SCIENCE

Vol. LXX | Friday, September 13, 1929 | No. 1811

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.

THE SECOND CELEBRATION OF THE TWENTY-FIFTH ANNIVERSARY OF RESEARCH IN THE CARNEGIE INSTITUTION OF WASHINGTON

Second Celebration

A first celebration of this anniversary was held at the Department of Genetics of the Carnegie Institution of Washington, at Cold Spring Harbor, Long Island, on May 31, 1929, Dr. Henry S. Pritchett, vice-chairman of the board of trustees of the institution, presiding. Addresses delivered on this occasion by President John C. Merriam, Dr. Edwin G. Conklin, of Princeton University, and General John J. Carty, member of the board of trustees, appeared in the June 7, 1929, issue of Science.

A second celebration of the anniversary was held on board the non-magnetic ship *Carnegie* in San Francisco Harbor on August 26, the presiding officer being Mr. William Benson Storey, member of the board of trustees. The following addresses by Dr. Henry S. Pritchett, vice-chairman of the board of trustees; Dr. W. W. Campbell, president of the University of California; Captain J. P. Ault, commander of the *Carnegie,* and Dr. Walter S. Adams, director of the Mount Wilson Observatory of the institution, were delivered at this meeting:

Address by Dr. Pritchett

The Department of Terrestrial Magnetism of the Carnegie Institution is world-wide in its operations. It is the child of the Division of Magnetics of the U. S. Coast and Geodetic Survey and, as I happened to be superintendent of the survey in 1899 when its work was expanded so as to undertake a systematic magnetic survey of the country, I have been asked to give some account at this meeting of the work in terrestrial magnetism carried on by the Coast Survey and whose development led ultimately to the larger project for a magnetic survey of the whole world.

The Coast Survey, although formally organized in 1816, dates back to the days of Thomas Jefferson and his great Secretary of the Treasury, Albert Gallatin. Its original field of activity was defined by its title. It was a survey of the coast and its purpose was to aid commerce by providing accurate charts showing the configuration of the coast and the depth of the adjacent ocean, so that navigation might be safe to vessels of all descriptions. Its mandate from the government related to all the coasts under the domination of the government of the United States and its mission might almost be described in the words of the Corsair of Lord Byron,

> Far as the breeze can bear, the billows foam,
> Survey our empire.

For the first five or six decades of its history, it remained a coast survey, but even in that day the making of a nautical chart involved some knowledge of the magnetic forces on the earth's surface, for the compass was in constant use in navigation.

The strength and direction of the magnetic force in the earth's field in horizontal and vertical planes are referred to as magnetic elements and vary from place to place, having also a slow progressive change from year to year. From its earliest work, therefore, the Coast Survey had to concern itself with the determination of the magnetic elements along the coast and of their changes. The primary purpose of such observation was to serve the needs of navigation and of survey. It is interesting to note that in our day air navigation imposes a still sharper demand for accurate knowledge of the magnetic elements.

As time passed, and the whole continent of the United States became settled and occupied, it became clear that a triangulation and a magnetic survey of the whole country would be necessary. The Coast Survey, therefore, was ordered to assume the functions of a Coast and Geodetic Survey in order that it might meet this continental need.

Up to the beginning of the present century the work of the survey has been confined mainly to these observations of the magnetic elements for the direct service to the navigator and to the surveyor. It became clear, however, by that time that it would be necessary to carry out not only a far more extensive survey of the whole United States, but that permanent magnetic observatories should be established for continuous observation of the magnetic forces. This was the situation when I came to the survey in 1897.

In the general examination of the various departments of the work of the survey which the President and the Secretary of the Treasury had desired me to make, the question of the magnetic survey was involved. In consultation with my colleagues of the Coast Survey, we decided to ask Dr. L. A. Bauer, who had formerly been connected with the survey under Mr. Schott, to make a report on the state of our knowledge of terrestrial magnetism and to indicate the sort of organization which, in his judgment, might be set up in the Coast Survey to deal with this problem from the standpoint both of its scientific value and of its commercial applications.

Dr. Bauer submitted to the superintendent of the Coast Survey a plan which contemplated the observations of the three magnetic elements over the whole country at stations that were from thirty to forty miles apart. In addition to the stations in areas of magnetic disturbance, certain other stations were to be occupied for repeating the observations in order to determine the secular changes of the magnetic elements, and finally a limited number of magnetic observatories at fixed stations were planned where continuous observations of the United States magnetic field could be made and recorded.

