SCIENCE

VOL. 76 FRIDAY, JULY 29, 1932 No. 1961

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

THE SCIENCE PRESS

New York City: Grand Central Terminal

Lancaster, Pa. Garrison, N. Y.

Annual Subscription, $6.00 Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

EDUCATION AND RESEARCH[1]

By Dr. FREDERICK H. SEARES

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TO-DAY'S program implies that I speak on the educational influence of the Mount Wilson Observatory. In education, a research foundation proceeds less consciously than a university. Without students in the technical sense, it has little concern with instruction. Its task is rather to procure information, which, rearranged and somewhat diluted, serves, among other ends, as a reagent for converting the uninstructed into cultivated human beings. The obligation to set forth its results is admitted; nevertheless, the chief business of a research establishment is investigation, and by its success in this undertaking its educational force finally is to be measured. Important conclusions soon become interwoven with the thought of the time; conclusions, however, must be provided.

The observatory is known as a place where the sun, stars and nebulae are studied with telescopes of great power. It is less known as the Mount Wilson Observatory of the Carnegie Institution of Washington. That, however, it is—one of a group of research units maintained by the Carnegie Institution. The educational influence of the observatory is to be appraised with this organic relationship in mind.

In 1902 Mr. Carnegie placed in the hands of trustees a large sum of money, which, with later gifts, appropriations from the Carnegie Corporation and accumulated reserves, yields income for the institution. The Congressional Act of Incorporation sets forth the purpose: "to encourage in the broadest and most liberal manner investigation, research, and discovery, and the application of knowledge to the improvement of mankind."

Study of the means of providing such encourage-

[1] Address before the Association of Colleges and Universities of the Pacific Southwest, at the University of California at Los Angeles, April 16, 1932.

ment has led to a method of operation suited to the needs of to-day: First, minor grants for special research, made to a few experienced investigators connected with other institutions, who rank as research associates of the Carnegie Institution; second, major grants to permanent divisions or departments, organized within the institution itself and directed by specialists. The Mount Wilson Observatory is one of these departments, of which at present there are ten.

A grouping of departmental names at once suggests relationships. Place together the Geophysical Laboratory, the Departments of Terrestrial Magnetism and Meridian Astrometry and the Mount Wilson Observatory. We thus begin with the earth as a physical body, studying the formation and alteration of its rocks by modern quantitative methods of physics and chemistry and the development and transfer of heat involved in mineral reactions and in changes from a liquid state to a solid. Geologic processes, hitherto treated only descriptively, are thus brought into the laboratory where they yield the exact numerical data so essential for fruitful scientific advance.

Next we study the earth's electric and magnetic conditions, with emphasis on problems of international concern. Vessels of the Department of Terrestrial Magnetism, notably the ship *Carnegie,* have cruised the waters of all the oceans from 80° latitude north to 60° south; the aggregate length of the observational trail is more than 400,000 miles. Meanwhile the land has not been neglected. Observers have visited all its parts, gathering data from nearly 6,000 stations. To obtain records of electric and magnetic changes, permanent stations are maintained in Australia and in Peru. Finally, at its laboratory in Washington, the department undertakes experimental and theoretical investigations required to interpret observations made in the field.

When we leave the earth for the stars, the first question is, Where are the stars and how do they move? The Department of Meridian Astrometry helps with the answer by providing Boss's Catalogue of the positions and proper motions of bright stars, an indispensable handbook of the astronomer. Precise observations of thousands of fainter stars, made by the department from both hemispheres and combined with earlier measures of positions, will also supply a rich store of data on stellar motions. The worth of such information shines forth when we recall that the first great advance since the time of Sir William Herschel in knowledge of the stars as a system was based on proper motions. In 1904 Kapteyn found certain regularities in the motions of stars, and from that moment the stellar system ceased to be a collection of individuals and became an organic whole.

Kapteyn's investigation of stellar motions was coincident with the foundation of the Mount Wilson Observatory, and together these events began a new epoch in astronomy. The observatory, at first an expeditionary undertaking for studying the sun under the favorable mountain conditions of this southwestern country, soon became a permanent establishment through the efforts of Hale, its first director, and the generous support of the Carnegie Institution. From his youth deeply impressed with the broader significance of evolution, Hale saw both the need and the opportunity for work on the developmental features of stars. What began as a specialized study of the sun, the nearest and most accessible of stars, thus naturally widened into investigations of the comparative history of stars as a class. Powerful telescopes were provided, and highly specialized instruments; and a physical laboratory equipped with spectrographs having the same efficiency as those used in observations on Mount Wilson turned astronomy more or less into an experimental science and increased immensely the effectiveness of the methods of research. Meanwhile Kapteyn's results on stellar motions had shown the importance of thinking of the stars as a vast structural organization.

