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THE ORGANIZATION, DIRECTION AND SUPPORT OF RESEARCH IN THE PHYSICAL SCIENCES[1]

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The Organization of Research

The American nation is in process of assuming, through the power of her military, naval and air forces, and the technological organization requisite to that power, a position of major responsibility for peace and civilization in the post-war era. Adequately to meet the commitments which such a responsibility entails, the United States will, of necessity, be forced to enlarge both political and social horizons and at the same time to develop, to a degree hitherto unrealized, the scientific bases which that enhanced influence in the counsels of the world will, in large measure, require.

The progress of science and the technological changes that have resulted therefrom have proceeded with auto-accelerating pace over the last thirty years. Some concept of what the coming decades may hold can be learned from the history of this country during World War I and the interwar years with respect to scientific achievement, and the pattern there revealed will be a miniature of what must inevitably follow from the revolutionary changes in technology that the present war has produced. In 1914 American science looked to Europe for leadership. As Dr. C. M. Stine noted in an address to American chemists one year ago:

> It was a simple, almost a scientifically primitive economy in which we Americans then lived. On all the seven seas, America-bound ships heavy with goods and raw materials testified to our dependency on foreign lands. The homes in which we lived differed little from those of our great-grandfathers; the tailors of the Caesars knew the textiles of which we made our clothes; the finishes of our

[1] Read on November 19, 1943, in the Symposium on the Organization, Direction and Support of Research of the American Philosophical Society.

1914-model horseless carriages dated to ancient Egypt and the building of the Pyramids. All steel rusted. The best rubber tires were worn out after about 3,000 miles of highly uncertain road service.

One shudders at what might be our plight if those were the tires of to-day, or if by some colossal blunder we had failed to establish an organic chemical industry in the United States as a consequence of that other war's bitter lessons.

Thank God, we did establish a chemical industry!

We did more than that. We established a nation-wide common consciousness of the power of science in every branch of American industry. Steel, textiles, transportation, foods, oil, in fact every basic producer, came to the turn in the lane where all signposts of progress pointed in one direction—to the research laboratory. We did not get there all at once, but most of us got there long before German hob-nailed boots were pounding over the streets of Warsaw.

Expenditures for industrial research in the United States rose from an inconsequential sum yearly in the pre-World-War-I period, to an amount estimated at $300,000,000 yearly in the pre-World-War-II period. The number of research laboratories grew to more than 2,000. Huge sums were spent in expanding technical and scientific schools to meet the demands of our awakened youth. The number of doctorates granted in chemistry alone was multiplied by 20 or 30 times.

Similar if less immediate changes occurred in the science and technology of physics with advances in communications and transport, based upon electronics and aerodynamics, reaching a tremendous pace of growth only within the last few years. Mathematics, pure and applied, shared in the effort and took its part in the scientific and technical educational task that was required. Immediately after World War I, when the impact of war had revealed the necessity for expanded training in science, the Rockefeller Foundation initiated through the National Research Council in Washington a series of post-doctorate national research fellowships in astronomy, mathematics, physics and chemistry. These fellowships aimed initially at the building up of a scientific personnel from which the required enlarged body of college and university science professors could be drawn. The record shows abundantly how this was in large measure accomplished, and in our present stress we can see how farsighted the policy was and how much to-day we lean for leaders upon the men so trained.

Industry also found that the available number of graduate students was inadequate to the demands of rapidly expanding programs of industrial research and itself took a hand in stimulating the supply. The E. I. du Pont de Nemours Company initiated such a venture early in 1922. To a selected group of universities with good reputations in chemistry, the company offered to the department of chemistry a fellowship at the graduate student level without any restrictions as to choice of fellow, nature of the research work pursued or ultimate ambition of the student selected. The aim was frankly to increase the number of students pursuing work for the doctorate in chemistry. The philosophy behind the fellowships was that, ultimately, an increase in the number and quality of graduate students in chemistry would mean an improved research personnel in their own laboratories. The example of the du Pont Company has been widely imitated by other chemical organizations. In physics, the policy has been notably less evident, but the current demand for research men in physics suggests that a similar intensive development of graduate students is due.