The report of Dr. Bauer, after a full discussion by the scientific men of the Coast Survey, was recommended, practically in the form in which he offered it, to the Secretary of the Treasury who approved the plan and approved, likewise, the application to Congress for a sufficient appropriation to inaugurate it. This appropriation was granted by Congress and a new division, known as the Division of Terrestrial Magnetism, was set up in the Coast and Geodetic Survey in May, 1899. Dr. Bauer was invited to undertake this work and became the first director of the division. He had, as an associate, Mr. D. L. Hazzard, who succeeded him in the direction of the division of magnetics when Dr. Bauer resigned the work in 1904.

It ought to be said that the establishment of the division of magnetics, as well as the development of the Bureau of Standards from a small office of weights and measures, would not have been possible without the cordial and effective cooperation and support of the Secretary of the Treasury, Mr. Lyman Gage, and the Assistant Secretary, Mr. Frank A. Vanderlip. As Jefferson's great Secretary of the Treasury, Albert Gallatin, had stood back of the Coast Survey in its early beginning, so Mr. Gage stood back of it a century later in its effort to meet the growing needs in a nation that had expanded over a whole continent.

During the period following the creation of the new Division of Terrestrial Magnetism, five observatories were established and put in operation. Special buildings were erected for the observatories at Cheltenham, Maryland; at Sitka, Alaska, and at Ewa in Honolulu. Similar buildings were erected later in Porto Rico.

Besides fulfilling the immediate needs of our own country, the magnetic observatories of the Coast and Geodetic Survey have cooperated with other magnetic surveys and observatories throughout the world and have rendered important contributions not only to the practical work of surveying and of hydrography, but also to our knowledge of the nature of that mysterious magnetic field which surrounds the earth. The survey began also the determination of the magnetic elements at sea but, inasmuch as the observations were made on steel vessels, the difficulties of accurate results under such circumstances were very great.

Meantime it became clear that since the problems of terrestrial magnetism are world-wide, there would be necessary some organization of a study of the magnetic elements and of their variations over the whole world. When, therefore, the Carnegie Institution of Washington was founded in 1902, and its trustees invited various scientific men to suggest projects which they believed to be of great importance, Dr. Bauer presented a plan for a world-wide study of magnetics. His plan was adopted by the trustees of the Carnegie Institution and he was invited to undertake the direction of that work. In 1904, therefore, he transferred his activities from the Division of Terrestrial Magnetism of the Coast and Geodetic Survey to the Department of Terrestrial Magnetism of Carnegie Institution of Washington. This is a brief story of the process by which the Division of Magnetics, which began a hundred years ago in the Coast Survey for purely utilitarian purposes, has gradually resulted in the establishment of a world-wide survey of the earth's magnetic field. It is no small credit to the Coast and Geodetic Survey that out of its scientific work, planned originally for purely utilitarian purposes, there should have arisen two great scientific agencies like the National Bureau of Standards and the world survey of the magnetic field of the earth.

The earth is charged with negative electricity. Although this escapes constantly into the air, the earth's charge is never permanently diminished, nor is the charge in the air increased. How the charge thus lost from the earth is replaced has not yet been certainly explained and is perhaps one of the most important and far-reaching problems of atmospheric electricity still awaiting solution.

As an agency in the prosecution of this problem the non-magnetic ship, *Carnegie,* upon which we meet to-day, was constructed. Since magnetic iron in any form affects magnetic instruments, the *Carnegie* was constructed of wood with cotton fastenings. The small quantity of iron on board is in the engine room, far enough away to have no appreciable effect on the instruments. It has therefore been possible, through this specially constructed ship, to continue observations over a very large part of the United States surface where hitherto such observation could not be accurately made. That this service has been of enormous benefit not only to the mariner but also to an understanding of the forces of terrestrial magnetism can not be questioned. It is interesting to note that as this world-wide survey has gone on under the leadership of the Carnegie Institution, the Division of Terrestrial Magnetism of the Coast and Geodetic Survey has continued to cooperate with it in the most helpful manner. It is by such cooperation that science makes its constant progress. On this day, therefore, when we celebrate the twenty-fifth anniversary of the Carnegie Institution of Washington aboard this unique vessel, it is both a pleasure and a duty to record our indebtedness to the Division of Terrestrial Magnetism of the U. S. Coast and Geodetic Survey of which this great enterprise under the direction of the Carnegie Institution is a daughter.