Until recently the work of the observatory has centered around these two problems: the stars as physical units having size, mass, density, temperature and constitution, subject to a developmental process involving genesis and decay; and, second, the stars as an organic system, having structure and regularity of motion and a cosmological history of its own. To-day, however, a third fundamental problem engages our attention—the extra-galactic nebulae, gigantic systems far outside our stellar system, some of which much resemble our own system. The press has been so full of the now famous red-shift of the spectral lines of these nebulae I need scarcely add that our views of the universe will certainly be much influenced by what we learn about these remote objects.

On the biological side the Carnegie Institution has its Division of Plant Biology, its Marine Laboratory at Tortugas on one of the Florida Keys, its Departments of Genetics and Embryology, its Nutrition Laboratory in Boston. On this occasion it suits my purpose better to indicate some of the interrelations of these varied fields of investigation, rather than to tell further, even in outline, what each department does. These interrelations are important because they greatly increase the scientific effectiveness of the institution.

Every one knows the contributions that come from highly specialized research, how little by little they increase our knowledge of the world in which we live, bring benefits to humanity, enrich our intellectual lives, and in the end subtly shape our thoughts about man's ephemeral existence in a universe whose duration eludes comprehension. It is not always recognized, however, that these results come about much faster when the specialist follows up connecting threads that lead into other fields of research. He then often finds an unsuspected interdependence which solves many riddles. Thus we learn much about plants by studying the animals that inhabit the same region. Plant distribution is a matter of soil and climate; more fundamentally it is a matter of geologic change, and only the paleobotanist, backed by the geologist as well as the physiographer, can tell why Monterey pines and redwoods grow where they do to-day. The life of the sea fluctuates with the physical-chemical conditions of its waters and is, therefore, also to be studied from the view-point of geophysics. The plant biologist splits a plant into a half dozen parts, places each in a different environment and watches the surprising results through successive generations. The stability of plant characters thus put to test is related to the work of the geneticist and the whole problem of organic evolution. Cycles in tree growth point to fluctuating rainfall, which may be related to changes in the sun. Geology is linked to geophysics, while the geophysicist tells us how to make glass for our telescopes. Terrestrial magnetism offers analogies for the magnetic field of the sun. Physicist, geologist and geophysicist combine to investigate earthquakes, and with the astronomer they study the surface features of the moon and tell us its substance.

With this degree of emphasis on interrelations, it may cause surprise to find among departments of the institution which are scientific in the technical sense a Division of Historical Research. The aim, however, is not altogether conventional history, but rather a concentration on those historical features that reflect man's development and career. Mayan archeology and the Pueblo civilizations of the Southwest fit into the program, and also the history of science. The investigator in the laboratory or at the telescope may reflect with profit to himself on the development of scientific thought; but other interconnections of man's activity with the physical world are less evident. The culture of a people, however, reflects the physiographic and climatic features of the region in which it develops. The student of trees, on the other hand, supplies a chronology for the culture and, through the intermediary of a human habitation, dates a volcanic outburst of interest to geophysics and geology. The astronomer is interested in the Mayan calendar; the archeologist, the paleontologist and the geologist find their interests converging in a cave in Nevada; and the geneticist and the botanist are provided with intellectual food as well as physical nourishment because aboriginal Americans developed from wild grasses most of our cereals.

Basic for all these things, of course, are the researches of the physicist and chemist and the powerful methods of mathematical analysis. The constitution of a star is a problem in atomic physics. The Carnegie Institution therefore aids Millikan and Noyes at the California Institute in order that they may join with the Mount Wilson Observatory in studying the constitution of matter, and supplements these efforts in its own Laboratory of Terrestrial Magnetism in Washington. It helps Michelson to repeat the famous Michelson-Morley experiment and to redetermine the velocity of light. In turn the astronomer directs the physicist to the stars as laboratories presenting conditions of pressure and temperature unattainable on the earth, under which he may test his theories of atoms.

Contacts of this kind between the Carnegie Institution and investigators connected with other institutions are represented by its group of research associates, whose roll is a list of distinction. Individually, the associates bring to the institution, besides their own contributions, fresh stimulus and wise counsel.