The universities themselves have contributed generously to the expansion of research personnel by the system of part-time assistantships. Here, also, owing to larger elections in the chemical field, the expansion has been greatest in the departments of chemistry, but the current demand for physicists and the probability that it will continue suggest that a similar measure of expansion is at hand in physics. It is via this path that many of the research personnel in industry and university have obtained their training for the doctorate in America, at least during one or two years of their training period. It is largely from the ranks of such assistants that the best are drawn to fill fellowship vacancies in the final years of study and research where freedom from other obligations constitutes a prime asset.

The growth of the educational supply to meet the research demand has led inevitably to steady improvement in the quality of educational and research activity in American colleges and universities in the inter-war years. American science and scientists have, in the main, been prepared for the tremendous calls that the present war has laid upon them. Leaders in the scientific effort have received a generous measure of support from educational foundations. There has grown up as a result, in and out of the universities, centers of research devoted to a group of connected problems. Dr. C. E. K. Mees, of the Eastman Kodak Research Laboratories, classifies such laboratories "as 'convergent' in distinction from the more usual 'divergent' laboratories, in which problems of many kinds are studied." Such a laboratory of the convergent type may well be described, Dr. Mees believes, as a "research institute," and it is this type of research institute that he expects to be the most important of the agencies for the production of fundamental science in the future. The research institute is a growth of the last half-century in the organization of research. It has grown out of the specialization of investigators, generally at universities, in some field of work important enough to attract students to the field and resulting finally in the establishment of the laboratory in question as the center for research in the subject. Abroad and at home many examples may be cited. The Cavendish laboratory at Cambridge, under J. J. Thomson for the study of the electron and under Rutherford for radioactive and nuclear studies, the Leiden laboratories under Kammerlingh Onnes for low-temperature research, are examples from universities abroad. The Kaiser Wilhelm Institute for Physical Chemistry in Dahlem under Haber is an example of a research institute that grew out of foundation foresight and generosity. The Geophysical Laboratory at Washington and the Mount Wilson Observatory are research institutes in this country established by the Carnegie Institution. The grant by the International Education Board for the 200-inch telescope on Mount Palomar, California, and the appropriation by the Rockefeller Foundation to the University of California for the construction of the giant cyclotron designed by E. O. Lawrence directly tend to make of these centers research institutes of the type under consideration.

To a lesser degree, over the whole country, monetary grants in support of promising research work and research men are producing research institutes convergent rather than divergent in nature, within the framework of existing universities or as separate organizations with some degree of affiliation with college or university. We may cite in this connection the Institute of Paper Chemistry at Appleton, Wisconsin, and the Institute of Gas Technology, with headquarters in Chicago. The American Petroleum Institute has made Ohio State University the headquarters of research effort which also provides materials for research work in many institutions. The American Petroleum Institute for many years has sponsored a large program of research in the U. S. Bureau of Standards in Washington. This is true, also, of the Textile Foundation, and from this research effort may spring a central institute for fundamental research in textiles, affiliated with some educational foundation. Cellulose chemistry, the chemistry of starch and of sugar, are examples of other research efforts which may mature into research institutes of the type here under discussion. Some of the industrial research laboratories can indeed be described as research institutes. The research laboratories of the Eastman Kodak Company at Rochester can be cited as a Research Institute for Photography. The research laboratories of the General Electric Company at Schenectady, of the Bell Telephone Company at New York City and Summit, N. J., and that of the Westinghouse Company at Pittsburgh, Pa., rate high among the research institutes of the country. In this last case, the institute aspect of the enterprise has been emphasized by the short-term fellowship scheme for post-doctorate research men that the Westinghouse Company has sponsored. The regional laboratories of the U. S. Department of Agriculture, with laboratories devoted specifically to research in the principal agricultural products of the East, South, Central and Western areas of the country, are government-sponsored research efforts of the research institute type.

In England, there are parallel developments. Under the Department of Scientific and Industrial Research there are organizations such as the National Physical Laboratory and the Government Chemical Laboratory, and also a number of industrial research associations notably in cotton, wool and silk. The British Rubber Producers Research Association sponsors a broad program of fundamental research on rubber. The Fuel Research Board has conducted a comprehensive program on liquid fuels during the years between the two World Wars, and plans for fundamental research on coal have developed during the present war years. Naturally, under the stress of war requirements, the scientific establishments, in England as here, devoted to the special problems of war urgency have multiplied considerably.