HENRY S. PRITCHETT

Address by President Campbell

If I were asked to name and describe the most wonderful fact known to man, my reply would be:

So far as our observations and experiences go, every particle of matter in the physical universe is endowed with the property and necessity of obeying the fundamental laws of nature. Our universe of stars, our own star and our earth in all its parts, have been developed through long ages, to their present states, under the guidance and compulsion of perfectly definite and apparently simple laws. We have no reason to suppose that these laws are ever set aside, or varied in the slightest degree. The operations of those laws are believed to be never capricious or undependable. In fact, the arbitrary and the capricious do not seem to exist in physical nature. Whether the arbitrary and capricious exist in human nature is quite another matter, but that is a bridge we need not cross to-day.

This earth of ours, when measured in astronomic units of length and mass, is a mere bagatelle, a negligible thing; but when measured in terms of human dimensions this earth is a perfectly enormous body.

Cutting a little notch in the Culebra ridge at Panama, a ridge only three or four hundred feet high, to let the ships pass through—that was a huge undertaking. Not all the developed wealth of the entire United States would suffice to level off a few small mountain peaks at the edge of Lake Tahoe, and use the resulting materials to fill the cavity now occupied by the waters of that lake!

This great planet of ours is still responding, in major degree, to the forces, to the laws, which controlled its evolution. There is nothing of greater importance to the well-being of the human race than that its universities and its other research institutions should determine the nature and the potency of those forces and the ways of those laws, so that the plans of man for doing the work of the world may be in harmony with them, and not in opposition thereto. Our engineers could compel the rapidly descending waters of a mountain stream to reverse their direction and go up hill, through pipes, to their source, but at what a heavy cost, day and night, day and night, and all to no good purpose. The same engineers could harness that stream and make its descending waters generate electricity and, by doing the work of the community, day and night, day and night, contribute to the comfort and happiness of men, women and children.

Now it took the people of this earth a very long time to learn a little something about electricity and chemistry and biology; and scores upon scores of able investigators are still finding out new things about those subjects; not really new things, not new laws and new principles, but old ones, immensely older than the hills, which had not yet been discovered—not yet uncovered—and brought to their notice and comprehension, and ours.

There are forces acting upon the earth whose effects are undoubtedly of great significance, but whose origin and laws are as yet very imperfectly known. I here refer especially to the subjects of terrestrial magnetism and terrestrial electricity. As this little pamphlet, recently issued by the Carnegie Institution, says:

> There exists about the earth a field of magnetic forces of which the origin is still unknown. The distributions and variations of this field present characteristics which are related not only to the magnetic and electric phenomena of the earth and its atmosphere, but also to solar and cosmic phenomena. The strength and direction of the earth's magnetism in the horizontal and vertical planes are referred to as the magnetic "elements," and these vary from place to place.
>
> An exact knowledge of the way in which they vary is demanded for the efficient use of the compass in maritime and aerial navigation; and a study of irregularities of distribution is one of the few means we possess for investigating the properties of subterranean masses. However, the values of the magnetic elements obtained at any point are not constant, but undergo periodic and irregular variations.

There is a diurnal variation in the pointing, a gradual shifting of the needle back and forth in a period of twenty-four hours, this diurnal shifting being greatest in summer and least in winter—obviously an effect, direct or indirect, of the sun's heat. There is another shifting of the needle, back and forth, in an average period of eleven years plus, which evidently bears intimate relation with the periodicity of the spots on the sun. Further, there is a long-period or secular change in the pointing of the needle. At the Greenwich Observatory, in southeastern London, the magnetic needle in the year 1570, when the long series of magnetic observations was begun, pointed 11° east of north; in 1660, ninety years later, its pointing was due north; in 1800 it pointed 24° west of north—a change of 35° in 230 years. Since 1800 the needle's pointing has been shifting easterly, until at Greenwich to-day the average reading is about 14° west of north.

