California Institute of Technology

Annual Report

1949-1950

Annual Report

TO THE BOARD OF TRUSTEES

1949-1950

Comprising the Reports of the President,
the Comptroller,
and Other Administrative Officers

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Part I

THE REPORT OF THE PRESIDENT

To the Board of Trustees:

I have the honor of presenting to the Board of Trustees of the California Institute of Technology a report of activities for the year 1949-50.*

The University and the Nation

Each year the President's Report has opened with a few comments on the ways in which Institute activities have affected, or been affected by, national problems and events. It is appropriate that this should continue to be our practice, since it is becoming increasingly clear that institutions like the California Institute are performing important functions in advancing the welfare and security of the nation as a whole. The services rendered by our institutions of higher education and research are of great importance in times of peace; in troubled times they become even more indispensable.

One year ago it was possible for me to report that "in the national scene there have been no major events which have had noteworthy impact on Institute activities." That statement is obviously not true today. World events of recent months have already had their impact, and it seems highly probable that in the year to come the Institute will be called upon to render services of many sorts to the nation and to the government in this time of need.

Even before the outbreak of the Korean emergency, the increasing complexity of our international problems had resulted in calls upon the Institute staff for government service. Mr. Horace Gilbert, Professor of Economics, was given leave of absence for the past year and until December 31, 1950 to serve as economic advisor to Mr. McCloy, the U. S. High Commissioner for Germany. In June 1950, Dr. H. P. Robertson, Professor of Mathematical Physics, was granted leave of absence for one year to serve as scientific director of the Weapons System Evaluation Group of the U. S. Joint Chiefs of Staff. In addition, a dozen or more members of the Institute staff have been serving during the past year on important governmental advisory committees or boards.

The outbreak of hostilities in Korea resulted in increased demands upon the staff and has called for more intensive work on the part of

*This report is officially for the fiscal year ending June 30, 1950. Since the annual meeting of the Board of Trustees was not held until November 6, 1950, a few items and events of the Summer and early Autumn of 1950 have been included.

those already engaged in governmental activities. Dr. C. C. Lauritsen, Professor of Physics, was asked to make a six weeks' trip to Korea to report on the use and requirements of various new weapons. The Institute's Jet Propulsion Laboratory has been called upon to make alterations in its program and increase its efforts in certain areas. It is evident that the expanded program of military research may also involve the Institute in other ways which cannot now be foreseen.

In order to meet some of the present and anticipated problems arising from the emergency, two Faculty committees have been established. One will examine the ways in which the Institute staff and facilities can be most adequately and effectively employed. The other will study problems arising from calls on staff and students from Selective Service or mobilization of Reserve Officers.

In a certain sense, the Institute faces now the problem of mobilizing to serve the nation in time of emergency. However, it must be remembered that in a very real sense the Institute is *always* mobilized. Its regular program of education and research in science and engineering is vital to national welfare and security in peace or in war. To disrupt these activities at this time would be highly dangerous. If, as seems probable, we are now facing a protracted period of "partial mobilization" it is of vital importance to continue and even to accelerate the rate at which our supply of young scientists and engineers is being built up. During the past four years the shortage of scientists and engineers, caused by the cessation of training during World War II, had just about been overcome. Now, however, the demand for such men is taking another upward spurt, and the training schedules should be increased accordingly.

In a period of long-continued emergency, it is also important to continue and accelerate *basic* research. From this research will come the new knowledge from which new applications of importance to national welfare and security will emerge. It would be as foolish to reduce our basic research activities in this country at this time as to reduce our production of steel and other critical materials.

For these reasons, it is essential that the Institute now remain strong, that it conserve its resources and improve its program. To this end it is important that we retain intact, to the greatest extent possible, our "team" of educators and research workers—one of the most competent and most closely integrated of all research teams in the world. Individual members of this team will, of course, be called upon to serve, either in part-time capacities or on leave of absence for short or long periods, in such capacities as are most appropriate to their talents and experience. Furthermore, the members of this team will remain continually alert to the problems of national de-

fense and to possible ways of converting the basic knowledge of science or engineering to the development of instruments or techniques to assist in solving these problems. But to be of maximum ultimate value the team should remain at "home base."

It is important in this period that a proper balance be maintained in the nation's research program; some effort should be devoted to immediate applications, some to development programs of one, two or three years' duration, and the rest to basic programs of longer range importance. The immediate—and intermediate—range programs will be largely the responsibility of government laboratories, but the universities retain primary responsibility for the longer range programs.

America's scientific resources and manpower constitute one of its greatest assets. The California Institute is an important center of strength, and it is incumbent upon all of us to see that this strength is maintained.

Faculty

Dr. Royal W. Sorensen, Professor of Electrical Enginneering and Chairman of the Division of Physical Education, retired from active service on September 1, 1950 after forty years of service to the Institute. Fortunately, he will continue a portion of his teaching and research activities on the campus. The great respect and affection in which he is held by his students was exhibited when it was announced at the Annual Alumni Dinner on June 7, 1950 that a group of former students had contributed funds to establish a permanent fellowship in electrical engineering to be known as the "Royal W. Sorensen Fellowship."

The major new appointment to the professorial staff was that of Dr. Richard Feynman, who comes to us from Cornell University as Professor of Theoretical Physics. Dr. Feynman is without question one of the leading young theoretical physicists in the country, renowned for his originality in research and for his brilliance as a lecturer and teacher. His addition to the physics staff not only lends distinction but rounds out our program of education and research in theoretical physics.

Dr. Alan R. Sweezy, formerly of Williams College, who assisted in the teaching of economics during Professor Horace Gilbert's absence, has now joined our permanent staff as Professor of Economics.

There were also 11 appointments of visiting professors, 6 new Research Associates, 4 Lecturers, 3 Assistant Professors, 3 Senior Research Fellows, 2 Instructors and 50 post-doctoral Research Fellows.

As in past years, many senior members of our Faculty have received very attractive offers of positions elsewhere either in industry,

in other universities or in government. The loss of some of these men would have been a serious blow, indeed, and it is a matter of great gratification that each of them decided to remain at the California Institute, often at a very considerable financial sacrifice. An educational institution can receive no greater tribute than the loyalty of the key members of its staff.

While our senior staff has remained relatively stable, there is every year a very considerable turnover among junior staff members. In fact, the California Institute operates a very substantial program of post-doctoral training for young scientists and engineers. Approximately 50 men who had already completed their graduate training came to the Institute this year on special fellowships or as Institute research fellows. These men normally remain for periods of from one to five years to assist with our program and to obtain additional research experience under the direction of some of the distinguished members of the Institute staff.

More and more also, the Institute is becoming a center to which well established research workers come for a few months or a year of work and study. It is tremendously valuable to our staff to have so many distinguished visitors here for brief or long periods each year, and we are honored by their desire and willingness to come. Among some of the distinguished visitors who have been present on the campus for varying periods (of a week or more) during the past year have been the following:

Visiting Professors:

J. M. Burgers, of the University of Leiden, Holland (Aero- and Hydro-dynamics)
Thomas G. Cowling, of Oxford University, England (Astrophysics)
Bryce L. Crawford, of the University of Minnesota (Chemistry)
J. B. Culbertson, of Cornell College (Chemistry)
Arthur C. Giese, of Stanford University (Biology)
R. M. Keefer, of the University of California (Chemistry)
Arthur W. Martin, of the University of Washington (Biology)
J. Robert Oppenheimer, Director, Institute for Advanced Study (Physics)
I. I. Rabi, of Columbia University (Physics)
Massimo Simonetta, of the University of Milan, Italy (Chemistry)
George Winter, of Cornell University (Structural Engineering)

Research Associates:

David R. Bates, of the University of London, England (Astronomy)
Sydney Chapman, Sedleian Professor of Natural Philosophy, Oxford University, England (Geophysics)
H. R. Crane, of the University of Michigan (Physics)
William M. Hiesey, of the Carnegie Institution of Washington (Biology)
Lord Rothschild, of Trinity College, Cambridge University, England (Biology)
Raymund Sänger, of the Swiss Federal Institute of Technology (Engineering)

It is of interest to note that the total number of full-time teaching

members of the Institute staff as of January 1950 was 160. In addition, there were 165 full-time research members of the staff not engaged in teaching (excluding off-campus contract operations), bringing the total number of full-time members of the teaching and research staff to 325. Our ratio of students to full-time *teachers* is therefore *6.9*, a remarkably low figure. In addition the "non-teaching" staff members frequently assist in directing the research work of graduate students, and there are many others who teach on a part-time basis.

Curriculum

The Institute curriculum is always under study. The Faculty Board and Curriculum Committee has the responsibility for reviewing all proposals for changes in courses and for maintaining a reasonable balance in each of the various specialized curricula. For many years it has been the Institute's policy to devote approximately 25 per cent of the student's time to nonprofessional and nontechnical subjects, that is, subjects within the Division of the Humanities. At the time this policy was inaugurated nearly 30 years ago, this was an unusually high percentage of time to devote to such studies in engineering schools. In recent years, however, most engineering schools have approached a similar standard.

The Division of the Humanities has been giving attention during the current year to possibilities for further strengthening our program in the humanities and social sciences. Under a grant from the Carnegie Corporation of New York, the chairman of the division, Professor Hallett Smith, made a two months' tour of Eastern universities and colleges to secure the latest information on successes and difficulties with programs under way at other institutions. Just as he returned, the Institute was informed that the Carnegie Corporation had made a grant of $150,000 to be spent over the next five years on the work in humanities and social science. The Institute warmly welcomes the support of the Carnegie Corporation. This grant will help us give our graduates a breadth of training which will make them not only effective scientists and engineers, but better citizens.

Student Enrollment

Student enrollment for the past year continued to show a decline from the postwar peaks. Ever since the war we have admitted only 180 men to the Freshman class, and last-minute withdrawals have usually reduced the actual size of the class to around 170. Until this year the upper classes have been somewhat larger because of the admission of returning veterans. Now, however, the peak of veteran

enrollment has passed, and we will consequently expect our total undergraduate enrollment to remain at its current level of about 650 students. Our freshman class this fall numbers 174 men; our total undergraduate body for the fall term numbers 645.

The graduate enrollment is limited by the high standards set for admission to graduate study. Each department also limits itself to the number of graduate students which its staff and facilities can adequately handle. At the conclusion of registration for the Fall term, 425 graduate students were enrolled.

The falling off in veteran enrollment is illustrated by the fact that while 72 per cent of the graduating class of June 1950 were veterans only 11 per cent of the freshman class were veterans. In the student body as a whole during the past year 39 per cent of the undergraduates and 60 per cent of the graduates were veterans.

Seventy Ph.D. degrees were awarded in June 1950, the highest number on record. It is noteworthy that of these Ph.D.'s 11 per cent took their undergraduate degrees at the Institute, 34 per cent were from other colleges west of the Mississippi, 39 per cent from east of the Mississippi, and 16 per cent from foreign countries.

The decline in the number of our students eligible for veteran's aid has meant, of course, a sharp rise in the need for other scholarship aid. A very considerable fraction of the students who apply for admission to the Institute also apply for scholarship assistance. Whether they come here or not depends often on whether we can provide the necessary scholarship aid. During the past year approximately 12 per cent of the undergraduate students received scholarships ranging in stipend from $100 to $600, for a total of $32,500. This is a sharp rise from the 1948-1949 figure of $19,575.

However, for the freshman class entering in the fall of 1950, scholarships have been awarded to 25 per cent of the students for a total of $22,400. This is more than twice the amount of the freshman scholarships awarded last year and three times the total amount awarded in 1948. This rise has taken place in spite of the fact that we have screened scholarship applicants even more carefully and are making awards only to outstanding students and then only in cases where there is clear evidence of financial need. The Institute is in urgent need of additional undergraduate scholarship funds. We trust that many individuals will wish to contribute such funds to aid efforts to assist able young men in securing educational opportunities.

There is an equal, if not greater, need for scholarship and fellowship funds for graduate students. Students who have completed their undergraduate training often find their own and their family resources exhausted. It has been pleasing to note that industrial corporations are becoming increasingly aware of this problem and are in-

creasing their fellowship grants to institutions. During the past year 20 graduate students received fellowship stipends provided by 13 different corporations to the total amount of $36,915. Several additional awards are available for 1950-51.

Though the number of applications for admission to the freshman class exceeds the number of places in the class, we still feel that there are many highly qualified students who should come to Caltech but who, for one reason or another, do not apply for admission. To a large extent, this appears to be attributable to the fact that high school students often lack adequate information about the opportunities here. Consequently, we are expanding our program for placing information about the Institute in the hands of high school students and teachers. We plan to supply more and better Institute publications to high schools, to seek the help of students and alumni in making direct contacts with students and teachers, and to increase the program of visits on the part of the Faculty to high schools in this area.