It is a matter of universal experience that the conduct of warfare, on the scale and with the equipment that modern technology has made possible, requires a tremendous research potential behind the actual military forces. It is not surprising, therefore, in the light of the achievements of the Russian forces during the last two years, that, in Russia, can be found the most extensive planned development of the research institute. The organization of these institutes has been described by J. G. Crowther in his book, "Soviet Science." They stem from the Russian Academy of Sciences, and, under separate committees of academicians and associates, various groups of institutes are organized in each field of science. Among the more notable of these are the Academy of Agricultural Science, with N. I. Vavilov, the eminent geneticist, as one of its outstanding members, the Physico-Technical Institute directed by Joffe, the Institute for Chemical Physics, associated with N. Semenov, and the Optical Institute, the three last with headquarters in Leningrad, the Karpov Institute of Physical Chemistry at Moscow, and many others. The year 1942 gave Russian Soviet science a welcome opportunity to summarize the progress which had been achieved in 25 years from the Revolution of 1917. In this process of self-examination it was, in one place, concluded without hesitation

> that Soviet science does not lag behind scientific achievements in other countries and that Soviet scientists are leaders in many branches of science. . . . The orginal plan for expansion of the chemical industry during the third

five-year plan (1938–1942) which provided for a 237 per cent. expansion of chemical industry is being stressed. The war did not decrease the scope of this development. It only brought forward the practical requirements of the day.

In addition to steel, non-ferrous metals and the heavy chemical industry, petroleum, synthetic rubber, plastics and the synthetic fiber industry were all included in the scope of the plans. The research effort by 1941 had resulted in 40 special chemical research institutes, 70 chemical and chemical engineering schools or departments in technical colleges, with from 35,000 to 40,000 students and some 5,000 chemists and chemical engineers graduated each year. The losses sustained in the initial year of war were compensated "with a substantial margin" by evacuation and resumption of work in research institutes, colleges and industrial establishments in the eastern territories of the Soviet Union.

Institutes of the type here considered can be in no sense regarded as substitutes for the industrial research laboratory. These latter are essential if the new developments in fundamental science are to be translated into industrial processes and products. The research institute must be regarded, with the university research laboratory, as the principal source of that body of fundamental science which the industrial research laboratory will bring into practical application. The energetic demands for applied science now with us due to war have only served to show, in sharper focus, how the solutions of desired industrial problems are oftentimes delayed by gaps in our fundamental knowledge. In the solution of pressing war problems how often have we to lose time in learning the science underlying the desired application. The industrial laboratory must look in large measure to the university and research institute, even in normal times, for such basic data. The advantage which industry would reap therefrom would lie not so much in the immediate returns from the fundamental research but in the speed and economy of effort with which industry can utilize such effort in the solution of its own practical problems. The contrast between American technology in World War I and to-day, in the volume of technical effort that it can put forth and in the speed with which new problems can be solved, is undoubtedly due to the great growth of fundamental science in this country in the inter-war years.

There is another aspect of the problem of organization for scientific research in the post-war world that is so comprehensive as to be outside the scope of our present considerations but nevertheless of extreme importance for the successful solution of the problem and the correlation of that solution with other aspects of post-war life. It will be necessary to re-examine the general processes of education at the primary, high school and college levels if we are to provide an adequately trained and broadly educated personnel to enter the field of scientific research in the years ahead. The educational institutions of the country have been challenged by the events of recent years, and in the processes of self-examination the leaders of educational thought have discerned that all was not well with the educational activities of the inter-war era. It is recognized that in many respects education is at the cross-roads, and various challenging analyses of our earlier efforts have recently been issued. The new civilization that must emerge from the stress of these times will call for the education of man for freedom, for the formation of free men in free commonwealths. To secure this it will be necessary that the immense needs for technological and scientific training shall be balanced by competent education in the liberal arts and humane studies. A balance must, however, be maintained, so that science and research shall continue to attract a steady quota of the competent minds in each succeeding generation of students. Nor should their scientific orientation be unduly delayed by too great a monopoly of their earlier formative years in excessive devotion to non-scientific training. There is a general measure of agreement and a corresponding fund of good will to find a solution of this vital problem of early education in a blend of the essentials of a humanistic education with those elements of a liberal education that can best be aroused by the record of man's attainment, through the years, to his present status in science and the consequences of that achievement on the lives of us all.