Then there are two principal types of sudden fluctuations of the needle pointings:

First, those due to special conditions called "magnetic storms," which in their more intense forms are usually accompanied by aurorae, by electric currents of cosmic origin on our telegraph and telephone lines which for a few hours may prevent our use of them, and by especially active or large or numerous spots on the sun; and

Secondly, those due to the near presence of magnetic materials in the earth. In 1922, as the ship on which we were passengers was approaching the harbor of Broome, on the northwest coast of Australia, and through the courtesy of the captain on the bridge, we watched the ship's compass needle vary its pointing through 70° and back again in the course of not more than three or four minutes of time. We were apparently passing nearly over a great subterranean mass of metallic iron ore, or other materials possessing magnetic properties.

Now these extraordinary magnetic happenings had long been studied, but almost exclusively by individuals working alone, and on land areas forming but a minute part of the earth's surface. This problem of terrestrial magnetism, relating to the whole of the great planet upon which we reside, is accordingly an extremely extensive, complicated and difficult one. The first step toward its solution consists in the acquiring of the facts; the making of millions of accurate observations of the magnetic elements upon the surface of the continents and the seas, and of the electrical elements in the depths of the waters and in the heights of the air. To complicate the subject, observations already made, no matter when, do not continue to fit their points of observation: the magnetic elements at any point of observation vary with the passing of time, as already explained. The problem is entirely too large for an individual: it is a problem for an institution, a continuing institution, of great financial resource.

We have heard anew, on this anniversary occasion, about the establishing of the Department of Terrestrial Magnetism in the Carnegie Institution of Washington, under the leadership of Dr. Bauer, in 1904, with definite purpose and commendable courage, to take up the study of this problem; and we have learned to-day about the good ships *Galilee* and *Carnegie*—something of their extensive cruises, back and forth, upon the seas, and just a little about the well-planned and well-executed activities of their staffs. The observations secured upon their decks have been supplemented, simultaneously, by similar observations made at thousands of land stations on all the continents except Antarctica. The very great number of accurate observations secured on land and sea and in the air and water have priceless value for the human race. The results thus far obtained from the study of these observations, results recognized by all students of the subjects as of very great importance, are but the first fruits of the heroic undertaking.

The commercial ships which are traversing the seas and making the whole world kin have during nearly two decades past been guided by charts whose magnetic elements are remarkably accurate, thanks to the work of the ship *Carnegie*. The staff of this ship upon which we are assembled discovered on its first cruises that the earlier charts used by the navigators were in error by astonishing amounts—approximately a degree as to the pointings of the compass in some parts of the intensively used north Atlantic trade route, and even as much as four, five and six degrees on some of the Pacific Ocean routes.

The extensive observations and the remarkable deductions on the subject of atmospheric electricity made by the department can scarcely fail to be of tremendous importance in the domain of radio transmission.

The knowledge gained by the Carnegie Institution in these fields will contribute generously to a better comprehension of some of the laws which have attended and will continue to attend the evolution of the earth; to a better understanding of the interrelationships of the earth and our sun, and quite likely to a better understanding of the interrelationships of our sun and its planets with the myriads of other suns in our own stellar system, and of our sun and its planets with the myriads of other great stellar systems as represented by the spiral nebulae distributed through wide space.

In closing, it gives me very great pleasure to express the conviction that no man ever made a better or more ideal investment in behalf of humanity's welfare than did Andrew Carnegie when he founded the Carnegie Institution of Washington. This is certified by the constant stream of dividends earned and distributed by the institution's many component parts which conduct investigations in the physical sciences, the biological sciences and the social sciences. Through the rich contributions made by the Carnegie Institution to our knowledge of these sciences we are being greatly assisted in putting ourselves in harmony with our surroundings on the earth and in the greater space above us, and we are bound to succeed the better in marching with the evolutionary current that is ever ready to serve us by joining forces with us.

W. W. CAMPBELL
UNIVERSITY OF CALIFORNIA

Address by Captain Ault

The plan of Dr. Louis A. Bauer, who organized this department twenty-five years ago, was to find out something more about the magnetic and electric state of this globe upon which we live, not only on the surface but also in the interior of the earth and in the air above and in the waters beneath the sea. The thinking and progressive mind could not ignore the challenge of the mysteries which surrounded the earth's magnetic and electric fields, not only in the fact of their existence but also in the untableted laws which seemed to govern their many and unusual variations and their relations, near and distant, to other terrestrial and cosmical phenomena. We make constant daily use of these mysterious manifestations of nature, in surveying, in sea and air navigation, in commerce, in manufacture, in telegraphic and radio communication and in countless other ways. We seek to broaden and extend this use and to brighten the dark places by added knowledge.

