and suffering that are the other term of the paradox.

My title is the supreme intellectual obligation. But every obligation is moral, and in its ultimate consequences social. The demands of the situation can not be met, as some reactionaries urge, by going backward in science, by putting restrictions upon its productive activities. They can not be met by putting a gloss of humanistic culture over the brute realities of the situation. They can be met only by human activity exercised in humane directions. The wounds made by applications of science can be healed only by a further extension of applications of knowledge and intelligence; like the purpose of all modern healing the application must be preventive as well as curative. This is the supreme obligation of intellectual activity at the present time. The moral consequences of science in life impose a corresponding responsibility.

As with almost everything in contemporary life, it is easier to diagnose the ill than to indicate the remedy. But there are some suggestions that occur to all who reflect upon the problem. The field of education is immense and it has hardly been touched by the application of science. There are, indeed, courses in science installed in high schools and colleges. That much of the educational battle has been won, and we owe a great debt to those who waged the battle against the obstacles of tradition and the inertia of institutional habit. But the scientific attitude, the will to use scientific method and the equipment necessary to put the will into effect, is still, speaking for the mass of people, inchoate and unformed. The obligations incumbent upon science can not be met until its representatives cease to be contented with having a multiplicity of courses in various sciences represented in the schools, and devote even more energy than was spent in getting a place for science in the curriculum, to seeing to it that the sciences which are taught are themselves more concerned about creating a certain mental attitude than they are about purveying a fixed body of information or about preparing a small number of persons for the further specialized pursuit of some particular science.

I do not mean of course that every opportunity should not be afforded the comparatively small number of selected minds that have both taste and capacity for advanced work in a chosen field of science. But I do mean that the responsibility of science can not be fulfilled by educational methods that are chiefly concerned with the self-perpetuation of specialized science to the neglect of influencing the much larger number to adopt into the very make-up of their minds those attitudes of open-mindedness, intellectual integrity, observation and interest in testing their opinions and beliefs that are characteristic of the scientific attitude.

The problem is of course much broader than the remaking of courses in science, which is nevertheless requisite. Every course in every subject should have as its chief end the cultivation of these attitudes of mind. As long as acquisition of items of information, whether they be particular facts or broad generalizations, is the chief concern of instruction, the appropriation of method into the working constitution of personality will continue to come off a bad second. Information is necessary, yes, more than is now usually obtained. But it should not stand as an end in itself. It should be an integral part of the operations of learning that construct the scientific attitude; that are, indeed, a part of that attitude, since the scientific inquirer is above all a continuing and persistent learner. As long as intellectual docility is the chief aim, as long as it is esteemed more important for the young to acquire correct beliefs than to be alert about the methods by which beliefs are formed, the influence of science will be confined to those departments in which it has won its victories in the past. I can not refrain from saying that one great obstacle is that many scientific men still hold, implicitly if not expressly, that there is a region of beliefs, social, religious and political, which is reserved for sheer acceptance and where unbiased inquiry should not intrude.

There is, moreover, a virgin field practically untouched by the influence of science. Elementary education is still a place for acquiring skills and passively absorbing facts. It is generally now admitted that the most fundamental attitudes are formed in childhood, many of them in the early years. The greatest indictment that can be brought against present civilization, in its intellectual phase, is that so little attention is given to instilling, as a part of organic habit, trust in intelligence and eager interest in its active manifestation. I take little interest in demonstrations of the average low level of native intelligence as long as I am aware how little is done to secure full operation of what native intellectual capacity there is, however limited it may be. Speaking generally, it is now everywhere subordinated to acquisition of special skills and the retention of more or less irrelevant masses of facts and principles—irrelevant, that is, to the formation of the inquiring mind that explores and tests. Yet childhood is the time of the most active curiosity and highest interest in continual experimentation. The chief responsibility for the attainment of a system of education in which the groundwork of a habit and attitude inspired and directed by something akin to the method of science lies with those who already enjoy the benefits of special scientific training.

I have spoken chiefly with respect to the education of the schools. But the problem and the responsibility of education go deeper. There are some signs of a rebirth of the educational interest that marked the Greeks who thought of it, as far as we can gather from the records, chiefly in terms of adults. The theme of adult education is in the air. There was never a time in the history of the world in which power to think with respect to conduct of social life and the remaking of traditional institutions is as important as it is to-day in our own country. There is an immense amount of knowledge available, knowledge economic, historical, psychological, as well as physical. The chief obstacle lies not in lack of the information that might be brought to bear, experimentally, upon our problems. It lies on the one hand in the fact that this knowledge is laid away in cold storage for safe-keeping, and on the other hand in the fact that the public is not yet habituated to desire the knowledge nor even to belief in the necessity for it. Hunger is lacking, and the material with which to feed it is not accessible. Yet appetite grows with eating. The trouble with much of what is called popularization of knowledge is that it is content with diffusion of information, in diluted form, merely as information. It needs to be organized and presented in its bearing upon action. Here is a most significant phase of the obligation incumbent upon the scientifically trained men and women of our age. When there is the same energy displayed in applying knowledge to large human problems as there is to-day in applying it to physical inventions and to industry and commerce many of our present problems will be well on their way to solution.