THE DIRECTION OF RESEARCH

The problem of direction of research is a personnel problem. It resolves itself when a competent director is found. If we think over the great centers of research in the physical sciences, whether in fundamental science or applied, do we not finally center our thoughts on the man who symbolized the laboratory? Berzelius, Arrhenius, Svedberg span a century in chemical science in Sweden; from Ostwald to Haber and Nernst runs the story of German research in physical chemistry. We think of the Cavendish laboratory in Cambridge in terms of Clerk Maxwell, Rayleigh, J. J. Thomson and Rutherford, of the Royal Institution in terms of Davy, Faraday, Dewar and Bragg. Michelson and Millikan, Richards, Compton, Lawrence, Whitney, Mees; is it not the directors who have made the research center by their own eminence in research or their own faculty of appraising the talents of others, organizing them and giving to them full scope? "I worked with X," is the formula that the young scientist will use to describe his training rather than "I worked at Y," and in so doing he will reveal the qualities of inspiration and leadership that he had the good fortune to enjoy. He will have told of the "director" who did not direct, but drew forth from his associate the best that he could give.

There is no problem in discovering a research director when the institute grows from small beginnings around the pioneer in a new field. The speed with which the institute grows, the health of that growth, will largely lie in the capacities for direction which the pioneer himself possesses. There will be those who, in relative isolation, or at best with a few chosen colleagues, will plan their pathway into the unknown. Some researches will demand large groups of cooperating assistants, large units of expensive equipment, which will require a director who, in addition to his own scientific gifts, must needs have the power of appeal to younger colleagues and to supporting foundations or industries.

It is in the choice of a research director to take on the mantle of his predecessor in an organization that has already attained to eminence that the principal problem of research direction arises. To step into the vacant directorship is no light undertaking for any new incumbent, nor is his selection an easy responsibility for any governing board. The learned societies and the scientific academies must assume a large share in such responsibility. It is for them to realize that "the supply of competent candidates," as Dr. Buckley, of the Bell Telephone Laboratories, observes, "is lamentably low." He doubts "whether it could be successfully augmented by any systematic educational procedure. The problem is more to find than to develop those who have the necessary qualifications." Dr. Mees would apply the pragmatic test to those who are selected.

> When an institute director is making a success and producing valuable work, his field of activity should be enlarged and the institute given increased scope. When he is doing only moderately well, it is probably unwise to expand his field even though he may blame insufficient support for his inability to produce results. Good men will produce results with a minimum of means, but, as soon as they do so, the further means should be supplied.

Nor does he worry too much about the situation that may arise if the staff and even the director should be appointed for other reasons than their competence. "This difficulty will supply its own remedy. The institute will simply fail, and the advance of science, locally checked, will proceed elsewhere."

It seems reasonably certain that the selection of research directors and research professors will in the long run be most successful if the body responsible for selection consists primarily of scientific men. Breadth of interest within that body of scientists may help to promote wisdom of choice. The important chairs of science in Sweden are filled only after consultation with colleagues abroad. Within one American university at least, the nominations to a research professorship in any one science must be approved by the research committee representative of all the sciences there taught. It is also quite certain that largely non-scientific boards of control with power to formulate scientific programs for both war and peace and with power to prescribe personnel and facilities for those programs, as is true of certain proposals originating in this country from legislative sources, can not conceivably be productive of the scientific direction and potential that the country needs in either war or peace.

The Support of Research

In the field of industrial research there is no problem of support. Technological progress has revealed, in an ever-increasing measure, that research is the price of industrial development, that it can revolutionize the bases of industry, render obsolete the equipment and techniques of to-day in the new procedures of to-morrow. Facing a fight for survival by the competition which originates in the research laboratories, individual organizations and cooperating groups are deciding to insure their own financial stability and future by a large premium of research effort. There is abundant evidence that such insurance pays real dividends.