Student Health and Physical Education

Continued progress has been made toward the improvement of the Student Health Center. A clinical laboratory has been outfitted with the assistance of the Women's Service League. The Health Center Building has been redecorated and additional furnishings acquired. The Service League has helped in many other ways in the operation and improvement of the Health Center, including additional gifts of funds for equipment and furnishings and the provision of special foods and reading material for Infirmary patients. Members have also agreed to provide rotating assistance to relieve the nursing staff of the general care of bed patients and the serving of meals. It is now possible to say that our facilities for taking care of the health of the students are excellent, indeed, but, of course, we still look forward to the day when a permanent building will house the Health Center.

The student athletic and physical education program continued its advance toward our goal of 100 per cent student participation. For example, 62 per cent of the members of the freshman class played on one or more of the eight freshman intercollegiate teams. Thirty-four per cent of the senior class of 1950 played on the varsity teams during their student life at the Institute, and 25 per cent made varsity letters. Caltech teams participated in a total of 114 varsity and 63 freshman intercollegiate contests during the year. Caltech teams took second place in the Southern California Intercollegiate Athletic Conference in three sports: track, swimming, and cross country. However, the lack of championship teams does not discourage participation in intercollegiate sports, for our students recognize that in their

heavy laboratory programs in engineering and science the time which can be devoted to athletics is more restricted than in other colleges. This puts Institute teams at a serious disadvantage, especially in such highly organized games as football and basketball.

Our most healthy and congenial competition with other teams in the Southern California Conference continues. All colleges in this Conference have similar scholastic goals, and the Conference colleges have jointly adopted a firm policy of awarding no athletic scholarships. We believe our Conference approaches more nearly than any other Conference in the country the ideal of complete non-professionalism in intercollegiate athletics.

Most of the students who do not participate in the intercollegiate program participate in some of the intramural athletic programs. There is lively competition in the sports between the four student houses and the Throop Club. The intramural sports also give an opportunity to varsity players to extend their athletic activities throughout the school year, since the varsity player in football, for example, may participate in intramural basketball and track.

Professor Royal W. Sorensen, who has been in charge of the athletic and physical education program at the Institute since 1913, retired at the end of this year. To him, more than to any other one person, the Institute owes a great debt for the development of the well-rounded program of athletics and physical education for all Caltech students. He took a leading part in the formation of the Southern California Intercollegiate Athletic Conference, and has been a prime mover in Conference activities ever since. His kindly, wise guidance of the athletic program will be sorely missed. Henceforth, the athletic and physical education activities will be directly under the supervision of H. Z. Musselman, who has been at the Institute since 1923. We can be confident that he will carry on the Institute's athletic traditions.

Employees

All too often college and university reports give extended attention to the problems and activities of students and faculty and neglect to mention the many nonfaculty employees without whom the institution would be unable to carry on operations. Therefore, I take this opportunity to express appreciation to the loyal service rendered to the California Institute by some 1260 nonfaculty employees. These men and women serve in the Business and Administrative offices, in the Buildings and Grounds Department, and as administrative and technical assistants in all divisions on the campus.

Two years ago some 150 employees who serve in supervisory or management capacities organized themselves into a Management

Club. This club has had frequent, well-attended and interesting meetings. One purpose of the club is to keep the members informed about Institute activities, policies and objectives. This most important function has been admirably performed. In addition, the club has raised funds to provide a scholarship for an able undergraduate student. This interest in the welfare of the Institute is most helpful and most gratifying. The Management Club and its officers and committees deserve great credit for this contribution to better employee morale and effectiveness.

The Industrial Associates

For many years, and especially since World War II, it has been increasingly evident that the industrial fabric of any country rests ultimately upon the fundamental research carried on in its institutions of higher education. The war showed how quickly the knowledge acquired in this research may be used to develop new weapons, new machines, new materials. It also showed that without this research, the stream of these new products will eventually dry up.

Accordingly, at the end of the war many large corporations realized that it would be good business to support the universities where fundamental research is carried on. They began to allocate money to them over and above the amounts they were already devoting to fellowships and specific research contracts.

In December, 1948, E. I. DuPont de Nemours and Company, Inc. transmitted a grant of $10,000 to the Institute as one of 10 institutions in the country selected for what is expected to be an annual grant for a period of years. A few weeks after that, the Standard Oil Company contributed $25,000 to the Institute, with the assurance that similar grants would continue for three years.

With these indications of business interest, the Institute proceeded with the development of a plan under which business might make allocations of funds to the Institute and receive concrete benefit in return. The outcome of this work was the organization of a group called the "Industrial Associates of the California Institute of Technology." This group officially came into existence on July 1, 1950, with the following companies as members: Douglas Aircraft Company, Inc., E. I. DuPont de Nemours and Company, Inc., Lockheed Aircraft Corporation, North American Aviation, Inc., Socony-Vacuum Laboratories, Standard Oil Company of California and Union Oil Company of California. In addition, four more companies signified their intention of joining the Industrial Associates and a number of others now have the plan under consideration.*

*As of November 15, 1950, the total membership was ten companies.

Under the terms of membership, an Industrial Associate is allowed access to fundamental research in all divisions of the Institute. Regular and special publications are sent to the company. Representatives of the company are invited to semi-annual seminars at the Institute where new developments in science and engineering will be presented, and these representatives are also given the privilege of a limited amount of consultation with Institute staff on problems of mutual interest.

In return for these services by the Institute, member companies pay a fee ranging from $10,000 to $50,000 a year, depending upon the size of the company and the extent of its interest in Institute research. This fee is considered by the companies as analogous to a consulting fee for technical information, and is charged as business expense. Fees paid by the member companies have now reached the level of $85,000 a year, and it is likely that this amount will increase for some years to come.

The drawing together for mutual support of independent companies and an independent research institution such as ours is a significant new development in the American economy. This trend will become more important in future years, and it is likely that smaller concerns will join the larger ones in gathering around the privately controlled universities to form "islands of independence."

The Campus

The major addition to the Institute campus during the past year has been the erection of the new Engineering Building. This engineering laboratory with 35,000 square feet of floor space was erected at a cost of $555,000 with funds appropriated by the Trustees from the Institute reserve funds. It constitutes a vitally needed addition to the space available for a program of education and research, particularly in the fields of mechanical and civil engineering. Inasmuch as these departments have vacated certain space in Throop Hall, additional space for electrical engineering laboratories and for administrative offices has also been made available. As was mentioned in last year's report, construction of this building was begun in the summer of 1949; the building was ready for occupancy in August 1950.

This new laboratory is a five-story building, including a subbasement, and is 136 feet long and 50 feet wide. It extends along the north side of the Olive Walk immediately behind Throop Hall, joining with the steam plant at its west end, while the existing mechanical engineering unit becomes a contiguous part of the new structure on the east. The building has been designed to provide great flexi-

bility in adapting the various rooms to a variety of purposes as needs develop. Class rooms, design rooms, student laboratories, research laboratories and office space are provided in convenient arrangements. Special dark rooms, drying rooms and a laboratory for work with radioactive materials are also provided.

Research Activities

The California Institute of Technology is one of the great centers for research in science and engineering in the world. Because its research activities are so extensive and so diverse, it is impossible to summarize them adequately in this report. The very brief summary reports prepared by the divisional chairmen each year occupy some forty printed pages, and even a complete listing of just the titles of all the books, articles and papers published by members of the Institute staff in the last 10 months of 1949 required a forty-page issue of the Bulletin of the California Institute (available on request). The following remarks, therefore, cannot be regarded as a summary of the research program of the Institute, but only a brief review of a few random samples of developments which have occurred during the year.

Astronomy. About one year ago the Hale 200-inch telescope and the 48-inch Schmidt-type telescope at Palomar went into full routine operation. The Schmidt telescope has now made excellent progress on its four-year program of surveying the entire sky visible from Palomar Mountain, a project which is financed through the generosity of the National Geographic Society. The pictures taken by this instrument are on photographic plates 14 inches square and astronomers are enthusiastic over the sharpness and detail which they exhibit. It has now become more clear than ever that the 2,000 or so plates which will be taken in this survey will be by far the most complete, the most detailed, and the most valuable map of the sky which has ever been attempted; and they will constitute an "atlas" which will be a guide to astronomical research for many, many years to come.

The Hale 200-inch telescope is now performing in a manner which equals or surpasses the fondest hopes of those who designed and built it. It is in operation every clear night. By June 30, 1950 a total of 510 direct photographs had been obtained. A large number of these photographic plates have been taken to secure more detailed information about the dimensions, magnitudes and distances of known or newly discovered extra-galactic nebulae (galaxies consisting of millions of stars, each similar to the Milky Way galaxy of which our own sun is a member). From studies of the distance and velocities

of such nebulae the most important information about the structure and nature of the universe will be obtained. It will require many years of painstaking studies, however, before any great new generalizations about the nature of the universe can be made. To show the magnitude of the problem of studying nebulae it need only be mentioned that in the ten per cent of the sky which was mapped by the 48-inch Schmidt-type telescope up to July 1950, more than 350 new *clusters* of nebulae had been discovered. Some of these are at distances of approximately 300 million light years.

The astonishing extent of the popular interest in the Palomar Observatory is indicated by the fact that during the past year nearly 150,000 people made the journey to Palomar Mountain to see the Hale telescope. This public interest is in many ways gratifying, but the unexpected volume of visitors presents a practical problem, which can be solved only by providing more adequate facilities for the public on Palomar.

Biology. A notable event of the past year in the Division of Biology was the inauguration of the full research program in Earhart Plant Research Laboratory. Among numerous projects now under way are (1) the identification of plant-damaging smog constituents and their manner of action on plants; (2) the effects of day and night temperatures on the growth, flowering and fruiting of such plants as the tomato; (3) a determination of conditions favorable for the growth of the plant *Veratrum* and production by it of alkaloids useful in the treatment of hypertension; and (4) an investigation of factors influencing growth and sugar formation by the sugar beet.

Through a generous grant from the James G. Boswell Foundation, the Division is in a position to strengthen greatly its research program in virology. As a means of summarizing the present stage of knowledge of plant, animal and bacterial viruses and of seeking effective ways of gaining new knowledge about these important disease-producing agents, a special three-day virus conference was held at the Institute in March 1950. Professor Max Delbrück was largely responsible for planning and managing this symposium which was attended by twenty leading virologists, representatives of the major research groups throughout the country. In addition, fifteen staff members of the Institute participated. The Institute published the proceedings as a 147-page volume entitled *Viruses 1950* which will be a milestone in the advance of the science of virology. With this conference as a background, plans are now being made to extend the Institute's virus research program to include work on animal viruses.

Of several major research activities of the Division the study of protein synthesis may be taken as an example. For some years, Professor Henry Borsook, Professor A. J. Haagen-Smit and a number of

their colleagues, through contract with the Office of Naval Research and the U. S. Atomic Energy Commission, have been investigating the manner in which proteins are made by animals. These giant-molecule compounds are essential constituents of all living things—viruses, bacteria, plants, animals and man. They are of many kinds, all made from a common set of some twenty building blocks compounded end to end to form long chains. The component parts are known as amino acids. Their structures are relatively simple and well understood by chemists, but the way in which they are built up to form proteins remains one of biology's unsolved problems. This is a problem of the most fundamental importance, because proteins are key substances in growth, in reproduction, in heredity, in the structure and function of enzymes, and in many other aspects of the normal functioning of organisms. In fact it can be said that the problem of protein synthesis impinges in one way or another on every branch of biology. By tagging individual amino acid building blocks with radioactive carbon atoms in strategic positions, and allowing these marked smaller molecules to be put together by living cells or suitable preparations made from living cells, the Borsook team is able to recover the resulting proteins marked in certain of their component parts. By carefully breaking up such proteins, much as one would break a pattern of dominoes into sidechains and subgroups, the investigators are finding it possible, since they can follow the distribution of radioactive carbon, to learn a great deal about how the original amino acids were put together to form the large and complex protein molecules.

Engineering. With the space made available by the new Engineering Building, the research program in this division will now be able to move forward at an accelerated rate.

In the field of engineering seismology, important progress was made during the year in the systematic study of the response of typical buildings to actual earthquake waves. Records of typical earthquakes are supplied by the U. S. Coast and Geodetic Survey and the analog computer of the Analysis Laboratory is now able to determine with great reliability and surprising speed the response of various types of structures to different types of earthquake shocks.

The Analysis Laboratory, with its large analog computer, and its newly installed digital computer, is now able to handle a wide variety of engineering calculations. In addition to the studies in seismology above mentioned, important studies of the vibration and flutter of aircraft structures have been carried out, yielding results of enormous value to aircraft engineers.

The number of wind tunnels for aeronautical studies now operating under Caltech auspices was increased to eight with the dedication of

the new Merrill Wind Tunnel on August 31, 1950. This tunnel is named for A. A. Merrill, one of the early pioneers in aviation and for many years a member of the Institute staff. Mr. Merrill delivered his first paper in the field of aeronautics in 1892 and has been continuously active ever since, though ill health now prevents his taking part in the Institute program.

