L. A. DuBridge

RESEARCH AT THE INSTITUTE

Research highlights from the Annual Report of the Institute, 1948-49

IN HIS ANNUAL REPORT for the year 1948-1949, which is being released this month, President DuBridge remarks that "this year has been one of normal steady progress without either spectacular new developments or difficult crises."

Nevertheless, the reports from the chairmen of the various divisions, on research conducted during the year, make some of this normal steady progress seem pretty spectacular after all.

Though it is obviously impossible to make even a cursory listing of all the research projects which were underway at the Institute last year, it is at least pertinent to note a few of the more impressive accomplishments of each division during the year.

Here, then, in the following pages, are some of the highlights from the reports of the divisions on research in progress—and progress in research—at the Institute in 1948-1949.

BIOLOGY

Smog Investigations

A DIVISION OF BIOLOGY might seem to be the least promising of all places in which to learn about industrial air pollutants. But the biologist has been forced to develop methods by which minute amounts of various chemical substances can be studied. Vitamins, hormones and other biologically active substances often produce significant changes in living things in amounts as low as one millionth of an ounce per individual per day. The result has been the development of laboratories of microanalysis in which routine analyses are made with incredibly small quantities of material.

The Institute has in its Biology Division such a laboratory—under the supervision of Professor A. J. Haagen-Smit. It was therefore not really remarkable at all that the Los Angeles County Air Pollution Control District should turn to him for assistance in determining just what are the dangerous and annoying eye-irritants in local smog. In an amazingly short time Professor Haagen-Smit tracked down the offending substances and identified them as organic peroxides—carbon-containing compounds related to the familiar hydrogen peroxide of the corner drug store. These are known products of the burning of hydrocarbons. While the biology laboratories are not designed to do such purely public service work, the Division is proud to contribute to public welfare when its facilities are necessary because of uniqueness and when the problem is in obvious and urgent need of solution.

Chemically Induced Gene Mutations

In 1865 the Austrian monk Gregor Mendel postulated the existence of units of inheritance that we now know as genes. After lying dormant for 35 years his theory was revived and developed with great vigor in both

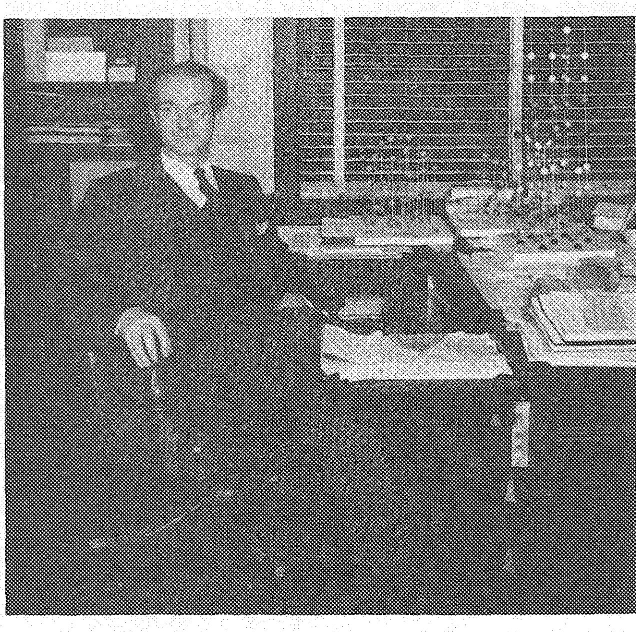
Europe and America. After the rediscovery, it was soon learned that genes are mutable, that is, that they suddenly become permanently modified so as to modify the character of the individuals of a plant or animal species that inherit the changed gene from its parents. But for many years—until 1926 in fact—it was thought that gene mutations were just accidents, beyond the control of man.