Although this is true of applied science, in basic science, from which all future applied science must inevitably stem, the financial problem of support is far from reassuring. Fundamental research is rarely directly or immediately profitable, nor can it readily be made self-supporting. Its principal assets are long-range in nature, whether from the body of workers which it produces or the new principles which it formulates from which applied science will ultimately derive the richest revenues. Faraday, formulating the principles of induction and the laws of electrolysis, is separated from the electrical age and the electrochemical industry by fifty years or more of technical incubation. Sabatier, in his humble laboratory in Toulouse, never shared in the wealth which the principles of catalysis that he laid down brought to a diversity of industries, in fat-hardening, synthetic alcohols and the petroleum industry. The discovery that the uranium atom undergoes fission processes induced by neutrons, while it makes the age of atomic energy attainable, will not secure the institutions in which such discoveries were made from future problems of support.

In large measure the support of fundamental scientific research has, in the past, been the proud privilege of private philanthropy. Only in recent decades has any measure of support come from industry and government. This is especially true in the English-speaking world. In Germany, industry has been more closely knit to and has more handsomely supported, hitherto, the prosecution of basic science. In Soviet Russia, the great development of her modern science has been closely tied to the State, in agreement with the prevalent political ideology, both for direction and for support. What of the future?

For many reasons the outlook for support from private philanthropy is not inviting. The leveling influence of destructive warfare, the heavy taxation on incomes and inheritance which inevitably accompany such effort, all imply that institutions of fundamental research which have so richly drawn upon private fortunes in the past for their foundation and continuance face a leaner future so far as such sources of income are concerned. It will be necessary to take all measures possible to maintain such private donations in support of science at as high a level as can be achieved, since it is certain that support of such a nature is, of all support, the most desirable and the least hedged around with difficulties of administration. If the accumulations of wealth in the future, being less, imply a decrease in the size of individual fortunes and a consequent diminution in size of donations to research, ways must be found to increase the number of donations that can be secured. The broadening interest in the potentialities and effects of scientific research should result in a broadening of the bases from which private support might come. Research scientists and research directors incur in this respect a definite obligation to the areas in which their work is in progress. Civic and state contacts with successful research work should amplify civic and state support if for reasons of local pride alone. The obligations of research scientists do not end when they have achieved successfully the scientific objectives which they set themselves. That something has been lacking hitherto in scientist-donor contacts is evident from some observations of Dr. Buckley:

> It seems to me that those concerned with the support of fundamental research have not taken into adequate account the need for winning recognition and acclaim for the donor. Those who conduct researches and publish their results are commonly very much concerned with their own recognition and very desirous of public acclaim. They have been notably deficient in calling public attention to the source of funds with which the work was done. In this regard, it seems to me that not only has real injustice been done, but research workers have failed to win support which they might have won had this matter of recognition for the donor been given proper attention, particularly in the case of private donations. This is a problem not easily solved, and I think there is real need for development of a technique of recognition that treats the donor fairly and that does not result in the promotion of donations in ways which will be unfortunate.

The officers of the American Philosophical Society have frequently noted this type of blind spot in the recipient of research support. The disease should be cured if for no other reason than that fair and encouraging recognition of donors is productive of wider donor activity. Giving is contagious.

The support of fundamental research by industries is a problem of great complexity. It has been argued by some that boards of direction of industry have no right to utilize the stockholders' monies in support of scientific research, the bearing of which on the profit-making of the industry is at best arguable and at worst very remote. The legal aspects of such support have been debated on many occasions. The returns to an industrial donor are generally indirect and are normally of benefit to the donor industry and its competitors alike. Industries of great breadth of activity with highly developed industrial research organizations of their own can most easily accommodate themselves to these factors in industrial support of basic research, and seize swiftly for their own advantage the results that accrue from such support. Taking the long-range view and admitting that immediate profits from new discoveries are rare, we must concede that industry does receive benefit from fundamental research in at least two important directions. The supply of adequately trained research workers inevitably increases in centers of intense research activity. The new discovery is as luring as gold in the Yukon Territory. Further, the broadening of understanding that accompanies each new scientific discovery means for the industrial research laboratory a surer, swifter and more economical approach to its own objectives. The history of synthetic toluene is instructive in this regard. In both World Wars I and II the need for toluene far exceeded the peace-time production from coal-tar sources. As early as 1916, in World War I, the possibility of producing toluene from petroleum source materials was realized. But expenditures running into millions of dollars did not solve the industrial problem at that time. Two decades of research in the basic aspects and principles of catalysis were needed to indicate in what direction the program, which led to failure in 1914–1918, could surely and swiftly be brought to a simple technical solution. There are many examples which could be cited of the auto-accelerating effects of basic scientific discoveries on the objectives of industrial research. Large industries have already decided, and will in increasing measure in the future decide, to support fundamental research.