With all of these facilities, research in aerodynamics, in structures, and in fluid mechanics continued on a high level during the past year. The advent of supersonic planes and guided missiles has introduced a whole new set of problems in this field and it is now necessary to investigate not only the behavior of air at these very high speeds but the behavior of new types of structures at all available speeds.

The new Guggenheim Center for jet propulsion research has completed its first year of operation with special attention to theoretical research in jet propulsion and the training of students in advanced aspects of this important field.

The Institute's Hydrodynamics Laboratory is without question one of the best equipped laboratories of its kind in the country. Though a knowledge of the flow of liquids around obstacles is as important to the marine engineer as is knowledge of the flow of air around obstacles is to the airplane engineer, it is rather astonishing that the latter field, though younger, is far more highly developed than the former. This is partly because air is a simpler material to work with than water, though it is also partly because experimental studies of liquids have been less vigorously pursued. This situation is being remedied in the Hydrodynamics Laboratory, where two types of water tunnels have yielded important information on fluid flow. The knowledge of hydrodynamics is desired not only by the marine engineer who designs ships, submarines and torpedoes, but also by engineers who are interested in propellers, pumps, turbines and the flow of liquids through pipes. For example, one of the most important phenomena in high speed flow is that of cavitation, the formation of tiny bubbles which "explode" against turbine or propeller blades with the result that, in extreme cases, hardened steel blades are chewed away as though they were made of cheese. The study of this phenomenon with modern techniques and high-speed photography has cast much light on the cavitation problem, leading to the hope that its damaging effects may be eliminated or at least minimized.

Chemistry. The Gates and Crellin Laboratories of Chemistry are now one of the leading centers in the world for studies in structure of molecules and crystals. These studies employ an amazing array of modern techniques, including X-ray and electron diffraction, infrared and microwave spectroscopy, and the use of radioactive tracers.

There is an especial attempt under way to investigate the structure of complex organic molecules, which are of importance in biochemistry. In addition to the work which has been going forward on the structure of amino acids and peptides, good progress has now been made toward a structural determination of chloromycetin and work has also begun on aureomycin and other anti-biotic compounds. A special room, designed for operation at temperatures as low as –40° F and equipped with X-ray facilities, is expected to advance greatly the work on the study of components of protein molecules.

The work in the field of immunochemistry and medical chemistry has shown increased activity. In the annual report of the Institute for 1948-49, Professor Pauling reported that a group working under him with Dr. Itano had discovered that the disease sickle cell anemia is caused by an abnormality in the structure of the hemoglobin molecules in the blood. This was the first human disease which could be identified as a "molecular disease." Further studies of this type of hemoglobin molecule have been made, together with a study of the genetic factors which determine the ratio of abnormal to normal hemoglobin molecules in the blood of those suffering from the disease. In the course of this study a new abnormal form of hemoglobin has been discovered, associated with a new disease which previously had not been differentiated from sickle cell anemia. The individuals suffering from this disease have in their red cells a mixture of two kinds of abnormal hemoglobin, sickle cell anemia hemoglobin, and this new third variety. These two abnormal types seem to be related genetically, one type coming from one parent and the other from the other.

These studies, and many others in chemistry and biology, illustrate again the great advantage of uniting these two great fields of science as they have been united in recent years at the California Institute. The joint program of chemical biology initiated several years ago is yielding remarkable dividends in new knowledge.

Physics. The major development in the field of physics during the past year was the beginning of the construction of a billion-volt electron synchrotron, a project being carried out with the support of the Atomic Energy Commission. This will be the most powerful electron accelerator in the world and will be a most important tool in studying new phenomena in the field of high-energy physics. The synchrotron work will be a connecting link between the low-energy nuclear phenomena, which have been studied here for many years under the direction of Dr. C. C. Lauritsen and his group, and the cosmic-ray physics work which has been carried on by Professor Carl D. Anderson. Many of the parts for this synchrotron were transferred from the University of California, where they had been used for a

preliminary study of the design problems in the construction of the multibillion volt machine for accelerating protons and other nuclear particles. Good progress has been made on the construction of the machine, and preliminary operation at low energies is anticipated by the spring of 1951.

In the field of cosmic rays, Professor Anderson and his colleagues have obtained important evidence for the existence of two new unstable particles. Preliminary evidence for these had been found by two British workers, Rochester and Butler, in 1947, but Anderson's work furnishes definite confirmation and provides further information about the properties of these particles.

Professor C. C. Lauritsen and his colleagues in the Kellogg Laboratory of Radiation have continued their work on studying the energy levels of light nuclei and securing further information on nuclear reactions which are of significance in the energy release in the sun and stars. Their results were studied by Professor Bengt Stromgren of the University of Copenhagen while he was a Visiting Lecturer in Astronomy, and he was able to make new calculations of the temperature of the sun. As a result it now seems likely that the nuclear reactions responsible for the production of solar energy may be rather different from the ones which have usually been assumed in recent years. Specificially, the direct reaction between two protons seems to play a more important role than has been previously thought.

Professor Jesse DuMond has continued his precision measurement of the gamma rays from various artificially radioactive nuclei, and has proceeded with the construction of a precision beta-ray spectrograph for accurate determinations of the energies of the electrons ejected by radioactive nuclei.

Geological Sciences. In the field of seismology the Institute group under the leadership of Professor Beno Gutenberg has continued to play a leading role in the rapid advances which have been made in this field in recent years. Improved instrumentation and improved interpretation of seismic phenomena have added greatly to our knowledge of the internal structure of the earth, and there have been great improvements in the precision and value of seismic measurements. The Institute laboratory now participates in the sea wave warning network inaugurated by the United States Coast and Geodetic Survey, in which reports of strong earthquakes are collected and analyzed in such a way as to give warning to stations in the Pacific of the possible approach of large tidal waves. Further advances have also been made in the study of "microseisms," which are the small seismic disturb-

ances caused by storms at sea. The path of such storms can now be followed and warning given of their approach to various stations.

In the fields of geology a variety of investigations have added to our knowledge of the origin and structure of certain types of rocks and the behavior of unusual geologic formations. There is especial interest in the study of the various types of minerals in the Southern California area. For example, a new and surprisingly abundant source of the rare metals cerium, lanthium, neodymium, and praseodymium, has been found in San Bernardino County, contained in a new mineral known as bastnasite. This mineral also contains thorium and is therefore radioactive. Other deposits of radioactive minerals have also been found in the desert areas of Southern California.

Professor Robert Sharp has continued his studies on the structure of glaciers in Alaska and on the northeast slope of Mt. Ranier, Washington. This work casts light on the origin and age of glaciers and is expected to contribute to the knowledge of chronology of the ice age.

In the field of paleontology Dr. Stock has continued his investigations of interesting material found in Mexico. Investigations promise to yield interesting and significant results on the interpretation of the history of life on the North American continent.

Humanities. The chief interest in the Division of the Humanities during the past year, and even more during the coming year, has been and will be the examination of the educational program of the Division to determine what forward steps can be taken to improve our offerings to the student body. This problem has been mentioned under the curriculum section in this report.

The scholarly activities of the members of the Division have also continued. Papers, articles, and books have been published during the year in the fields of economics, English and American history, philosophy, and on various subjects in English literature. Mr. Tanham spent the summer of 1950 in Belgium gathering material for the study of the Belgian resistance movement during World War II. Professor Alfred Stern has continued his program of publication of studies in the field of contemporary philosophy, a field in which he has recently received considerable recognition.

Professor Hallett Smith has completed the manuscript of a book on Elizabethan poetry, and Professor Rodman Paul has completed a publication on the early history of California.

One of the chief features of the teaching program of the California Institute is that the instructional program is carried on in an atmosphere of active scholarly research. This is no less true in the Division of Humanities than in the divisions of the sciences and engineering, a fact which has contributed substantially to the success of the humanities program at the Institute.

Jet Propulsion Laboratory. Recent world events have accelerated activities at the Jet Propulsion Laboratory, with increased emphasis, of course, on bringing the results of recent research to bear on the practical problems of design of new types of guided missiles.

Although the Jet Propulsion Laboratory is owned and financed by the Federal Government, it is managed by the Institute under contracts with various defense department agencies, and is an important asset to the Institute's general program of education and research. Much of the work on the design of actual missiles is, of course, kept in a confidential or secret category by the military services. Much of the basic research, however, is not "classified" and is generally published and can be publicly reported.

A considerable amount of work directed toward the investigation of the physical properties, the propulsion performance, and the combustion kinetics of both liquid and solid propellants has been going forward. For example, a new smokeless solid propellant has been developed and is now ready for the pilot plant stage. The reaction kinetics of nitric oxide have received detailed experimental study because of the importance of this material to acid-based propellants. Detailed information on the combustion of existing propellants, of new propellants, and of new combinations of fuels and oxidizers continues to throw valuable light on the basic elements of jet propulsion processes.

During recent years the major program of the Laboratory has been a study of materials of interest in the construction of jet motors. Much of the laboratory work in this program has now been completed, although new investigations are being made on the properties of titanium and its alloys, a material which has recently come into great prominence.

The problems of heat transfer, critical in all jet motors, have been the subject of many fundamental investigations.

In the engineering field the mechanical and electronic design aspects of the so-called ORDCIT guided missile were brought to completion and a sample of this missile was successfully fired. This is one of the first ground-to-ground guided missiles to be built and flown in the United States.

A new 18-inch by 20-inch supersonic wind tunnel has gone into operation during recent months, and this will contribute greatly to the studies in the flight properties of missiles and jet engines. A Reeves electronic analog computer has also been installed and has been enormously useful in solving problems involving trajectories, flight stability of jet vehicles, flutter, etc.

During the year twenty unclassified publications by JPL authors appeared in journals of the national technical societies. In addition about ninety classified JPL reports, and ten unclassified ones were submitted to Government agencies. Some 350 copies of each report were distributed to authorized agencies.

Finances

The report of the Comptroller and Business Manager for the fiscal year ending June 30, 1950 shows that the net assets of the California Institute had reached by the end of the year the total of $45,146,000. This is an increase of $1,407,500 over the corresponding figure for one year ago. The increase in assets during the year is largely due to funds received in the settlement of various estates willed to the Institute in previous years. The major items of current assets are endowment funds of $23,219,900, and plant investment of $16,648,000.

The total current income for the fiscal year amounted to $8,886,939; the total expenditures were $8,901,355. This left an excess of expenditures over current income of $14,416. The details of income and expenditure are set forth in the Report of the Comptroller.

The endowment income amounted to $1,451,493; that portion which accrued from interest and dividends on marketable securities amounted to $1,145,383. This amounted to an average return on invested funds of 5.0 per cent. The corresponding figure for the year 1948-49 was 4.6 per cent. The increase is largely attributable to the higher return on common stocks of industrial and utility corporations.

Gifts received for current operation during the year totaled $738,081. Of this amount $678,379 was credited to current income and the rest reserved for expenditures in future years. Over 75 individuals, foundations, agencies, or corporations contributed $1000 each or more. Three largest gifts were from the James G. Boswell Foundation, $100,000; the Rockefeller Foundation, $94,146; and the United States Public Health Service, $63,641. In addition, the California Institute Associates turned over to the Institute $96,092 representing the individual contributions of its members. To all of those who have contributed so generously to the Institute, the Trustees, the Administration, and the Faculty express their deep appreciation.

The Future

The California Institute of Technology faces the future not only with confidence, but with optimism. The difficult period of post-war readjustment has passed. Assuming that another major emergency does not arise in the near future it seems evident that the Institute can continue along its path of rendering an important service to the

public in education and research in the fields of science and engineering.

On the financial side the Institute also has reasons to be optimistic. In spite of most disturbing increases in the cost of operation during the past five years our income has also increased, and we have not been faced with the serious deficits which were anticipated two or three years ago.

This does not mean that we may relax our efforts to improve or expand our resources. On the contrary, we must continue and increase such efforts. The value of the privately owned educational institution has become more widely appreciated in recent years, and the public response to a need for additional support has been most encouraging. There is reason to believe that our efforts to increase our endowment funds and our annual income will meet with success.

We hope that there will be a similar generous response to our efforts to secure funds for needed additional facilities on the campus. These include:

Gymnasium and Swimming Pool. The Alumni Fund is making excellent progress toward providing these sorely needed additional athletic facilities, but substantial additional gifts would greatly accelerate the realization of this goal.

Dormitories. Two graduate dormitory units to house some 200 graduate students are urgently needed and an additional undergraduate student house to supplement the present overcrowded houses.

Student Union. A permanent building to serve as a center of student extracurricular activities is badly needed. In addition to providing office space for student organizations, this building should house the bookstore, the campus Y.M.C.A., Throop Club, and should provide dining facilities for off-campus students and conference rooms for student and alumni groups.