In 1926, Professor Herman J. Muller, then of the University of Texas and a former student of Thomas Hunt Morgan, made the important discovery that X-rays could increase the frequency of gene mutations a hundred fold or more. At once a new field of investigation was opened. How do X-rays produce this effect? What other high energy radiation will act similarly? Can mutations be produced by chemical treatments? Advances at first seemed rapid and spectacular. The so-called "direct hit" hypothesis of radiation-induced gene mutations was proposed and appeared to be supported by many experimental facts. It postulates that as a result of absorption of energy in a gene a direct chemical modification is produced.

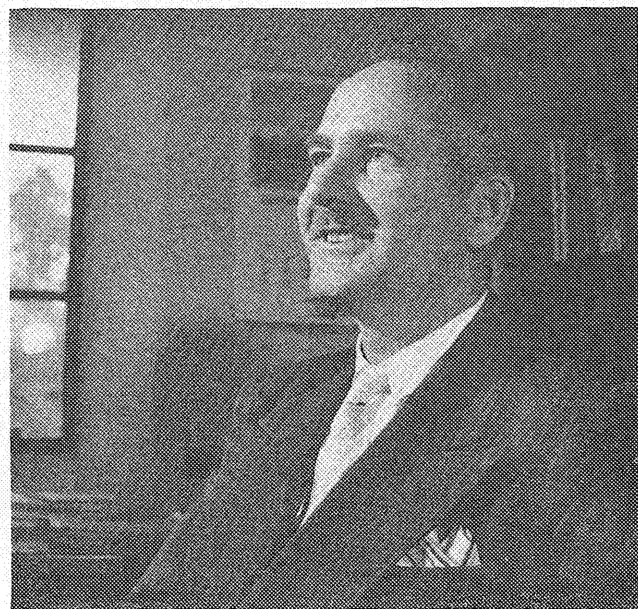
Within the past few years the growing doubts as to the correctness of the direct hit theory were strengthened when Stone, Wyss and Haas of the University of Texas found that certain types of mutations are induced in bacteria if a culture medium in which they are grown is irradiated with ultraviolet *prior to adding the bacteria to the medium*. For several reasons peroxide formation was suspected as a factor in this mutation production.

At this point in the story two graduate students at the Institute entered. They were Frank H. Dickey and George Cleland, both at the time candidates for the Ph.D. degree with majors in organic chemistry and minors in genetics. During the war Mr. Dickey worked with organic peroxides and became an authority on them. On theoretical grounds he believed that induced mutations in general—those produced by direct irradiations of the organism, those resulting from irradiated medium, as well as those resulting from mustard gases—could be the result of organic peroxides as mutagenic intermediaries.

As graduate students, Dickey and Cleland carried out a series of experimental tests of the Dickey peroxide theory. The results were so promising that it was obviously highly desirable to push the work vigorously. Mr. Dickey (now Doctor Dickey) was awarded a Noyes Fellowship by the Division of Chemistry with the understanding that a part of his time would be devoted to studies on the mechanisms by which chemical mutagens produce their effects on genes. Technical assistance and laboratory facilities for this work are currently being supplied in Kerckhoff Laboratories by the Biology Division.



Linus Pauling, Chairman of the Division of Chemistry and Chemical Engineering



George W. Beadle, Chairman of the Biology Division

Dickey's peroxide theory of gene-mutation may well prove to be an outstanding example of progress in understanding living systems through collaboration of chemistry and biology. It is certainly an example of how the attack on an important biological problem can be assisted by collaboration such as is encouraged by the joint Chemistry-Biology research program at the Institute.

Virus Research

Viruses are important to man because they produce many serious diseases in him and in the plants and animals on which he depends directly or indirectly. But the fact that many viruses produce diseases of direct significance in man's existence is not the only reason for learning about them. They represent the simplest systems known to possess the properties of self-multiplication and mutations, two fundamentally significant characteristics of all things that live. Like genes, the units of self-multiplication and mutation of higher plants and animals, viruses are composed of giant nucleoprotein molecules.

At the Institute two viruses are being studied, tobacco mosaic virus, which is the first virus to be isolated in pure crystalline form (by Wendell Stanley in 1937); and a virus that attacks and kills the colon-bacillus. The latter is known as a bacteriophage or bacterial virus.