The chief accomplishment from a visible and tangible aspect has been the completion of a world magnetic survey, on land and sea, with its attendant contributions in geography, astronomy, meteorology and oceanography.

In this brief summary, the story of individual endeavor and enterprise, of invention and accomplishments can not be told. In the performance of this work many men visited practically all the countries of the world and the two vessels used in the ocean survey sailed many times over all the seven seas.

More than 180 expeditions have determined the values of magnetic elements at 5,800 land stations and 600 of these were repeat observations giving information as to secular-variations or change constantly taking place. The ten ocean expeditions have determined the magnetic values at 6,000 stations at sea, and secular-variation data have been secured at over 150 localities where cruises have intersected, involving from 2 to 10 stations at each intersection.

Continuous records of the changes in the magnetic elements have been made for ten years at our permanent observatory at Watheroo, Western Australia, and for seven years at Huancayo, Peru. These two observatories were established in the Southern Hemisphere to supplement the work of other observatories maintained by the different countries of the world, chiefly in the Northern Hemisphere.

The investigation of the earth's electric field has been confined chiefly to the ocean expeditions and to our observatories in Australia and Peru. The values of the atmospheric-electric elements have been determined daily at sea during the cruises since 1914 and continuous records of their variations have been made at these two observatories for about seven years.

Thus the department has fairly completed the picture of the distribution of the earth's magnetic and electric fields over the surface of the globe and many additional facts have been recorded concerning the laws which control the variations in these fields.

In addition to the virtual completion of this general survey on land and sea, may I briefly outline some of the more specific contributions to the physical sciences made by the department during the past twenty-five years.

First, in theoretical studies, much progress has been made in locating the causes of the earth's magnetic and electric fields and of their many variations which are constantly taking place, in establishing relationships between magnetic and electric and other cosmical phenomena such as polar lights, variations in radio conditions and changes in solar activity. Practically all variations in magnetic, electric, earth current, radio conditions on our globe and in polar lights can be connected with some activity on the sun. That these fields are modified when the sun's rays are cut off from a portion of the earth and of its atmosphere during a total eclise of the sun by the moon has been shown conclusively by the results of seven eclipse expeditions sent out by the department since 1905.

Considerable advance has been made in the study of the nature of magnetism and electricity and atomic structure. It has been found that certain bodies become magnetic due to rotation and conversely that rotation may be caused by magnetization. These facts have been confirmed by extensive experiments made in the department's experimental laboratories at Washington.

During the past few years more attention has been paid to a study of the structure of the atoms and in devising methods and instruments for detailed experiments. To produce high-speed electrical particles, available voltages of 5,200,000 volts have been obtained and methods for handling and applying this power are being perfected.

Laboratory experiments also have proved the existence of the Kennelly-Heaviside radio reflecting layer and its height and variations have been determined.

In atmospheric electricity, a study of the ocean results shows that the daily variation in the earth's electric charge, the so-called potential-gradient, is a function of universal time and not of local or sun time. A similar variation occurs in the theoretical current induced by the action of the rotating magnetic field of the earth on charged particles coming into the earth's atmosphere from the sun.

These facts shed new light on some of the fundamental problems of cosmical physics.

More concretely, magnetic charts issued periodically by the various governments for the use of navigators have shown marked improvement. Twenty-five years ago, errors as great as 3, 5, 10 and even 16 degrees occurred in the declination charts; 8 to 10 degrees in dip and 10 per cent. in horizontal intensity. The charts recently issued are rarely in error more than 1 degree.

An international magnetic standard has been determined and adopted. Our standard instruments have been compared with those of practically every observatory in the world, so that now all observations may be reduced to the same standard and used in any general analysis or discussion without any uncertainty.

This leads to probably the most important factor in the department's contribution—the advance in instrumentation. Research in the physical sciences can go forward only as rapidly as new methods and instruments are designed. This has been particularly the case with this department. New design and new instruments have been the cause of progress. The man chiefly responsible for this advance is now our assistant director, Mr. J. A. Fleming. The ocean work called, and is still calling, for new designs to allow for improved results and for expanded program. Land work and our new observatories have had similar histories. Especially is this true for atmospheric-electric and earth-current equipment. At no other observatory in the world is the equipment in these two branches so complete.