Engineering Building. The new engineering unit fills a long-felt need, but it does not solve the problems of adequate housing for engineering education and research. Civil and mechanical engineering are now cared for, but additional space for chemical and electrical engineering must be the next goal.

Library. Our small central library and all of the departmental libraries are now crowded well beyond capacity, both as to book storage space and reading-room facilities. Space on the campus has long since been reserved for a fine central library building, which could immediately become the most valuable library for science and engineering in the southwest.

Chemical-Biology Building. Additional laboratory facilities to house the rapidly growing and very important activities in the field

of chemical biology are necessary if this most important program is to reach its full possibilities.

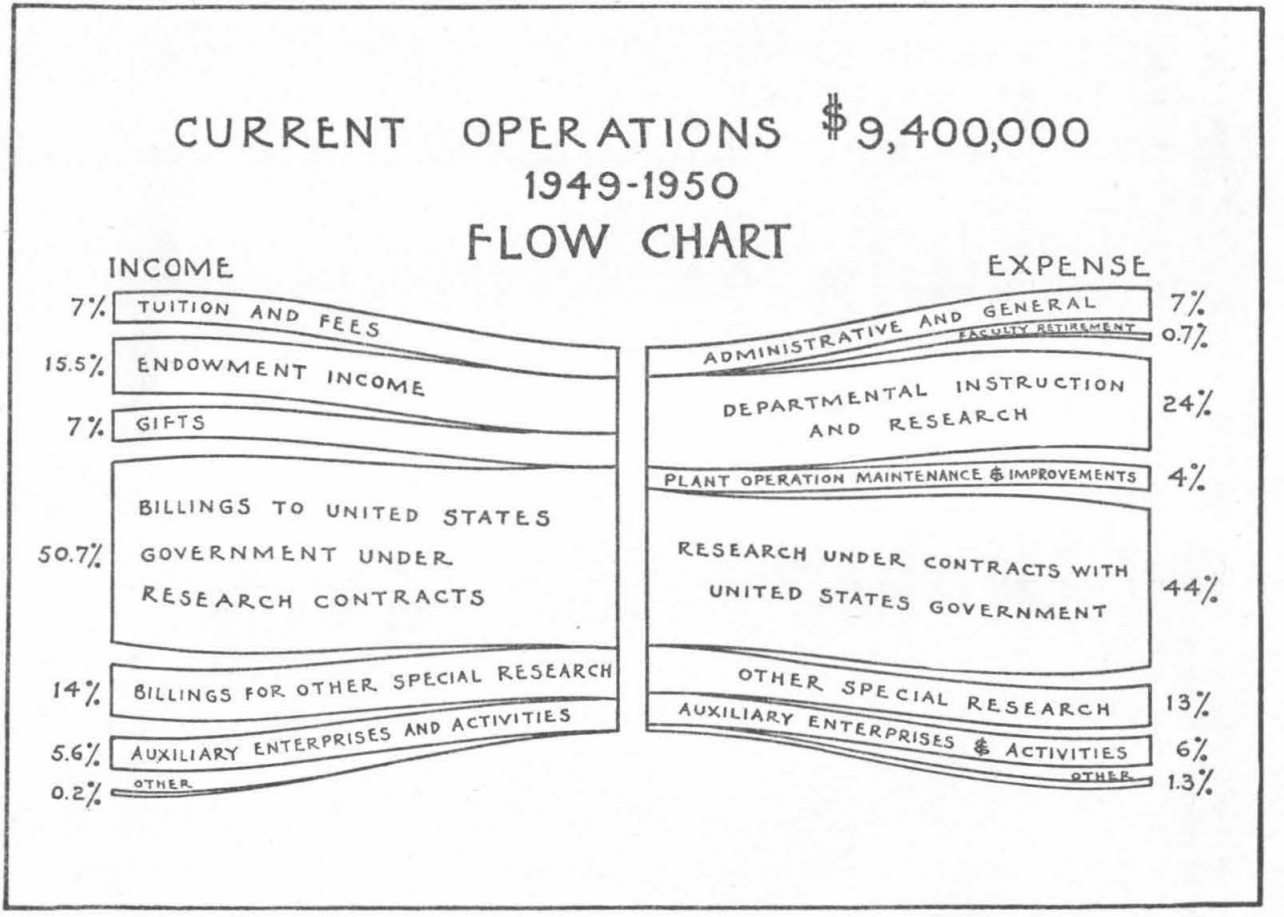
The Institute during the coming year will increase its efforts to secure funds for all of these important projects.

Acknowledgment

In conclusion, I should like to express appreciation to all members of the Board of Trustees for the active interest which they have taken in the Institute and for their generous contribution of time and energy to Institute affairs. This group of outstanding public-spirited men who assume responsibility for the continued success and financial stability of this great institution are performing a difficult and often thankless task—but one whose value to the community and to the nation can hardly be overestimated.

Respectfully submitted,

L. A. DuBridge, *President*


CURRENT OPERATIONS $9,400,000
1949-1950
FLOW CHART
INCOME
7% TUITION AND FEES
15.5% ENDOWMENT INCOME
7% GIFTS
50.7% BILLINGS TO UNITED STATES GOVERNMENT UNDER RESEARCH CONTRACTS
14% BILLINGS FOR OTHER SPECIAL RESEARCH
5.6% AUXILIARY ENTERPRISES AND ACTIVITIES
0.2% OTHER
EXPENSE
ADMINISTRATIVE AND GENERAL 7%
FACULTY RETIREMENT 0.7%
DEPARTMENTAL INSTRUCTION AND RESEARCH 24%
PLANT OPERATION MAINTENANCE & IMPROVEMENTS 4%
RESEARCH UNDER CONTRACTS WITH UNITED STATES GOVERNMENT 44%
OTHER SPECIAL RESEARCH 13%
AUXILIARY ENTERPRISES & ACTIVITIES 6%
OTHER 1.3%

Part II

REPORT OF THE COMPTROLLER

To the Board of Trustees:

The Institute's accounts have been examined by Price, Waterhouse & Co., independent public accountants, and their report, with financial statements for the year ended June 30, 1950, is set forth in Exhibits 1-5 inclusive. In addition, there is presented below a brief summary of the Institute's affairs for the year.

SUMMARY OF FINANCIAL POSITION AND OF TRANSACTIONS FOR THE YEAR

The following table is a condensed summary of the consolidated financial position of the Institute at June 30, 1949 and 1950:

	1949	*1950*
Bonds, stocks and other investments	$24,818,423	$26,356,690
Plant and equipment	16,029,241	16,661,412
Cash	1,578,644	1,752,846
Receivable from U. S. Government	969,088	1,036,180
Other assets—books and supplies, student loans, miscellaneous receivables, etc.	886,992	632,171
	$44,282,388	$46,439,299
Deduct—		
Advances by U. S. Government for certain research contracts		$ 772,500
Current accounts payable and other liabilities	$ 543,871	520,762
	$ 543,871	$ 1,293,262
Net assets	$43,738,517	$45,146,037
Representing capital of:		
Current fund—		
Surplus:		
Unappropriated	$ 867,077	$ 761,141
Appropriated	413,627	423,623
Unexpended gifts and endowment income	1,371,271	1,600,612
	$ 2,651,975	$ 2,785,376
Loan funds	91,926	98,053
Endowment funds	21,957,277	23,219,877
Plant fund—		
Invested in plant	16,015,740	16,647,912
Unexpended	829,571	412,424
Trust funds	1,600,125	1,620,058
Agency funds	591,903	362,337
As above	$43,738,517	$45,146,037
Net increase during the year		$1,407,520

It should be borne in mind that the foregoing table does not show either the segregation of assets and liabilities by funds or the interfund balances which are set forth on the accompanying balance sheet (Exhibit 2).

It will be seen from the summary which follows that the net increase of $1,407,520 in Institute surplus and capital has come chiefly from gifts received during the year:

Current income (particulars on the following page)		$ 8,886,939
Gifts received:		
A. C. Balch	$ 378,618	
Janet Jacks Balch	407,389	
E. W. Crellin	120,814	
Others, excluding gifts treated as current income	152,447	
		1,059,268
Unexpended investment income (not included above in current income)		234,022
Profit on disposal of investments (net)		256,836
Other additions (net)		66,445
		$10,503,510
Current expenditures (particulars on the following page)	$ 8,901,355	
Less—Expenditures for plant added to plant capital	178,806	
	$ 8,722,549	
Agency funds disbursed, less receipts	231,312	
Other expenditures charged to reserves, etc.	142,129	
		9,095,990
Net increase during the year		$ 1,407,520

CURRENT FUND

There follows a condensed comparative summary of current income and expenditures in the two years ended June 30, 1949 and 1950:

	1949	*1950*
Income:		
Tuition and fees	$ 621,363	$ 660,464
Endowment income	1,341,166	1,451,493
Gifts	559,715	678,379
Billings to United States Government under research contracts	4,400,396	4,787,468
Billings for other special research	832,039	1,248,750
Auxiliary enterprises and activities (net)	(5,280)	17,365
Other	40,078	43,020
	$ 7,789,477	$ 8,886,939
Expenditures:		
Administrative and general	$ 546,378	$ 617,215
Departmental instruction and research	2,038,282	2,251,531
Plant operation, maintenance and improvements	429,923	394,707
Research under contracts with United States Government	3,859,154	4,186,673
Other special research	767,053	1,226,806
Other	159,918	224,423
	$ 7,800,708	$ 8,901,355
Excess of expenditures over income	$ 11,231	$ 14,416

Unappropriated surplus decreased during the year by $105,936, as summarized below:

Excess of expenditures, as above	$ 14,416
Appropriations for:	
Plant purposes	85,693
Restricted current purposes	26,323
	$ 126,432
Less—Reversal of surplus appropriations made in prior years to cover expenditures	20,496
	$ 105,936

Income from endowment investments used for current purposes totaled $1,451,493 during the year ended June 30, 1950, as compared with $1,341,166 in the year ended June 30, 1949, as summarized below:

	1949	*1950*
Income received from investments in:		
Marketable securities (see table below)	$ 1,015,257	$ 1,145,383
Real estate	237,085	222,654
Beneficial interests in—		
Eudora Hull Spalding trust	200,000	340,000
Other trusts and estates	11,090	7,160
Receivables and other investments	63,430	25,735
	$ 1,526,862	$ 1,740,932
Portion of income from certain investments applied in reduction of their carrying value in recognition of depreciation and depletion	(54,511)	(55,417)
Net investment income	$ 1,472,351	$ 1,685,515
Less—Income retained and added to unexpended income balances of endowment and other funds (net)	131,185	234,022
Remainder applied as current income	$ 1,341,166	$ 1,451,493

In accordance with the Institute's established policy, all investment income is recorded on the cash basis. Interest and dividends received from marketable securities during each of the two years ended June 30, 1949 and 1950 are summarized by classifications in the table below. This table also shows the percentage of such income to the average of the investment balances at the beginning and end of the year; it should be borne in mind that this method of calculation produces merely an approximation of the yield rather than a precise figure.

	Income received		*Percentage of average investment*	
	1949	*1950*	*1949*	*1950*
Bonds:				
United States Government	$ 77,665	$ 102,360	1.6	2.1
Municipals	2,331	6,381	2.7	4.8
Canadian and foreign	13,557	14,034	3.1	2.5
Utilities	28,017	31,778	3.1	3.4
Industrials	12,840	10,940	3.0	2.7
Rails	8,000	8,000	7.2	7.2
Other	6,700	6,682	10.3	10.3
	$ 149,110	$ 180,175	2.1	2.5
Preferred stocks:				
Utilities	$ 90,645	$ 72,122	4.8	4.7
Industrials	112,827	113,302	4.2	4.4
Rails	7,535	7,116	5.1	4.8
Banks and other financial	7,245	10,069	4.4	1.8
	$ 218,252	$ 202,609	4.5	4.2
Common stocks:				
Utilities	$ 132,569	$ 182,915	5.6	6.4
Industrials	385,030	448,062	7.5	8.5
Rails	29,910	30,215	7.4	6.7
Insurance	9,002	11,077	4.8	4.4
Banks and other financial	91,384	90,330	4.5	4.3
	$ 647,895	$ 762,599	6.4	7.0
	$ 1,015,257	$ 1,145,383	4.6	5.0

Expenditures during the two years for departmental instruction and research are summarized by divisions and departments in the following table:

Division	*Expenditures 1949*	*1950*
Engineering:		
Administration	$ 35,185	$ 31,724
Civil engineering	44,254	44,784
Mechanical engineering	125,411	122,660
Electrical engineering	72,321	85,658
Applied mechanics	36,918	27,952
Aeronautics	97,589	104,840
Jet propulsion	2,013	20,151
Industrial design	9,141	
	$ 422,832	$ 437,769
Physical sciences:		
Physics	$ 165,761	$ 186,897
Astronomy	26,244	15,414
Mathematics	76,603	84,646
	$ 268,608	$ 286,957
Chemical sciences:		
Chemistry	$ 433,958	$ 503,415
Chemical engineering	79,321	88,897
	$ 513,279	$ 592,312
Geological sciences:		
Geology	$ 178,808	$ 203,451
Meteorology	5,820	
	$ 184,628	$ 203,451
Biological sciences	$ 373,388	$ 389,136
Humanities	132,919	152,331
Palomar Observatory	66,092	105,796
Physical education	50,636	52,915
Industrial relations	25,900	30,864
Total	$ 2,038,282	$ 2,251,531
The total expenditures in the two years were for:		
Salaries	$ 1,581,523	$ 1,774,254
Materials, supplies, etc.	283,005	340,801
Equipment added to plant capital	173,754	136,476
As above	$ 2,038,282	$ 2,251,531

Expenditures for research under contracts with the United States Government in the two years ended June 30, 1949, and June 30, 1950, are summarized below:

	1949	*1950*
Departments of the:		
Air Forces	$ 400,825	$ 394,776
Army	2,552,878	2,772,291
Navy	789,546	936,715
Others	115,905	82,891
	$ 3,859,154	$ 4,186,673

Billings under these contracts were $4,400,396 in 1949, and $4,787,468 in 1950.