Several phenomena of significance in bacterial virology are currently being investigated at the Institute and elsewhere. One of these is the production of recombination types when two related viruses infect a single bacterial cell. This has been extensively studied by Doctor A. D. Hershey who spent the first half of 1948 at the Institute. It is found that permanent recombination types are found in definite proportions, indicating that the bacterial virus contains units like the genes of higher plants and animals and that there is some recombination mechanism, possibly involving a primitive form of sexual reproduction. A similar conclusion is reached by Dr. S. E. Luria of Indiana University who finds that viruses inactivated with ultraviolet radiation may be reactivated if two or more viruses, each inactive if adsorbed singly by a bacterium, simultaneously infect a single bacterial cell.

Dr. Albert Kelner of the Long Island Biological Association Laboratory at Cold Spring Harbor, Long Island, New York, discovered during the past year that certain bacterial spores inactivated with ultraviolet radiation can be reactivated with visible light. This remarkable finding was very soon extended to bacterial viruses by Doctor Renato Dulbecco of Indiana University, and to Neurospora asexual spores by Mr. Albert Siegel, a graduate student at the Institute. Doctor Dulbecco will continue his studies of photoreactivation of bacterial viruses during the academic year 1949-50 in the laboratories of Professor Delbrück. Such studies may well provide entirely new clues as to how living systems are constructed and how they operate.

CHEMISTRY

■ Special mention may be made of two discoveries, the discovery of a method of manufacture of specific adsorbents, and the discovery that a certain disease is a disease of a molecule, the hemoglobin molecule, rather than a cellular disease.

Frank H. Dickey, DuPont Fellow in Chemistry, who received his Ph.D. degree in June 1949, made an important contribution to the general technique of chromatographic analysis when he discovered a way of preparing specific adsorbents to order. The technique of chromatographic analysis, in which Professor László Zechmeister is a leading authority, is very useful for the separation of substances from complex mixtures. It is especially useful in the investigation of natural products.

In applying this technique a substance such as silica gel is packed into a glass tube and a solution of the mixture to be separated is poured over the column of adsorbent and then developed by the passage of additional solvent through the column. The different substances in the mixture are absorbed with different strengths to the silica gel, and accordingly move down the column at different rates.

A difficulty in applying this technique is that it is not always possible to find an adsorbent that has the power of holding the substance in which one is interested more strongly than other substances. Dr. Dickey found that by preparing silica gel in the presence of a particular substance, and then afterward removing the substance by treatment with a solvent, the silica gel made in this way has a special power of attracting that particular substance, and can accordingly be used to separate that substance from others. He found that it was possible to increase the power of adsorption of silica gel made in this special way for a particular substance by as much as 20-fold by the application of this technique. It is likely that this discovery will lead to many important advances.

During the past three years Dr. Harvey Itano, at present U. S. Public Health Service Fellow in Chemistry and formerly American Chemical Society Fellow, has been studying the disease sickle-cell anemia, in collaboration with Professor Linus Pauling. This disease is responsible for about 10,000 deaths each year, and no satisfactory therapeutic treatment is at present available.

During the past year Dr. Itano and Dr. S. J. Singer (U. S. Public Health Service Fellow) discovered that the hemoglobin contained in the red cells of patients with this disease is different from ordinary human hemoglobin, in respect to its chemical composition and its electrical charge. It seems to be this difference in the nature of the hemoglobin molecule (which is determined by genetic factors) that is responsible for the symptoms of the disease. This is the first time that any adult human hemoglobin different from the normal hemoglobin has been found. The investigation of sickle-cell anemia hemoglobin is being continued, in the hope that information may be obtained which can be used in developing a therapeutic treatment of the disease.