Some of these new instruments have been adopted by other countries and the department's influence has been felt in many ways, leading to improvements in methods and results, extension of surveys, increase in numbers of observatories and expansion of observatory programs. Among the factors exerting this influence may be mentioned the quarterly journal, *Terrestrial Magnetism and Atmospheric Electricity,* the prompt publication of results, the generous support of expeditions with loaned equipment and training of observers, the personal contact through observatory intercomparison and through visits of interested scientists to our laboratory in Washington and through the visits of the *Galilee* and *Carnegie* to many parts of the world.

J. P. AULT

Address by Dr. Adams

The return of the *Carnegie* from distant seas with all the store of information which it has collected can not fail to stir the imagination deeply. It has brought us knowledge of the electric and magnetic currents of the earth, so vital to the mariner's compass, of life in the great depths of the sea, of the constitution of the ocean-floor, and of the mysterious winds of radiation which sweep the face of the waters from the depths of space. And yet this ship and the work of the men who have labored in it represent but one phase of the activities of the Carnegie Institution of Washington in promoting and extending the growth of knowledge. During the twenty-five years of the life of this great research organization there have been few branches of scientific thought to which it has not made notable contributions: and were one to attempt to define the field of its activity this could hardly be stated in terms less broad than as the history and development of life in all its forms, its relationship to its environment, and the nature of the physical world within which it exists.

One of the well-known younger writers of England in a skilful analysis of some of the aspects of modern life has stated that the progress of civilization is due to those who do the unnecessary work of the world. The author, the artist, the musician and the scientist are not contributing directly to the satisfaction of the material wants of men, and it is in this sense that Aldous Huxley uses the term "necessary." But if the word is extended to include what is vital and needful to the mind and spirit of men, the craving for beauty and for knowledge so deeply implanted within us, the unnecessary work of the world in a material sense becomes its most precious heritage and the distinguishing factor in the progress of the race. The dark ages of mankind are recognized, not as the periods of decline in material comfort, but as those within which the creative faculties are temporarily eclipsed, and the light of learning and discovery is dimmed. It is probable that the conditions of living in Europe about the year 1000 A. D. were superior to those in ancient Greece, but as between the contributions of the two periods to the culture and intellectual life of the world no comparison is possible.

The space of twenty-five years covering the life of the Carnegie Institution has seen by far the most extraordinary development of the physical sciences for any comparable period in history. It has been a time of remarkable discoveries, but, even more important, it has been a time of synthesizing of results, of establishing general principles and rules, and of placing facts in their proper relationship to one another and to the fundamental laws of nature. The last quarter of the nineteenth century might be characterized as a period in which isolated facts were observed and collected: the first quarter of the twentieth century as one in which these facts and many others were explained on the basis of broad and far-reaching generalizations. Between the relative values to the progress of science of these two types of contribution there can be little comparison; and it is the immense importance to research of new methods and new principles which makes the work of the bold but judicious imagination so essential a factor in the development of knowledge.

As an illustration of the value to science of a powerful and well-grounded theory, I should like to refer briefly to one taken necessarily from the field with which I am most familiar. If a metal like iron is melted and then vaporized in a furnace of very high temperature, and the light of the glowing gas is analyzed it is found to consist of a great number of lines characteristic of this metal, and this metal alone. Hydrogen has its own set of lines, carbon another, and so for all of the ninety elements known to the chemist. These lines are found in the light of the sun, the stars and even the immensely distant nebulae; and just as the chemist uses their presence in the analysis of materials in his laboratory, so the astronomer uses them to analyze the composition of the farthest stars.

The amount of observational labor devoted to the study of the spectral lines has been enormous. Their positions, their intensities, the nature of their variations and many other data have been catalogued, all in the realization that locked up in these lines is a wealth of information concerning the constitution of the atom and of matter which could lead to applications of the most far-reaching character. The key to the problem was provided by the theory of the atom developed by the great Danish physicist Bohr. This led at once to the first rational explanation of the mechanism by which an atom gives out light and radiation, and opened the way to the interpretation of essentially all that had previously remained unknown. Developments and applications have followed one another with amazing rapidity, the great mass of accumulated observations has been brought into a consistent and logical order, and the range of our physical knowledge has been steadily widened until it stretches from atom to sun, from sun to star, from star to universe. By its aid we can measure the life of a radiating atom in a star at the limits of our universe in billionths of a second of time, and the temperature in the interior of our sun in tens of millions of degrees.