ENDOWMENT FUNDS

The following is a comparative classified summary of the Institute's investments (excluding investments of trust funds) at June 30, 1949 and 1950:

	Market value of securities		*Carried at*		*Per cent of total*	
	1949	*1950*	*1949*	*1950*	*1949*	*1950*
Marketable securities:						
Bonds—						
U.S. Govt.	$4,841,940	$5,080,910	$4,857,379	$5,119,004	20.9	20.7
Municipals	127,160	129,070	133,995	133,995	.6	.5
Canadian and foreign	421,488	679,820	436,670	701,520	1.9	2.8
Utilities	866,325	978,499	897,843	955,547	3.8	3.9
Industrials	408,693	397,585	416,521	395,450	1.8	1.6
Rails	149,500	163,000	111,588	111,588	.5	.4
Others	121,295	133,730	64,887	64,887	.3	.3
	$ 6,936,401	$ 7,562,614	$ 6,918,883	$ 7,481,991	29.8	30.2
Preferred stocks—						
Utilities	$ 1,678,440	$ 1,439,458	$ 1,660,565	$ 1,401,799	7.2	5.7
Industrials	2,427,859	2,336,576	2,715,014	2,434,042	11.7	9.8
Rails	116,640	112,000	147,539	147,539	.6	.6
Banks, etc.	190,500	933,300	186,175	930,900	.8	3.8
	$ 4,413,439	$ 4,821,334	$ 4,709,293	$ 4,914,280	20.3	19.9
Common stocks—						
Utilities	$ 2,718,358	$ 3,379,032	$ 2,657,660	$ 3,092,136	11.5	12.5
Industrials	5,829,821	7,154,372	5,230,896	5,259,469	22.6	21.3
Rails	331,280	388,580	401,689	495,935	1.7	2.0
Insurance	200,388	350,082	192,343	314,193	.8	1.3
Banks, etc.	1,551,252	1,914,964	2,050,123	2,159,039	8.8	8.7
	$10,631,099	$13,187,030	$10,532,711	$11,320,772	45.4	45.8
Total marketable securities	$21,980,939	$25,570,978	$22,160,887	$23,717,043	95.5	95.9
Stocks and bonds without market quotations			33,869	37,842	.1	.2
Notes and contracts receivable			20,953	18,091	.1	.1
Real estate and leasehold			988,951	945,553	4.3	3.8
Beneficial interests in estates and trusts (carried at nominal amounts)			31	29		
Total investments			$23,204,691	$24,718,558	100.0	100.0
Comprising:						
Consolidated portfolio			$20,392,628	$21,082,439	87.9	85.3
Separate investments			2,812,063	3,636,119	12.1	14.7
			$23,204,691	$24,718,558	100.0	100.0

Gifts added to endowment fund capital during the year were received from:

Estates of:	
A. C. Balch	$378,618
Janet Jacks Balch	407,389
E. W. Crellin	120,814
John H. Eagle	33,543
Callie Wood Ross	24,999
Alumni Association	26,688
Others	5,727
	$997,778

PLANT FUNDS

Changes during the year in the accounts for land, buildings and equipment comprised:

	At June 30 1949	*Net additions*	*At June 30 1950*
Campus, buildings and equipment:			
Land	$ 688,182		$ 688,182
Land improvements	194,275	$ 125	194,400
Buildings	5,786,746	473,275	6,260,021
Equipment	2,725,276	205,512	2,930,788
	$ 9,394,479	$ 678,912	$10,073,391
Construction costs of Palomar Observatory and related buildings and equipment:			
Buildings and equipment on Institute campus	$ 957,379	$ (64,313)	$ 893,066
Experimentation and manufacture of reflectors	1,371,096	(43,599)	1,327,497
Design and mountings	3,044,542	41,087	3,085,629
Telescope site and improvements	838,618	8,647	847,265
Expense of committees	275,037	1,458	276,495
Auxiliary equipment	148,090	9,980	158,070
	$ 6,634,762	$ (46,740)	$ 6,588,022
	$16,029,241	$ 632,172	$16,661,413

In accordance with the practice commonly followed by endowed educational institutions, no provision has been made for depreciation of plant facilities.

GIFTS FOR RESTRICTED AND GENERAL PURPOSES

Gifts received during the year for restricted and general purposes amounted to $738,081 as compared to $744,622 in the prior year. Presented below is a list of gifts totaling $1000 or more, indicating the purpose for which each was contributed:

Educational and general purposes:

Restricted—

Rockefeller Foundation for:	
Combined research in biology and chemistry	$ 94,146
Aeronautics:	
Hughes Aircraft Company	6,500
Other	900
Biology:	
American Cancer Society	10,850
James G. Boswell Foundation	100,000
Coe Chemical Company	6,240
Herman Frasch Foundation	10,000
County of Los Angeles	6,416
Merck & Co., Inc.	8,158
National Foundation for Infantile Paralysis	30,000
Nutrition Foundation, Inc.	7,000
Elbridge and Mary Stuart Foundation	5,000
United States Public Health Service	9,504
University of California	10,225
F. S. Markham	3,400
Leonard G. Strater	2,000
Williams-Waterman Fund	4,000
Carnegie Institution of Washington	1,372
Pioneer Hi-Bred Corn Company	1,500
National Academy of Sciences	1,500
International Minerals and Chemical Corporation	1,000
Others—7	1,059
Chemistry and Chemical Engineering:	
American Petroleum Institute	36,000
Carbide and Carbon Chemicals Corporation	15,000
Eli Lilly and Company	20,000
National Foundation for Infantile Paralysis	30,000
United States Public Health Service	54,137
Allied Chemical and Dye Corporation	1,300
American Academy of Allergy	3,000
California Research Corporation	2,200
E. I. DuPont de Nemours and Company	2,800
Ethyl Corporation	1,300
Fluor Corporation, Ltd.	3,500
Merck & Co., Inc.	2,500
Shell Oil Company	2,115
Standard Oil Company of California	1,850
United States Rubber Company	2,800
Research Corporation	4,524
Others—3	1,068

Engineering:		
A. O. Smith Corporation	10,000	
John B. Keating	1,000	
Research Corporation	4,000	
Shell Oil Company	1,600	
Westinghouse Educational Foundation	1,000	
Kelman Electric and Manufacturing Company	4,000	
Southern California Edison Company	4,000	
Department of Water and Power—City of Los Angeles	3,000	
Other	500	
Geology, Paleontology and Seismology:		
Childs Frick Corporation	3,000	
Standard Oil Company of California	1,350	
Stanolind Oil and Gas Company	1,350	
Rock of Ages Corporation	2,250	
Other	450	
Industrial Relations:		
American Potash and Chemical Corporation	1,000	
Lockheed Aircraft Corporation	2,000	
General Petroleum Corporation	2,500	
Joyce, Inc.	1,000	
Richfield Oil Corporation	2,500	
Consolidated Vultee Aircraft Corporation	2,000	
Southern California Edison Company	1,500	
Union Oil Company of California	2,500	
Signal Oil and Gas Company	1,000	
Sundry donors for support of Industrial Relations Section	7,965	
Mathematics:—1	400	
Physics:		
Research Corporation	5,550	
California Research Corporation	1,430	
E. I. DuPont de Nemours and Company	2,200	
William E. Hale Fund	1,500	
Other	1,680	
Other restricted purposes:		
Alumni Association—California Institute of Technology	2,898	
Carnegie Foundation for the Advancement of Teaching	1,800	
Others—3	480	
General or undesignated purposes:		
Keith Spalding	5,750	
California Institute Associates	88,217	
Standard Oil Company of California	25,000	
James G. Boswell Company	1,000	
C. F. Braun & Company	1,000	
Others—4	1,365	
		$706,599

Auxiliary enterprises and activities:		
Athenaeum—California Institute Associates	$ 7,875	
Health Center—Emergency Hospitalization Fund	4,516	
		12,391
Non-educational purposes:		
Anonymous	$ 9,000	
C. F. Braun & Company	1,000	
Dorothy H. Clendening	1,000	
General Petroleum Corporation	2,250	
Others—6	5,841	
		19,091
		$738,081

Respectfully submitted:
E. C. BARRETT, *Comptroller*
G. W. GREEN, *Business Manager*

PRICE, WATERHOUSE & CO.

Exhibit 1

530 WEST SIXTH STREET

LOS ANGELES 14

September 22 1950

The Board of Trustees,
California Institute of Technology,
Pasadena, California.

We have examined the balance sheet (Exhibit 2) of California Institute of Technology as of June 30 1950 and the statements of current income, expenditures and surplus (Exhibits 3 to 5) for the year then ended. Our examination was made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the aforementioned statements present fairly the financial position of California Institute of Technology at June 30 1950 and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

Price Waterhouse & Co.

CURRENT FUND ASSETS:		
Unrestricted—		
Cash		$ 465,045.14
Receivables:		
United States Government		1,036,179.96
Advances to trust fund		21,815.40
Tuition and fees, fully reserved	$10,713.55	
Other receivables		61,511.55
Supplies, food and books, at cost		132,470.30
Deferred charges		61,776.38
		$ 1,778,798.73
Restricted—		
Cash	$ 738,423.39	
Advances to current unrestricted fund	576,663.77	
Share in endowment fund assets	1,481,647.77	
		2,796,734.93
		$ 4,575,533.66
LOAN FUND ASSETS:		
Cash	$ 21,169.08	
Share in endowment fund assets	35,000.00	
Loans receivable, $49,322.49 less $300 reserve	49,022.49	
		105,191.57
ENDOWMENT FUND ASSETS:		
Cash	$ 173,857.23	
Receivables	169.24	
Investments carried at	24,718,558.56	
		24,892,585.03
PLANT FUND ASSETS:		
Invested in plant—		
Campus buildings and equipment	$10,073,390.55	
Palomar observatory	6,588,021.70	
	$16,661,412.25	
Uninvested cash	289,426.25	
Share in endowment fund assets	122,997.67	
		17,073,836.17
TRUST FUND ASSETS:		
Cash	$ 10,524.16	
Investments carried at	1,638,131.18	
		1,648,655.34
AGENCY FUND ASSETS:		
Cash	$ 54,400.75	
Receivables	221,534.28	
Share in endowment fund assets	33,062.49	
Wind tunnel modification design costs	46,168.67	
Prepaid insurance	59,517.69	
		414,683.88
		$48,710,485.65

-BALANCE SHEET, JUNE 30, 1950

Exhibit 2

CURRENT FUND LIABILITIES AND CAPITAL:		
Unrestricted—		
Accounts payable		$ 247,327.51
Accrued salaries and wages		167,170.04
Deposits and advance collections		26,496.89
Payable to current restricted fund		576,663.77
		$ 1,017,658.21
Unappropriated surplus (Exhibit 3)		761,140.52
		$ 1,778,798.73
Restricted—		
Advances from United States Government for expenditures under certain research contracts	$ 772,500.00	
Appropriations of surplus for current purposes (Exhibit 3)	423,622.67	
Unexpended gifts for current purposes	873,763.54	
Unexpended endowment income	726,848.72	
		2,796,734.93
		$ 4,575,533.66
LOAN FUND LIABILITIES AND CAPITAL:		
Loan fund returnable to donor	$ 7,138.58	
Loan fund capital	98,052.99	
		105,191.57
ENDOWMENT FUND LIABILITIES AND CAPITAL:		
Share of other funds in endowment fund assets	$ 1,672,707.93	
Endowment capital	23,219,877.10	
		24,892,585.03
PLANT FUND LIABILITIES AND CAPITAL:		
Invested in plant—		
Deferred liability due in 1957	$ 13,500.00	
Plant capital	16,647,912.25	
	$16,661,412.25	
Unexpended plant funds	412,423.92	
		17,073,836.17
TRUST FUND LIABILITIES AND CAPITAL:		
Payable to current fund	$ 21,815.40	
Undistributed income	6,782.16	
Trust capital	1,620,057.78	
		1,648,655.34
AGENCY FUND LIABILITIES:		
Accounts payable and accrued expenses	$ 52,346.52	
Agency funds	362,337.36	
		414,683.88
		$48,710,485.65