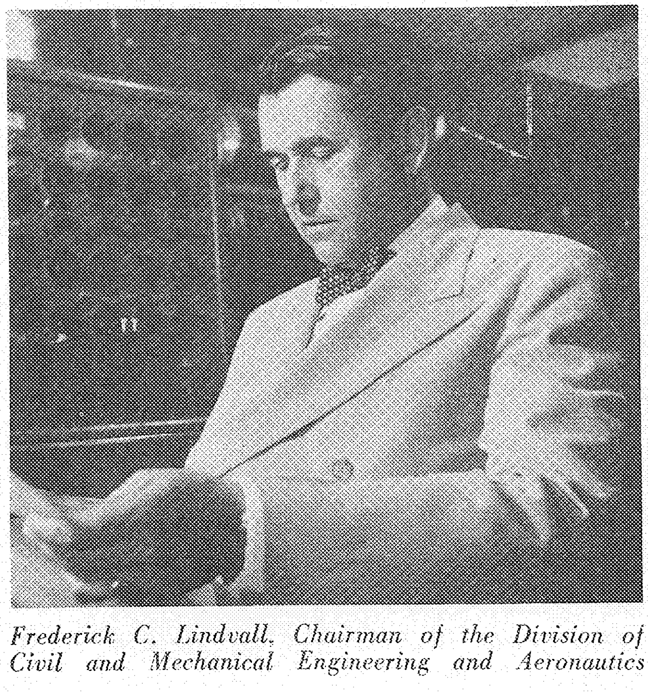
ENGINEERING

Civil Engineering

■ In research, the principal increase in effort has been the study of the response of building structures to earthquakes. This work has been implemented by a contract with the Office of Naval Research for a systematic analysis of seismograms obtained on a nationwide basis by the U. S. Coast & Geodetic Survey. The response of arbitrary building structures to these earthquakes is to be analyzed with the Institute's Analog Computer. This work is the first large-scale systematic study of this type.

Mechanical Engineering

■ Research in rapid loading of materials is continuing under sponsorship of the Office of Naval Research. The initial project for study of the axial flow compressor, which has been under way for two years, as an ONR contract, has led to a final report, and the work is to be continued under contract extension through 1950.



Frederick C. Lindvall, Chairman of the Division of Civil and Mechanical Engineering and Aeronautics

Hydrodynamics

■ In the Hydrodynamics Laboratory fundamental work in cavitation has been of primary interest in the water tunnel and in particular in studies of rotating channels. This latter work is producing results of fundamental significance to designers of centrifugal turbines and pumps.

The studies at the Azusa laboratory on the Guam Harbor model have been completed, and this program has been extended to include fundamental studies of arbitrary shapes and inlets to establish design criteria for harbor works.

The Soil Conservation Laboratory, which has been inactive during the past year, will provide facilities for work on a new contract with the Office of Naval Research on the general subject of fluid transport of particulate matter.

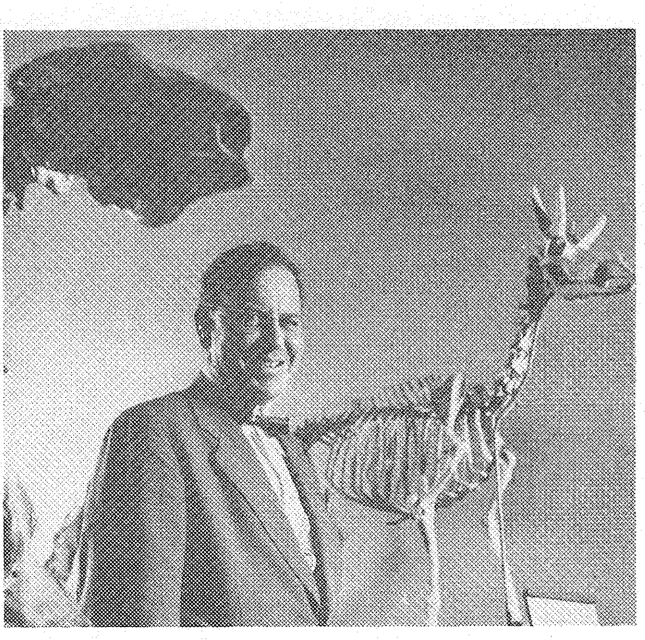
Applied Mechanics

■ Under an Army Engineer Corps contract fundamental studies have been in progress on soil compaction by vibration. Methods have been developed for measurement of static and dynamic physical properties of aeolotropic granular media. Concurrent theoretical work on such aeolotropic media has materially advanced the analytical approach to the soil compaction problem and is about to be correlated with the experimental data.