What of the decentralized industries that operate in small, widely distributed units with only a relatively small number capable of maintaining research laboratories for their industrial problems? What measure of support for pure science can they supply? How can they meet the competition from without, to which large industrial research organizations by the breadth of their own research efforts subject the little industry? The answer would seem to lie in a cooperative effort shared in limited amount by each but, in aggregate, large and impressive. It would seem to lie in the development of the research institute, whose main objectives should be (1) the prosecution of fundamental studies in the general field of the pertinent subject, its physics, chemistry, biological and engineering aspects, (2) the dissemination of research information covering scientific and economic aspects of the field, and (3) the training in the methods of research of specially selected personnel at the graduate student level for future positions of responsibility within the industry. Coordinated with an existing educational foundation, such a research institute could produce mutual advantages for both. Each would enlarge its own research horizons, each could supplement the others' activities with personnel and facilities. The advent of the cooperative research institute in the educational centers of the land can be made of significant importance in the general problem of support for research.

State and Government support of fundamental research is at once the most obvious and at the same time the most hazardous of all the forms of support. By its nature it recognizes that the endowment of research is the concern of all citizens alike and all should share in its burdens and its benefits. Such support tends, at the same time, to enmesh the laboratory with the hurly-burly of competing ideologies or conflicting interests that hamper even the most liberal forms of government and, in the worst cases, tend to destroy that independence of scientific opinion, that autonomy of science, without which it can not fulfil its proper functions to society. We are too near to recent efforts to break the autonomy of scientific effort, to subordinate it to State ideologies and totalitarian control, to be unmindful of its real dangers. We must not forget that even democratic legislative bodies have attempted to define $\pi = 3$, in the supposed interests of their growing youth. Can we hope, in these democratic forms of government, for that larger measure of political wisdom that is prepared to surrender to competent scientific bodies, such as the National Academy of Sciences, the problem of disposition of community support to scientific sections of the universities and research foundations, freeing it thus from every vestige of political or ideological control? The history of the relations between the United States Government and the National Academy of Sciences in the past does not augur well for future improvement in this regard. May we not hope, however, that the lessons of these harsh years, in which scientifically trained university presidents, executive officers of scientific and research foundations, professors of science, have crowded the offices of government departments in striking contrast to the days of peace, may we not hope that those lessons will show that the peace can be lost, has in the past been lost, because of neglect or oversight of the major role that scientific discovery, no less than applied science, plays in those days of peace? May we not hope for the realization that, no less in peace than in war, local, state, national and international relations, social and political affairs, have become inseparable from the discoveries of the scientist in his laboratory and their manifold applications? And, realizing this, may we not hope for that measure of disinterested financial support which shall best promote that scientific harvest? To secure this with maximum efficiency and least impedance it seems necessary that the scientists shall be masters in their own households.