	Total surplus	*Unappropriated*	*Appropriated*
Balances at June 30, 1949	$1,280,703.94	$ 867,076.81	$413,627.13
Current income and expenditures for year ended June 30, 1950:			
Income (Exhibit 4)	9,427,834.51	9,427,834.51	
Expenditures (Exhibit 5)	(9,442,250.15)	(9,442,250.15)	
Reversal of surplus appropriations made in prior years to cover expenditures included above		20,495.32	(20,495.32)
Appropriations for:			
Current purposes		(26,323.26)	26,323.26
Additions to plant	(85,692.71)	(85,692.71)	
Allocation of profit on disposal of investments of consolidated portfolio (Income of $18,333.33 allocable to appropriated balances invested in the consolidated portfolio was included in current fund income—see Exhibit 4)	4,167.60		4,167.60
Balances at June 30, 1950	$1,184,763.19	$ 761,140.52 (Exhibit 2)	$423,622.67 (Exhibit 2)

APPROPRIATED FOR				
Aeronautics research	*Income stabilization*	*Biology*	*Chemical Engineering*	*Scholarships*
$194,345.71	$142,501.92	$58,517.25	$2,740.72	$15,521.53
(3,256.19)		(7,312.63)		(9,926.50)
6,597.44	15,841.91			3,883.91
1,525.29	1,738.86	714.05		189.40
$199,212.25	$160,082.69	$51,918.67	$2,740.72	$ 9,668.34

Exhibit 4

CURRENT INCOME—YEAR ENDED JUNE 30, 1950

Educational and general:		
Tuition and fees		$ 660,464.27
Endowment income—		
For restricted purposes	$915,248.62	
For general purposes	483,966.03	
		1,399,214.65
Gifts—		
For restricted purposes	$565,246.31	
For general purposes	104,640.14	
		669,886.45
Billings to United States Government under research contracts		4,787,467.70
Billings for other special research—wind tunnel tests, etc.		1,248,749.97
Income from investments allocable to appropriations of current surplus		18,333.33
Sales and services of educational departments		5,492.03
		$8,789,608.40
Auxiliary enterprises and activities:		
Bookstore	$ 94,274.27	
Cafeteria	66,592.32	
Student houses—		
Campus	212,613.35	
Arcadia	18,415.42	
Athenaeum	116,406.50	
Dormitory	8,334.85	
Health center	33,306.52	
Student athletic fees	8,315.94	
		558,259.17
Other noneducational income:		
Endowment income—		
For annuities, scholarships, fellowships and prizes	$ 52,278.11	
Gifts—		
For scholarships, etc.	8,492.24	
Rentals	5,247.97	
Miscellaneous	13,948.62	
		79,966.94
		$9,427,834.51

(Exhibit 3)

Exhibit 5

CURRENT EXPENDITURES—YEAR ENDED JUNE 30, 1950

	Salaries and wages	*Materials, supplies, etc.*	*Equipment added to plant capital*	*Total*
Educational and general:				
Administrative and general	$ 400,508.00	$ 208,472.79	$ 8,234.42	$ 617,215.21
Departmental instruction and research	1,774,253.65	340,800.73	136,476.35	2,251,530.73
Operation and maintenance of academic plant	289,030.79	97,026.32	6,934.22	392,991.33
Expenditures for campus improvements	1,361.17	229.52	125.00	1,715.69
Direct expenditures under research contracts with United States Government	3,015,510.07	1,170,119.86	1,043.33	4,186,673.26
Expenditures for other special research	542,868.74	663,326.73	20,610.79	1,226,806.26
General library	26,704.88	2,734.41	1,858.53	31,297.82
Retirement allowances and annuity premiums		68,643.31		68,643.31
	$6,050,237.30	$2,551,353.67	$175,282.64	$8,776,873.61
Auxiliary enterprises and activities:				
Bookstore	$ 11,705.40	$ 79,365.06	$ 139.12	$ 91,209.58
Cafeteria	24,447.67	42,328.76	114.08	66,890.51
Student houses—				
Campus	82,844.98	121,649.73	819.94	205,314.65
Arcadia	4,230.00	4,950.70	1,125.58	10,306.28
Athenaeum	48,056.28	67,988.59	27.53	116,072.40
Dormitory	5,336.85	2,475.41		7,812.26
Health center	28,011.48	13,980.32	1,296.90	43,288.70
	$ 204,632.66	$ 332,738.57	$ 3,523.15	$ 540,894.38
Other noneducational expenses:				
Scholarships		$ 88,421.03		$ 88,421.03
Annuity payments		30,260.20		30,260.20
Other		5,800.93		5,800.93
		$ 124,482.16		$ 124,482.16
	$6,254,869.96	$3,008,574.40	$178,805.79	$9,442,250.15

(Exhibit 3)

NOTE—Approximately $270,000 was expended during the year for equipment under United States Government contracts which provide that the government retains title to the property; therefore, such expenditures have not been added to the Institute plant accounts but are included above in "materials, supplies, etc."

Part III

REPORTS OF THE DEANS AND OTHER ADMINISTRATIVE OFFICERS

THE DEAN OF THE FACULTY

To the President:

In addition to carrying on the many important researches described in the various Division reports, the Faculty of the Institute has continued to study and improve its educational procedures. Faculty meetings have been unusually well attended, and many matters of educational policy have been discussed and acted upon. The interest in the monthly Seminar on Educational Problems and Methods has continued, and the lively discussion that takes place during these meetings has led not only to a better understanding on everyone's part of the educational aims of the Institute but also to a number of specific improvements in teaching procedures.

The Faculty was strengthened during the year by the appointment of Richard P. Feynman of Cornell University as Professor of Theoretical Physics and Alan R. Sweezy of Williams College as Professor of Economics, together with a number of lecturers, assistant professors and instructors. Professor Feynman is regarded as one of the most brilliant theoretical physicists in the world today. Although he is a young man, he has made notable contributions to the fundamentals of quantum mechanics and quantum electrodynamics. Professor Sweezy, who is one of the able group of Harvard trained economists, has made an enviable reputation as a teacher.

In addition to these important additions to the permanent staff, a distinguished array of visiting professors and research associates continues to be attracted to the Institute. Besides carrying on research, many of these men have contributed greatly to our instructional program by their brilliant lectures. Nearly twenty such men, coming not only from this country, but from England, Holland, Italy and Switzerland, were appointed during the year for varying periods. Most notable among these are J. Robert Oppenheimer, Director of the Institute for Advanced Study at Princeton, I. I. Rabi, Nobel Laureate and Professor of Physics at Columbia University, Sydney Chapman, Sedleian Professor of Natural Philosophy at Oxford, and the brilliant astrophysicist, Thomas G. Cowling, also of Oxford University.

Post-doctoral research fellows from all over the world continue to flock to the Institute. Of the more than fifty new appointees during the year, 19 are from foreign countries—four from Switzerland, two each from China, England and Germany, and one each from Australia, Canada, Denmark, Israel, Italy, Norway, South Africa, Sweden, and Turkey.

One major administration change was made at the close of the academic year. As of July 1, 1950, Professor R. W. Sorensen retired as Professor of Electrical Engineering and Chairman of the Division of Physical Education, and the Division of Physical Education was discontinued. The work in physical education will in the future be carried on under the direction of Harold Z. Musselman, Director of Athletics and Physical Education, who will be responsible to the Faculty Committee on Physical Education. Professor Sorensen has rendered a unique and invaluable service to the Institute as Chairman of the Division of Physical Education during the entire period of 27 years of its existence. Throughout this long term of service Professor Sorensen succeeded in keeping the Institute's athletic activities on a very high plane while at the same time maintaining a a spirit of good will and cooperation among the varied interests concerned.

Changes in the Faculty

(a) administrative officers

1. Chester Stock will next year replace George R. MacMinn as Chairman of the Faculty.
2. As of July 1, 1950, Royal W. Sorensen retired as Chairman of the Division of Physical Education and the Division was discontinued. In the future Harold Z. Musselman, Director of Athletics and Physical Education, will be directly responsible to the Faculty Committee on Physical Education, of which Dean Paul C. Eaton is the new chairman.

(b) promotions

1. *To the rank of Professor:*
   Dan H. Campbell (Chemistry)
   R. F. Christy (Physics)
   Robert T. Knapp (Hydraulics)
   Verner F. H. Schomaker (Chemistry)
   Albert Tyler (Embryology)
2. *To the rank of Associate Professor:*
   Leverett Davis, Jr. (Physics)
   Thomas Lauritsen (Physics)
   Howell N. Tyson (Mechanical Engineering)
   Vito A. Vanoni (Hydraulics)
3. *To the rank of Assistant Professor:*
   J. Kent Clark (English)
   Eugene W. Cowan (Physics)
   William C. Kinard (Business Economics)
   Robert V. Langmuir (Physics)
   Richard H. MacNeal (Electrical Engineering)
   Lester L. McCrery (English and Public Speaking)
   Rolf Sabersky (Mechanical Engineering)
   Alfred Stern (Languages and Philosophy)

(c) NEW APPOINTMENTS

1. *Professors:*
   Richard P. Feynman (Theoretical Physics)
   Alan R. Sweezy (Economics)
2. *Visiting Professors:*
   J. M. Burgers, of the University of Leiden, Holland (Aero- and Hydro-dynamics)
   Thomas G. Cowling, of Oxford University, England (Astrophysics)
   Bryce L. Crawford, of the University of Minnesota (Chemistry)
   J. B. Culbertson, of Cornell College (Chemistry)
   Arthur C. Giese, of Stanford University (Biology)
   R. M. Keefer, of the University of California (Chemistry)
   Arthur W. Martin, of the University of Washington (Biology)
   J. Robert Oppenheimer, Director, Institute for Advanced Study (Physics)
   I. I. Rabi, of Columbia University (Physics)
   Massimo Simonetta, of the University of Milan, Italy (Chemistry)
   George Winter, of Cornell University (Structural Engineering)
3. *Research Associates:*
   David R. Bates, of the University of London, England (Astronomy)
   Sydney Chapman, Sedleian Professor of Natural Philosophy, Oxford University, England (Geophysics)
   H. R. Crane, of the University of Michigan (Physics)
   William M. Hiesey, of the Carnegie Institution of Washington (Biology)
   Lord Rothschild, of Trinity College, Cambridge University, England (Biology)
   Raymund Sänger, of the Swiss Federal Institute of Technology (Engineering)
4. *Lecturers:*
   Nicholas A. Begovich (Electrical Engineering)
   Carey H. Conley (English)
   Bernard D. Davis (Visiting Lecturer, Biology)
5. *Assistant Professors:*
   Tom M. Apostol (Mathematics)
   David C. Elliot (History)
   Stanford S. Penner (Jet Propulsion)
   David Wood (Mechanical Engineering)
6. *Senior Research Fellows:*
   Bernard Axelrod (Biology)
   G. Victor Beard (Chemistry)
   Mathew L. Sands (Physics)
7. *Instructors:*
   Heinz E. Ellersieck (History)
   Caleb W. McCormick (Civil Engineering)
8. *Research Fellows:*
   Robert A. Alberty (Chemistry)
   Robert E. Barieau (Chemistry)
   Otto Bastiansen(Chemistry)
   Markus Båth (Seismology)
   Guiseppe Bertani (Biology)
   Henry D. Block (Mathematics)
   Carsten Bresch (Biology)
   Christoph H. Burckhardt (Chemistry)
   Stanley C. Burket (Chemistry)
   Robert Casamajor (Biology)
   Feng Kan Chuang (Aeronautics)
   Richard E. Cline (Chemistry)
   Ellis P. Darley (Biology)
   Ellsworth C. Dougherty (Biology)
   David L. Douglas (Chemistry)
   Henry A. Dye (Mathematics)
   Kazim Ergin (Geology)
   P. G. Gane (Geology)
   Harold R. Garner (Biology)
   Dan U. Gerstel (Biology)
   Edwin A. Goldsmith (Biology)
   F. Charlotte Green (Chemistry)
   Felix L. Haas (Biology)
   Baynard L. Hammond (Biology)
   Edgar Heilbronner (Chemistry)
   Ewald Herzog (Astronomy)
   Herbert M. Hull (Biology)
   Harvey A. Itano (Chemistry)
   Anton Lang (Biology)
   George G. Laties (Biology)
   J. L. Leemann (Chemistry)
   Joseph Lein (Biology)
   Henry Lemaire (Chemistry)
   Peter H. Lowy (Biology)

Richard E. Marsh (Chemistry)
Charles B. Metz (Biology)
Thomas C. Nelson (Biology)
Roger Newman (Chemistry)
John M. O'Gorman (Chemistry)
Daphne Osborn (Biology)
R. A. Pasternak (Chemistry)
Vincent Peterson (Physics)
Edwin A. Phillips (Biology)
Bruno Rosenfeld (Biology)
Tsu-chia Sheng (Biology)
Robert G. Shulman (Chemistry)
John S. Stamm (Biology)
Melvin L. Stehsel (Biology)
Charles Sutherland (Chemistry)
You-Chi Tang (Chemistry)
John G. Teasdale (Physics)
Donald L. Thomsen, Jr. (Mathematics)
Alvin V. Tollestrup (Physics)
Wilton E. Vannier (Chemistry)
Marguerite M. P. Vogt (Biology)

(d) RETIREMENTS

Royal W. Sorensen reached retiring age during the year and became Professor Emeritus of Electrical Engineering as of July 1, 1950. He will, however, continue to teach one course and carry on research.