Aeronautics

■ *Experimental Fluid Mechanics*—Researches in turbulence and transonic flow have been energetically pursued, and work in supersonic aerodynamics has also been actively pushed with significant results. The 10-foot wind tunnel has been utilized to an increased extent for low speed, aerodynamic investigations.

Theoretical Fluid Mechanics—The fundamental investigation of the mathematical foundations of viscous compressible flow (sponsored by the Office of Naval Research) continues as one of the most significant of the department's activities.



Chester Stock, Chairman of the Division of the Geological Sciences

Elasticity, Mechanics of Solids, and Structures—A program of fundamental research on the analysis problems of thin, swept aircraft wings, sponsored by the Air Force, is being continued. An experimental investigation of a promising new type of metal sandwich construction was carried out under contract with the Bureau of Aeronautics. And research programs were continued on the fatigue properties of aircraft materials, loads in aircraft landing gears, and on the plasticity of aluminum alloys.

JET PROPULSION LABORATORY

■ The shift in emphasis from applied research and development work to basic engineering research continued steadily through the year. An example of an outstanding practical application toward which the Jet Propulsion Laboratory has contributed is the Bumper-WAC, a two-stage vehicle which attained 250 miles altitude when fired at White Sands Proving Grounds, New Mexico. The research program for 1948-1949 has covered:

Propellants—The physical properties and performance of both solid and liquid propellants, as well as the kinetics of their combustion, have been studied. For example, liquid hydrogen and liquid oxygen have been operated in a regeneratively cooled rocket for the first time.

Materials—The study of porous metals for "sweat cooling" has been continued to the point where large-scale fabrication for specific applications can be undertaken. And the investigation of refractory oxides suitable for rocket liners has been extended to some of the nitrates, for which suitable methods of pressing and sintering are being sought. A new program of considerable promise is the study of titanium and its compounds as structural materials.

Combustion — Several large-scale phenomenological studies of combustion in burners have been completed during the year. These studies have led to an understanding of the practical, empirical limitations that the combustion process imposes on flameholders, injectors and ramjets.

Heat Transfer — Progress has been made in understanding the process of cooling by a *boiling* fluid at high heat flux densities. Bubble growth and collapse have been photographed with a very high-speed camera using a Kerr cell shutter.

Fluid Dynamics — In the field of hydraulics, studies have been made of the pressure losses in helical coils and of the phenomena of jet atomization into low-pressure chambers.

GEOLOGY

■ During the year C. F. Richter began a study of the seismograms of the Desert Hot Springs earthquake (near Palm Springs) of December 4, 1948. Shortly after the earthquake instruments were installed at Desert Hot Springs to obtain records from two points situated close to the epicenters, which, in addition to records from eight permanent stations, promise to supply important data on the location of the aftershocks, as well as on the change in position of epicenter and depth of these shocks with time.

The work on rock creep by Dr. Hugo Benioff, which began as an attempt to determine the origin of aftershocks, has been expanded considerably during the year. With regard to aftershocks, his results appear to show that these are, in fact, produced by elastic afterworking of the fault rocks.

Application of the creep method to sequences of earthquakes has yielded some unexpected results. With the aid of the Tonga-Kermadec sequences in the South Pacific Ocean, for example, it was possible to discover the existence in this region of a great fault some 2,500 km. in length by about 900 km. in transverse dimension. A similar study of the South American sequences has indicated the existence of an even larger fault off the coast of South America, which extends some 4,500 km. in length. These two great faults are very much larger than any hitherto known.