The gain to science from the correlation of work in different fields has proved so great that under the administration of President Merriam the organization of the Carnegie Institution has gradually been adjusted to a fuller coordination of its activities with each other and with those of other agencies. A unity of spirit and purpose has thus developed within the institution which contributes effectiveness to each of its departments.

So much for the prosecution of research. Perhaps the gist of what is pertinent here to-day might be put in a phrase, if you will permit phrase making, to the effect that a beautiful building can not be viewed through the gloom of night by casting a spotlight on the architectural detail of a doorway.

There remains, however, the vexed question of making scientific results available to that part of humanity not concerned in their accumulation. Here, of course, we come close home to the problems of scientific education. Some responsibility in this direction on the part of a research institution is recognized by all, but with the greatest diversity of opinion as to how far it extends. Part of the obligation is discharged automatically by the publication of technical results. Some investigators believe that responsibility ends when the last proof of the formal presentation has been read; and for such the matter perhaps should end at that point. Such individuals are likely to be temperamentally unfitted to recast and summarize an investigation in a form comprehensible to a public not technically trained. Others find in the effort a self-clarification that brings new vision when they turn again to their own work. Among such are the great expositors of science, successful in instructing others, perhaps because they best succeed in instructing themselves. The dissemination of the results of research, however, is always an exacting business, demanding more than cold rationalistic approach. When most successful, the effort involves something akin to dramatic sense and a literary skill which touch the imagination without doing violence to verities or distorting perspectives, and still leave those instructed with a dominant feeling of the power of reason. He that hath the talent clearly should not hide it; nor is he likely to do so, for he will probably feel the stimulus of a responsive public. The conflicting demands of the public and the laboratory he will somehow adjust, usually, I think, to the benefit of both.

To these general reflections I may add that the Carnegie Institution recognizes its responsibility and continually seeks means by which it may present the results of its work to scientific workers and the public. Its volumes issued through the division of publications and the special publications prepared by some of its departments have prompt and wide distribution. Careful statements of its work are distributed to the press as news releases. An exhibition of its diversified activities, held annually in Washington, and series of lectures by its investigators are other means by which it approaches the public.

We at the observatory share in the responsibility. Each year we care for thousands of visitors at Mount Wilson. We give public addresses; cooperate with the Astronomical Society of the Pacific in providing annual series of popular lectures and general articles for its publications; aid with the news releases issued by the Carnegie Institution, with its yearly exhibition and its own series of lectures. We open our library to students qualified to use it, and, as occasion permits, welcome at the telescope men on fellowships of the National Research Council, the General Education Board, the Commonwealth Fund and other foundations.

Technical results printed in periodicals and books are the source for fellow workers in science and those who prepare texts for instruction; news releases, lectures and popular articles reach the general public; visits to the observatory reveal something of the atmosphere of research not conveyed by printed words. Behind all, however, and giving life to all, is the power of organized effort and the work of earnest men. Herein lies the spring that draws its waters from the heavens and from the earth and all its life. As that flows, so shall the mind of man grow and put forth new fruits and his spirit become fine.

THE STUDY OF THE MIND[1]

By Dr. WILLIAM A. WHITE

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I MUST preface the few remarks which it seems to me that an occasion of this sort warrants by expressing my deep sense of appreciation at being elected to membership in this distinguished body. Nothing could be more gratifying than the opportunity of associating myself with you through the medium of this Greek letter society. I naturally feel highly honored that my past performances have been of such a character as to lead you to ask me to join with you, and I assure you that in the future I will consider the honor of this association as a stimulus to work that will continue to command your regard.

In the few minutes at my disposal I feel that the most appropriate thing that I can do is to formulate very briefly what might be called a profession of faith, by which I mean a statement of what I conceive to be the significance of my chosen work both as it appears to me in the present and as I vision it for the future.

In the first place, no adequate understanding of the present status of the study of the human mind can be reached, as indeed might be said of any other scientific subject, without some knowledge of the historical aspects of the subject. And I may remind you in this connection that it is only very recently that the study of the human mind in its various reaches has escaped from the limitations of its associations with philosophy, theology and morals and has finally become, in my opinion, a biological science which undertakes to investigate and explain not only the outwardly observable behavior of living beings but the circumstances in that world within us, which can only be approached by methods of introspection, which are of such apparent significance in connection with our

[1] Address at the annual meeting of the District of Columbia Chapter of the Society of Sigma Xi on April 26.