Upon the completion of the 200-inch telescope construction last Fall, Walter S. Adams and Max Mason retired as Research Associates in Astronomy. The Institute owes them both a great debt of gratitude for their willingness to see this important project through to a successful conclusion even though they had both passed the normal retiring age.

(e) RESIGNATIONS

Josef J. Johnson, Research Associate in Astronomy, resigned on July 1, 1950 because of ill health. It is hoped, however, that with improving health he may resume some association with the Institute.

Wilhelm Magnus, Research Associate in Mathematics, resigned on July 31, 1950 to accept a professorship at New York University. It is expected, however, that he will continue to act as a consultant for the Bateman Manuscript Project.

Henry F. McCreery, Assistant Professor of History, resigned on July 1, 1950 to enter the business world.

(f) LEAVES OF ABSENCE

Charles Hewitt Dix, Associate Professor of Geophysics, was granted leave of absence for the second and third terms of the academic year 1949-50. This leave has now been extended until January 1951.

Arthur W. Galston, Senior Research Fellow in Biology, has been granted leave of absence for the academic year 1950-51 to enable him to carry on research in Sweden under a Guggenheim Foundation Fellowship.

Samuel Karlin, Assistant Professor of Mathematics, has been granted leave of absence for the academic year 1950-51 to enable him to carry on research at Princeton University.

David A. Lind, Senior Research Fellow in Physics, has been granted leave of absence for the academic year 1950-51 to enable him to carry on research in Sweden and Switzerland under a Guggenheim Foundation Fellowship.

Charles W. Merriam, Associate Professor of Invertebrate Paleontology, has been granted leave of absence for the fall term, 1950, to complete a project in the Inyo mountains for the U. S. Geological Survey.

H. P. Robertson, Professor of Mathematical Physics, has been granted leave of absence for the academic year 1950-51 in order to enable him to accept a one-year appointment as Director of Research, Weapons Systems Evaluation Group, Office of the Secretary of Defense.

Respectfully submitted,
E. C. WATSON, *Dean of the Faculty*

The Dean of Graduate Studies

To the President:

The year 1949-50 showed a continued decrease in the number of graduate students from the excessively high enrollment which reached a peak of approximately 600 students in 1946-47. The successive second-term enrollments during these years have been 593 in 1946-47, 519 in 1947-48, 505 in 1948-49, and 429 in 1949-50. The decrease shown by the last year occurred more in the field of engineering than in science. It resulted from efforts made by several departments to choose more critically the students granted new admission. The number of graduate students in science exceeded that in engineering for the first time since a heavy emphasis began to be placed some years ago on engineering training for war service. This decrease brings the ratio of graduate students to faculty members to the favorable figure of 2.5, and in no department does the ratio exceed 5.5.

Foreign students in graduate work increased from 10 per cent of the whole group in 1948-49 to almost 14 per cent. Of the 19 countries involved, Canada and China contributed the two largest groups, with India, Holland, and Turkey next.

For many students who had been in military service, eligibility to receive veteran's benefits to assist them in financing their education reached an end before or during the academic year. Among the incoming students there was a smaller proportion of veterans. These conditions resulted not only in a smaller proportion receiving benefits, but also in a smaller average allotment per student. Because of this decline in governmental assistance, a greater demand was felt for aid from Institute scholarship funds. It is expected that this trend will continue for several more years. Fellowships made available by various donors to provide financial assistance for graduate students through Institute channels were awarded to 32 students, whereas 12 more students received similar awards from other agencies.

Although the number of Ph.D. degrees granted at the Commencement exercises in 1949-50 was the largest in the history of the Institute, an unusually small proportion — 11 per cent of the 70 degrees — went to men whose baccalaureate degrees came from the Institute. Other colleges located west of the Mississippi River contributed 34 per cent; those in the eastern part of the nation, 39 per cent; and foreign countries, 16 per cent. The numbers of master's and engineer's degrees granted in 1950 were substantially lower than those given the year before.

The Committee on Graduate Study gave consideration during the year to methods whereby improvement might be made in the contribution of graduate assistants to the Institute's teaching program. In the selection of new graduate assistants greater emphasis will be placed upon the appraisal by former instructors of the teaching promise of the applicant. More effort will be directed by experienced senior instructors to the training and guidance of new graduate assistants. The Committee believes that efforts expended in the training of graduate students as teachers will be of benefit to them no matter whether they follow later the pursuits of teaching, scientific research, or industrial activity.

Respectfully submitted,
WM. N. LACEY, *Dean of Graduate Studies*

THE DEAN OF STUDENTS

To the President:

The academic year 1949-50 just closed marks the mid-century point, and for the California Institute, the passing to a large extent of the special conditions experienced following the war. The report of the Registrar shows that veterans comprised 39 per cent of the undergraduate group during the past year, but of the 197 seniors, 143 or 72 per cent were veterans. In contrast, only 11 per cent of the freshman class were veterans. By no means can the reduction of the proportion of veterans be regarded as an advantage, for by reason of their maturity and earnestness of purpose they have constituted a highly gratifying group of students. The decreased proportion of veterans, 30 per cent of whom were married, will, however, result in a more homogeneous student body and one in which there may be more uniformity of interests from the standpoint of campus life.

It has been traditional for many years that the officers of the Student Body administer student government and the cherished Honor System with a high order of responsibility. At times, circumstances develop which put the sincerity and responsibility of the student officers to critical tests. During the past year there arose several occasions when campus citizenship was displayed involving much personal inconvenience, and it was gratifying to observe the stability of the officers in the maintenance of established principles and standards of student honor.

A project successfully carried through the financing stage during the past year is that of the residence and conference center for the Institute Y. M. C. A. Largely due to the initiative and personal gen-

erosity of the president of the Board of Directors, Mr. J. Stanley Johnson, class of 1933, a large lot was acquired a few hundred feet north of the campus on Holliston Avenue and a suitably designed house is now under construction. This house will serve as the residence of the executive secretary of the Y. M. C. A. and a readily accessible center for numerous informal social and discussion activities which should prove stimulating as well as enjoyable.

The Caltech Service League, comprising parents and friends of students, has shown resourcefulness in identifying opportunities for helping with special situations. The quarters of the Throop Club —lounge for the students not residents on the campus—were redecorated and refurnished. Also a room in the Health Center has been equipped for numerous additional clinical services. These special undertakings are in addition to many activities providing help of wide diversity for students and their families.

Following the death of Colonel E. C. Goldsworthy, Master of the Student Houses, in the spring of 1949, Mr. George K. Tanham, Instructor in History, was appointed to that important administrative position. Colonel Goldsworthy's geniality and his skill in dealing with young men, supplemented by Mrs. Goldsworthy's friendly hospitality, have been greatly missed, but the past year under Mr. Tanham's direction has been a good one with significant progress made in adjustment from some of the conditions inherent in the transition period following the war.

This occasion is taken to express appreciation of the cooperation provided by the Associate Deans. Professor Paul C. Eaton, Associate Dean for Upper Classmen, has been mainly responsible for the preparation of a plan for student counseling which will be put in effect with the beginning of the college year 1950-51. Professor Foster Strong, Associate Dean for Freshmen, has conducted an investigation this past year endeavoring to determine causes of difficulty of those students whose scholastic performance is below the standard of their abilities. Remedial classes will be arranged next fall in the hope of overcoming some of the obstacles to good progress which have beset some students.

Each new year brings new situations. The experience of the past is a great aid in identifying guide-posts for unfamiliar conditions. The objective of the deans is to assist every student to achieve the maximum benefits possible from his sojourn at the Institute.

Respectfully submitted,

FRANKLIN THOMAS, *Dean of Students*

The Associate Dean for Upper Classmen

To the President:

A dean who fails to receive the fullest cooperation from other members of the college community is of limited usefulness. Again this year, the work of this office has been greatly assisted by the consistently cheerful efforts of staff, administration, non-academic personnel and, last but by no means least, undergraduate students.

Every year the Associated Students of C. I. T., in their selection of the president of the undergraduate student body, provide the deans with invaluable assistance. Student body presidents are uniformly of high caliber, but the incumbent this year, Mr. Ralph Lovberg, was particularly energetic, resourceful, and conscientious. Applause was gratifyingly enthusiastic when, upon his graduation—with honors and with an Honor Key—he was awarded the Frederic W. Hinrichs, Jr., Memorial Award, presented to "the senior who, in the opinion of the undergraduate deans . . . . has made the greatest contribution to the welfare of the student body."

Mr. Lovberg was one of a number of able upperclassmen who, during the year past, presented before Dean Watson's Seminar on Educational Problems and Methods recommendations for the improvement of instruction. Some of these recommendations have, thanks to their thoughtful and effective presentation, been adopted by the Faculty, and should pay dividends in improvement both of morale and pedagogy.

Increasingly apparent during the post-war years at the Institute has been the too frequent reluctance on the part of undergraduates to avail themselves of the opportunities for advice and assistance from Faculty members in their own professional fields. There has been no criticism of the willingness or the availability of the professors to discuss matters pertaining to their courses; but there has been no general mechanism, outside the classroom and chance association, for bringing Faculty members and students into close association on matters of mutual interest.

To remedy this defect, or rather to make more general a relationship which had worked well in individual cases, the Faculty voted on February 20, 1950, to establish a system of departmental advisers to upperclassmen, and to implement its operation. Each division chairman in science and engineering assigns students registered in each option of his division—rarely more than five in each of the three upper classes—to a departmental adviser, a man of Faculty rank in that option. This adviser reviews the student's pre-registration in the option, assists him in the choice of elective courses, and, by occasional conferences, assures himself and the student that satis-

factory progress is being made in the right direction. Ideally, the five students assigned to an adviser in the sophomore year will continue with him through the senior year, during which latter year the adviser will interest himself particularly in the best placement, in industry or in graduate school, and assist the student in achieving that placement.

Such a "system," of course, is only as good as the participants make it. Judging from the evidence of the past term, co-operation of participating departmental advisers has been of the highest order, and student reaction is indicated by the following closing line of the *California Tech's* editorial on May 18, 1950: "Although Caltech never could lay claim to being an educational factory, this advisor system will be even one more step in the direction of an ideal individualized relationship between the Institute and the undergraduate."

Respectfully submitted,

P. C. EATON, *Associate Dean for Upper Classmen*

THE ASSOCIATE DEAN FOR FRESHMEN

To the President:

One hundred and seventy-one freshmen registered in September, 1949 and went to the New Student Camp. By coincidence, this was exactly the same number as for the previous year.

One hundred and seventy of these returned from camp and started instruction. In the course of conversations with one student at camp, it became evident that he would be better off at another school, so upon return from camp assistance was given him in registering at this other school, and his registration at the Institute was cancelled.

The New Student Camp for 1949 was considered to be a successful one. As predicted last year, the program has become stabilized, and the effect achieved is probably approaching the maximum that can be expected. An improvement was made at this camp in conducting the "How to Study" seminar, and further improvements will be attempted next year. As before, the enthusiastic cooperation received from the Faculty and student leaders was the foundation of the camp's success.

We still have with us the problem of getting new students adjusted to the realities of a hard-working college campus. Too many new students are insulated by their natural optimism and by the exciting drama of their arrival at college from a penetrating realization that the statements made at camp, concerning self-discipline, study, and the selected use of time and energy, apply to them. This atmosphere of excitement and drama is abruptly shattered at the middle of the

first term by the blue slip warnings of academic deficiency. With the freshman class almost entirely made up of young 17- and 18-year-olds, who have never before been seriously challenged by rigorous demands made on them, it is a delicate job to retain the optimism and enthusiasm of the new student and at the same time persuade him to become organized for disciplined, consistent hard work. The Student Houses are giving more attention to the problem, as it applies to freshman house residents, and in attempting to find a satisfactory solution, the Deans' Office has received excellent cooperation from the Master of the Student Houses and from his Resident Associates.