Professor C. Hewitt Dix has continued his study of the gravity field of the earth. In connection with this investigation, two projects may be specifically mentioned: (1) The observation of relative gravity taken with a LaCoste and Romberg gravity meter at approximately 300 U. S. Coast & Geodetic Survey bench marks, and (2) A study of the yielding of the earth to tidal forces by observing gravity every half hour for three days in Room 0012, Mudd Laboratory, California Institute, just before full moon and for two and a half days at Mt. Wilson just after full moon. The measured yielding was found to be significantly different at the two locations.

Professor John P. Buwalda is compiling information on the origin of San Gorgonio Pass, one of the great gateways to southern California. Its origin has never been satisfactorily explained.

Professor Ian Campbell has initiated, in cooperation with Mr. L. A. Wright of the California State Division of Mines, a program of research on the kyanite deposit near Ogilby, California. Kyanite is a relatively rare mineral, and the deposit at Ogilby is one of the largest known occurrences in the western United States. The mineral is of fairly simple composition, yet, unlike the majority of simple silicates, all attempts to synthesize it have thus far failed.

PHYSICS

■ *Cosmic Rays and Fundamental Particles* — It has been known for several years that cosmic ray mesons of the type found at sea level undergo spontaneous decay with a mean life of slightly over two-millionths of a second and that an electron is emitted in the decay process. In the past year Professors C. D. Anderson, R. B. Leighton and their students have measured the energy of 75 of these decay electrons. The results show that the decay electrons are not emitted with a unique energy as was previously supposed, but instead that there is a broad distribution in energy from very small values to an upper limit of 55 million electron volts. From these results it can be concluded that the meson decays with the simultaneous production of an electron and *two* neutrinos. The upper limit of the energy spectrum leads to a value of 217 plus or minus 4 electron masses for the mass of the meson.

A small number of cosmic-ray mesons occur with exceedingly large energies. Preliminary results obtained by Professor Anderson's group extend the measurements of the energies of these particles to 40 billion electron-volts as compared with the previous upper limit of 20 billion electron-volts.

Professor Anderson is also embarking upon a program for the detailed study of the high energy nucleon-nucleon collisions that occur in the cosmic rays. Such collisions in which the incident nucleon has several billions of electron-volt energy are extremely complicated and result apparently in the simultaneous production of protons, neutrons, heavy and light mesons, positive and negative electrons, and photons.

Robert F. Bacher, Chairman of the Division of Physics, Astronomy and Mathematics

Nuclear Physics — Research in the Kellogg Radiation Laboratory under the directions of Professors C. C. Lauritsen, W. A. Fowler, and T. Lauritsen during the past year has progressed along these lines:

The 8 x 13-foot electrostatic generator has been employed continuously on various problems in nuclear spectroscopy. A precision determination to one part in 200,000 of the mass of the neutron was made during the year, and numerous new energy levels in light nuclei were found. Gamma radiation from the capture of protons by deuterons has also been discovered.

The most difficult and significant accomplishment in the past year by Professor J. W. M. DuMond, Dr. D. A. Lind and their co-workers has been the extension of the scale of the 2-meter curved-crystal gamma-ray spectrometer to include the gamma-ray range well above 1,000,000 electron-volts. Their work on the Co^{60} lines establishes an all-time record for the shortest wave lengths ever directly measured. In addition, the precision calibration of the 2-meter curved-crystal gamma-ray spectrometer with X-ray wave lengths has been effected for the first time.

Electrical Engineering

■ Last year's report indicated that the then newly constructed McCann analog computer and the Analysis Laboratory of which it is the nucleus comprised the outstanding advance of the year in the engineering facilities of the Institute. During the year 1948-49 the laboratory has surpassed even the highly optimistic predictions made for it. The demand for its use by industry having difficult problems to be solved has occupied practically all of the available time for such work. Contracts with government agencies such as ONR, the Coast & Geodetic Survey, Bureau of Ordnance, Naval Ordnance Test Station, as well as for industrial service indicate that during the coming year the laboratory will be taxed to capacity, and thus the cost of operation will be assured. Some of the problems already set up include studies of the effect of earthquakes on buildings, guided airborne missiles performance, and underwater missile research.