A second marked characteristic of recent developments in science has been the realization of the intimate relationship, we may even say interpenetration, of its various branches. No department of physical science is sufficient unto itself. Biology and astronomy lean heavily upon physics and chemistry; physics depends more and more upon mathematics;

and, as the methods of statistical mechanics become more widely applied, the greater becomes the need for adequate check and control through the facts of observation. An excellent illustration is afforded by one of the important discoveries of recent years, that the molecule of oxygen, the basis of the whole system of the atomic weights of the elements, exists in two forms instead of the single form universally assumed. The discovery belongs to the field of chemistry; but the practical evidence was afforded by astronomical observations at Mount Wilson; and its interpretation is due to the theoretical physicists of the University of California working through intricate mathematical processes. I think it may justly be said that the Carnegie Institution has been a leader in the realization of this close interdependence of the various fields of science, and of the power for research of groups of coordinated investigators. Many of us will see to-morrow at Stanford University the dedication of a new laboratory in which will center the studies of men of wide diversity of training who are joining in a common effort to solve many of the great problems of the life and growth of plants and their adaptation to environment.

A very interesting development in modern science has been the remarkable boldness in the use of hypothesis, and the success which in nearly every case has attended it. A period which has produced the theory of relativity with its profound implications in science and philosophy, and has solved the age-old problem of the source of energy in the universe through the well-established theory of the conversion of matter into radiation, is certain to rank high in any history of the triumphs of the human mind. Although a speculative hypothesis of itself is often futile, that which is founded upon the facts of observation, and is developed to keep pace with them, becomes frequently the most powerful weapon of research within the capacity of science to use. It is this application of the highly trained imagination to the facts of nature which has made so extraordinarily productive the years within which we are living.

In any summary of the contribution of physical science to society chief stress is often laid upon the fundamental nature of the relationship of pure science to all inventions and processes which tend to increase the comfort and the productivity of men, and their ability to control and direct the forces of nature. The familiar example of the growth of the entire electrical industry of the world out of the scientific researches of Faraday is only one of innumerable instances. But the intangible effects of science are in many respects more interesting. Of its function in satisfying one of the deepest interests of life, the joy of discovery and the love of knowledge, I have already spoken. In its influence upon the judgment of men, their reasoning powers and the skilful weighing of evidence, its value is extraordinarily great. But perhaps beyond all else is the kindling and stimulation of the imagination. The child clothes with his imagery the simple things of nature; the intelligent man finds the phenomena of nature wonderful beyond all conception, and in the reaction to them of the powers of his imagination he finds one of the most enduring values of life.

Of the many and varied contributions of the Carnegie Institution to physical science it is impossible to speak in detail. They form an integral and vital part of the history of knowledge. Its investigators have studied deeply into the mysteries of life and the development and modification of species; they have searched into the complex processes by which the animal and vegetable life of the earth derives its growth and energy; they have added greatly to our knowledge of the past history of life upon the earth, and have welded links in its unbroken chain; they have studied the powerful forces within the earth, and have charted the magnetic field about it; they have numbered the stars and pushed far back the frontiers of the universe; they have penetrated deeply into the mysteries of matter and the world of space and time. Extending through all of these and many other investigations has been the realization of the unity of science and of the essential part it plays in the life of the race. On this anniversary of the establishment of the Carnegie Institution it may justly be said to have fulfilled amply the hopes of its founder in carrying the torch of learning and spreading its light among men.

Walter S. Adams

OBITUARY

RECENT DEATHS

Dr. Morton Prince, professor of neurology at Tufts College and later associate professor of abnormal and dynamic psychology at Harvard University, died on August 31 in his sixty-fifth year.

Dean Frederick Franklin Moon, head of the New York State College of Forestry for nine years, died following an operation on September 3 at the age of forty-nine years. Mr. Franklin D. Roosevelt, governor of New York State, wrote as follows: "The sudden death of Franklin Moon, dean of the State College of Forestry, comes to me as a great shock. I saw him not long ago and he seemed to be in fine health and spirits and very much interested in the program of reforestation for the State of New York. Under Dean Moon the State College of Forestry at