But, masters in their own households, there still lies upon them the paramount necessity of integrating their skills and their findings with the broad stream of life which flows outside the laboratories. To go forward to meet the years of difficulty ahead, we shall need the effort of all men of good will, among whom the scientist, by the nature of his calling, must certainly be numbered. The processes of mutual cooperation and assistance among the individual sciences must be multiplied. The isolation of one science from another must become progressively less and less, even though the degree of specialization within a science becomes perhaps greater and greater. This calls for an increasing breadth of culture and of education among the scientists, an increasing dedication by the noblest minds to the forward march of knowledge; but it calls also for a fuller appreciation of the social consequences of that knowledge, a franker recognition of the other factors contributory to true knowledge, to wisdom. "The modern world," says Maritain, "by which I mean that world which is coming to an end before our eyes, has not been a world of harmony between forms of wisdom, but one of conflict between wisdom and the sciences, and," he adds, "it has seen the victory of science over wisdom." Have not we scientists, so to speak, to surrender that victory? We shall not yield our energy, our courage, our diligence in search of truth. We shall but renounce the primacy to which a sick world has thrust us; and we shall gain by our renunciation. In the free world to which we still dare to look forward, with the soldiers and statesmen, artists, humanists, philosophers and priests, we must integrate our scientific skills with the social and spiritual aspects of human life and nature. That goal attained, we shall not lack either direction or support for the physical sciences.

OBITUARY

EDWARD OSCAR ULRICH

EDWARD O. ULRICH was the last survivor of the five great invertebrate paleontologists who were the dominating figures in Paleozoic work in 1900. Charles E. Beecher died forty years ago. John M. Clarke, Charles D. Walcott and Charles Schuchert fortunately survived much longer, and, with Ulrich, were universally considered the leaders in the field so long as they lived. These four paired admirably: Walcott and Clarke, suave, diplomatic, executive; Ulrich and Schuchert, blunt, outspoken, indefatigable workers, zealous for detail. Each was a man of strong personality. They were at times great friends, at others great foes. But all of them were seeking scientific truths. The writer came to know all of them, and the thing which stands out best in his memory is that, however much we differed on scientific matters, we were always good friends.

Ulrich was a delightful personal companion, equally eager to argue or joke. But he was always good-natured. I never knew him to express anger, no matter what he might feel.

But this is neither a biography nor an appreciation. Since I heard of his death, I have been trying to appraise his position in the field of invertebrate paleontology. It seems to me that he was the greatest descriptive paleontologist that America has ever produced. He had a remarkable eye for form and a genius for detail. His memory was extraordinary. It is doubtful if he forgot the details of any species he ever studied. In contrast to much of the rather hasty work of some of his contemporaries, his descriptions have stood the test of time. His skill as an artist and lithographer was probably the basis of his success. After the publication of his work for the Illinois and Minnesota State Surveys he was accused of making far too many species, the innuendo being that he was paid for his labor at so much per new species. Later workers have shown that his species were good, and that he could have made many more if he had had access to more and better material. His work is the foundation for later studies on Paleozoic Bryozoa, Ostracoda and Conodonts, Ordovician Gastropoda and Pelecypoda. He also contributed much to knowledge of Cambrian and Ordovician trilobites and Mississippian pentremites.

During his long life, Ulrich probably saw more of the Paleozoic formations of the eastern half of the United States than any other man. His contributions to stratigraphy and correlation were voluminous, not only in what he himself published, but in the aid which he gave to other geologists during the many years of his association with the U. S. Geological Survey. Some one else will have to appraise this side of his work, for his ideas were so diametrically opposed to those of the present writer that he can offer no judgment. But he made a great contribution in this field, for he provoked—and I really mean provoked—many geologists to make much more careful studies than would otherwise have been done. His discussions furnished food for thought, and much good came of them.

Edward Oscar Ulrich was born in Cincinnati on February 1, 1857, and died in Washington on February 22, 1944. He was a member of many learned societies, and a great contributor to knowledge in his field. His was a useful life, well lived. If it had not been for him, we should have had no Schuchert in geology, and there are many others who owe their start to him.

PERCY E. RAYMOND

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DEATHS AND MEMORIALS

DR. HARRIS HANCOCK, who retired with the title emeritus in 1937 as professor of mathematics at the University of Cincinnati, died on March 19. He was seventy-seven years old.

DR. BENJAMIN MILLER, since 1907 head of the department of geology of Lehigh University, died on March 23. He was in his seventieth year.

DR. CARL KOLLER, consulting ophthalmic surgeon at the Mt. Sinai and Montefiore Hospitals, New York City, died on March 21 at the age of eighty-six years.

AT the graduating exercises of Lafayette College on March 26 a memorial address was made by Dr. B. W. Kunkel, professor of zoology, on "The Life of Dr. J. McKeen Cattell," who graduated from Lafayette College in 1880.