I can not close without reference to the pertinence of the theme discussed, however inadequate its mode of presentation, to the honored guest of the evening. James McKeen Cattell is himself an active scientific worker, one who has initiated in his own field of psychology many movements that have borne rich fruit. But he has found time, thought and energy to devote to the larger questions of the bearing of science upon life. He has given himself without stint to the better organization of scientific workers in all fields; he has striven valiantly for moral and financial improvement of the condition of academic workers; he has been the leader to the task of editing and diffusing the achievements of scientific inquiry. I do not need to press home the moral in connection with the intellectual obligation of which I have spoken. Laboring of the point is unnecessary as long as we have Cattell with us. He is a living example of the ways in which a scientific man can perform the supreme intellectual duty and as such we gladly greet and honor him this evening.

SCIENTIFIC EVENTS

RESEARCH IN THE BRITISH POST OFFICE[1]

WHEN the state purchased the telegraphs in Great Britain in 1869, the number of electrical workers in the whole country could almost be counted on the fingers. To-day the engineer-in-chief of the Post Office controls a staff of about 30,000 and maintains plant of a value of 130 million pounds. Starting from the needle instruments, skilled Post Office experimentalists developed the Wheatstone transmitter and receiver; instruments capable of operating up to 300 words per minute.

Captain B. S. Cohen, the engineer of the Post Office Research Station at Dollis Hill, in a paper read to the Institution of Electrical Engineers on February 1, said that these instruments still stand unsurpassed today in their design, workmanship and performance. It was not until 1912 that a research section was established. During the war period, the thermionic valve was perfected and at one stroke opened a boundless vista of possibilities in the way of universal telephone communication. The paramount necessity was to obtain the closest coordination between the research and the operating organizations. Without full access for research purposes to the working telegraph and telephone plant, the work of the research engineers would have been immensely increased. The Research Station at Dollis Hill was started in 1921 by using ex-army huts, and the permanent buildings were completed last year. Much excellent work has been done at this station which could not have been done elsewhere.

To the research workers at Dollis Hill the increase in the volume and weight of road traffic brought with it a new problem. There are apparently under the streets an ever-increasing number of cracked gas mains. Modern road surfaces make it difficult for this gas to escape into the open and so it sometimes accumulates in Post Office cable ducts and manholes, involving a serious hazard. The research engineers have developed a simple form of gas detector for general issue to Post Office workmen. The detector operates in a way somewhat similar to a photographic exposure meter. It utilizes a filter paper moistened with a few drops of palladium chloride solution and will indicate the presence of 0.05 per cent. of carbon monoxide, the dangerous constituent of coal gas.

The capital value of automatic switching apparatus installed in exchanges is now very large, and great precautions against corrosion have to be taken. Sir Robert Hadfield has said that the corrosion of iron and steel alone costs the world 700 million pounds per annum. Experiment shows that the life of galvanized iron stay wire is proportional to the thickness of the galvanizing. In some parts of south Lancashire, the normal life of a stay wire is little more than two years. It is now possible to estimate the life of any particular grade of wire in a given area.

In long telephone lines the "echo" used to be very troublesome but the engineers have invented, using valves only, a very efficient echo-suppressor. A non-reflecting room at the station has linings of cotton-wool one foot thick. This room has a totally silent background of noise. It is especially useful for listening tests where the threshold of hearing has to be found.

[1] *Nature*.

THE LEVERHULME RESEARCH FELLOWSHIPS IN GREAT BRITAIN

THE Advisory Committee of the Leverhulme Research Fellowships invite applications for 1934. These fellowships will be awarded to citizens resident in the United Kingdom for the assistance of experienced workers rather than to add to the provision already existing for workers in the early stages of their careers. The trustees have in mind particularly men and women who are prevented either by pressure of routine duties or by any other cause from undertaking or completing an investigation of value. No definite limit will be placed on the amount of individual grants, but they will be adjusted according to the circumstances of each particular case. Fellows will usually be required to work at or in connection with a recognized