Another student problem that has come increasingly to our attention in the past few years is the inability of many students to read with speed and comprehension. Judging by comments in educational journals, this problem is a national one affecting all colleges. In an attempt to see what might be done in improving the reading habits of our students, Dr. William G. Perry of Harvard was invited to the campus for three days in the spring of 1950 to discuss with members of the Faculty his experience in improving reading comprehension. Out of this visit has come a tentative plan to install in the near future a course, available to students on a voluntary basis, in the improvement of reading and study.

This year the orientation talks to freshmen for the purpose of vocational guidance were continued. They were followed by compulsory referral to various option consultants. This was an improvement over previous years. General student opinion seems to indicate that the compulsory reporting to an option consultant was not objected to, and that the students were surprised and pleased at the ease with which it was possible to obtain interesting and pertinent information from the consultants.

Of the 170 men in the freshman class this year, 141 are expected to return as sophomores next year. This loss of 29 is made up as follows:

Formally failed scholastically	7	
Withdrew to avoid scholastic failure	3	
Total of those academically deficient		10
Withdrew, or will not return, for financial reasons		2
Withdrew to change vocation		3
Withdrew because of disaffection		1
Reinstated to repeat work next year		7
Known to be doubtful returnees, but not yet formally withdrawn		3
Reinstated to return as sophomores, but strongly urged to transfer elsewhere—probably will not return		3
		29

This attrition of 29, or 17 per cent of the class, is larger than last year. There is no significant change from previous years except perhaps in the one category: "Reinstated to repeat work next year." In 1947-48 there were 2 students in this category, in 1948-49 there were 4, and now this year, 7. This reflects the feeling of the Freshman Registration Committee that there is apparently an increasing number of students who fail, not because of lack of ability or lack of serious purpose, but because of lack of experience in knowing how to get down to work.

Respectfully submitted,
FOSTER STRONG, *Associate Dean for Freshmen*

THE DEAN OF ADMISSIONS AND REGISTRAR

To the President:

Enrollment figures for the opening of the 1950-51 academic year show a total of undergraduate and graduate students of 1070, a decrease of somewhat over 6½ per cent from the figures of September, 1949. Comparative figures are listed below.

Registration Figures

	September 1948	*September 1949*	*September 1950*
Undergraduates	753	697	645
Graduates	518	444	425
	1271	1141	1070

Figures on Veteran Enrollment

	1948		*1949*		*1950*	
	No.	*Per cent of Total*	*No.*	*Per cent of Total*	*No.*	*Per cent of Total*
Undergraduate veterans	422	56	272	39	147	23
Graduate veterans	308	59	267	60	264	62.1
	730	57	539	47	411	38.4

In the report for 1949-50 it was pointed out that with the graduation of the large post-war classes the size of the undergraduate body should stabilize at around 675. It was also pointed out that with the decrease in the number of veterans receiving government support, lack of money on the part of many applicants would have an adverse effect on enrollment. The drop in undergraduate registration in September, 1950, below what might be considered a normal figure, is owing to the fact that for three years the entering class has numbered 170 instead of the anticipated 180, and this in turn is due to

late cancellations mostly from those who had to be refused scholarships or who received larger awards from other colleges. As of the date of writing this report, the prospects for a full freshman class in September, 1950 are somewhat better. While it is too early to predict the effect which the revival of the draft will have on final enrollment, there have been fewer cancellations by this date (July 25) than there have for the past three years. This is in part at least due to the larger number of freshman scholarships available this year.

In 1948-49, 63, or 8 per cent of the undergraduates received scholarships ranging from $100 to $500 and totalling $19,575. In 1949-50, 83, or 12 per cent of the undergraduates received scholarships ranging from $100 to $600 and totalling $32,500. To be eligible for a scholarship a student was required to demonstrate need and to rank in the top quarter of his class. Figures are not now available for the amount which will have to be awarded to the three upper classes this fall. The trend arising from the factors mentioned in the preceding paragraph is indicated, however, by the awards totalling $22,400 made to 25 per cent of the freshmen entering this September as contrasted with 12 per cent who received $6,500 in 1948 and 18 per cent who received $12,150 in 1949. The figures for freshmen awards in 1948 and 1949 are included in the totals for undergraduates mentioned above.

Applications for freshman admission in 1950 were 22 per cent under 1949 figures. One reason for this is the current inflationary trend which naturally hits hardest those colleges which must charge tuition. However, a decrease in applications this year has been reported by the great majority of colleges throughout the country. The most generally accepted explanation relates to the decrease in the birth rate during the depression years from 1930-1937, the early effect of which was compensated for by the post-war flood of veterans. If this explanation is correct we may expect to have a relatively small number of applications until the increased birth rate of subsequent years, which is now overcrowding the elementary schools, is reflected at the college level about 1954.

This means that for some time to come there will be considerable competition between colleges for the better high school graduates and a tendency on the part of these graduates and their school counselors to choose from among those colleges which present the best picture of themselves in the most effective manner. College catalogues are notoriously and perhaps necessarily dull. To supplement the catalogue we have this year issued a booklet entitled "Facts about the California Institute," which gives in a much more convenient and interesting manner the information which a high school student wants to know when he is trying to select a college.

There is, however, nothing quite as effective as direct and personal contacts with students and teachers. In the fall of 1950 there will be a day-long program of lectures and exhibits to which high school juniors and seniors and their teachers will be invited. In addition, the Admissions Committee is each year enlarging its program of visits to schools and of securing the help of alumni whenever possible. In this connection we labor under two disadvantages. Our alumni are largely concentrated in Southern California, and the members of our staff find it difficult, if not impossible, to be away for an extended period in the fall and spring when such visits are most effective. It may some day be necessary to consider the appointment of a man who can devote full time to this aspect of our relations with schools. It is hardly necessary to point out that a college which does not attract a number of applications several times greater than the size of the entering class must either cut down its enrollment or make some sacrifice in its standards of admission.

One other compelling reason for improving our relations with schools concerns the matter of the geographical distribution of the localities from which our students are drawn. It is obvious that as a general rule the farther away an applicant lives the more information and encouragement is needed to persuade him to apply and in the end actually to enter the California Institute. It is all too easy to become simply a community college drawing almost entirely from the local area.

The homes of freshmen who entered in September, 1950 are distributed as follows: 127 or 73.8 per cent live in California; 43 or 25 per cent live in the United States outside of California; 2 or 1.2 per cent live in foreign countries. It is to be hoped that the number of applications from outside of California can be substantially increased.

Respectfully submitted,
L. W. JONES, *Dean of Admissions and Registrar*

THE DIRECTOR OF STUDENT HEALTH

To the President:

Reorganization and improvement of the Health Center have been in progress since June 1, 1949. The following changes have been completed:

A clinical laboratory has been established with a full time licensed and registered technician in charge.

The medical building has been painted both inside and out, drapes have been added to the windows, a lounge with writing desk, comfortable chairs, reading tables and lamps has been provided.

Each bed in the ward has been provided with sliding curtains permitting proper isolation or privacy as desired. It is anticipated that these curtains will prevent cross infection from upper respiratory disease, a factor which has not infrequently prolonged the period of hospitalization in the past.

More efficient and satisfactory business methods have been adopted, and various economies of operation have been effected. The duties of business stenographer and receptionist have been combined and placed in the hands of a person qualified to handle both positions.

Miss Elizabeth McMichael, R.N., will retain the position of supervisor of nurses.

The cost of diagnostic equipment for the laboratory was considerable and was partly met by a generous gift of $1000 from the Caltech Service League. The following pieces of equipment were purchased with the above fund: a Spencer binocular microscope with lamp attachment; a Leitz electro-calorimeter; a McKesson basal metabolator; and a high speed electrical centrifuge.

Mrs. H. W. Hitchcock, President of the Caltech Service League, and Mrs. Ray Gerhart, Chairman of the Health Center Committee, have both been greatly interested in developing our Health Center. Under their direction, the Caltech Service League and its members have provided the Health Center with a total sum of $1354.00 during the year of 1949-50. Exclusive of the $1000 for the purchase of laboratory equipment, which is included in the above sum, the balance of this amount has been spent for kitchen equipment, pillows, curtains, lamps, etc.

In addition, the League has provided large amounts of canned foods and home baked goods, not otherwise available for special diets, and also has provided current magazines and has maintained the baby clinic.

Arrangements have been made with the Service League for their membership to provide rotating assistants who will help with the general care of bed patients and with the preparation and serving of meals. This service will be available October 1, 1950. Our graduate nurses will, consequently, be able to devote their entire time to their professional duties.

The clinical laboratory is now functioning and is filling an urgent need. The benefits are available not only to the students but to the members of the Faculty and to the employees and their families as well.

It has not been necessary to increase the number of personnel nor to increase the operating costs of the Health Center by the changes which have been introduced.

Arrangements have been completed with the Pasadena unit of the

Los Angeles County Tuberculosis Association to X-ray all students, the members of the Faculty and all employees associated with the Institute. The X-ray units will be set up on the commencement of the school year. There will be no charge for this service.

Along similar lines, progress has been made in arranging for a mass survey of the visual health and efficiency of the students as well as Faculty and employees. The correction of visual defects and refractive errors, as detected by such surveys in many corporations and educational institutions, has greatly improved the over-all efficiency of the group so examined.

If the interest along this line is adequate, such a survey may be conducted on the campus this fall. The charge per individual will be very nominal, probably not exceeding 50 cents per person.

Respectfully submitted,
W. S. GEVURTZ, M.D., *Director of Student Health*

THE DIRECTOR OF LIBRARIES

To the President:

The Library's report of inventory for 1949-50, unlike that of former years, is based upon an actual physical count of the book stock. In former years the Library has reported as inventory the last number of the total which had been entered in the Accession Book at the end of each fiscal year. These numbers have been cumulative since 1910, when the Accession Book was opened. For purpose of inventory they have become increasingly undependable because they have not taken into account volumes lost or withdrawn unless replaced, yet each volume replaced has been counted twice. It was in order to determine, therefore, the inevitable discrepancy, between the total number of volumes received within a period of nearly forty years and the total number on hand at the end of that period, that the Library made a physical count of its holdings.

Total number of books and bound periodicals received between Oct. 4, 1910 and June 30, 1949	76,101
Total number of books and bound periodicals on hand on June 30, 1949	69,186
Difference between volumes received and volumes on hand	–6,915

Henceforth, the Library proposes to use as the basis for inventory the total number of the volumes on hand on June 30, 1949, plus the sum of annual net gains as they accumulate. A summary of inventory and acquisitions for 1949-50 is as follows:

	Totals June 30, 1949	*Added 1949-50*	*Totals June 30, 1950*
Books	44,640	2,991	47,631
Periodicals	24,546	3,576	28,121
	69,186	6,567	75,752

The Library has abandoned the Accession Book, as have most libraries throughout the country, because other methods of recording acquisitions have been found to be more efficient.

The Library gratefully acknowledges many valued gifts received during the year. In addition to single volumes presented by numerous donors, the Library received four sizeable collections. Mrs. Ira W. Clokey and her daughters presented to the Division of Biology the library of the late Ira W. Clokey. It comprises about 200 monographs and 900 volumes of periodicals, including several long runs of scarce and valuable botanical journals. Mrs. Louis G. Stokvis presented the professional library of her late husband. The collection is largely in the field of electrical engineering. Mr. Feodor Foss, of Santa Barbara, presented the first installment of a gift comprising his entire library of monographs, journals, and books in the fields of metallurgy, economics, and political science. Mr. Keith Anderson, an alumnus of the California Institute, presented several hundred volumes of state geological publications. Still another gift, in somewhat a different category, is that of Mrs. Oliver B. Scott, who in association with friends, and in memory of Mr. Scott, established a fund for the purchase of books in the fields of botany and biochemistry.

Among the numerous important acquisitions the Library purchased this year, the *Library of Congress Catalog of Printed Cards* probably is most nearly indispensable. This great reference work will facilitate operations in every branch of the Institute's library system.

The Periodicals and Catalog departments are jointly preparing a Periodical Catalog, which will be finished by the beginning of the Fall term. This catalog incorporates sufficient cross references to enable anyone, however unfamiliar with library practices, to find the title of every periodical the Institute holds, to learn where it is located, and how extensive is the run. The catalog incorporates also those titles and runs of journals, in the Library of the Mount Wilson Observatory, which the California Institute lacks.

The Periodicals Department broke its own record by acquiring and processing almost a thousands more bound periodical volumes than it did last year. In addition to its routine work, and compiling the titles for the new periodical catalog, the Department also compiled a want list which forms the basis for a buying program to cover the next ten years.

During the year, the Library has made a survey of book shelf space on the campus—with disheartening results. Only the Humanities Library has shelf space for several years' growth. Several of the divisional and departmental libraries will have filled all their space in a year of two. Several others have already used up their shelf space and must resort to crowding and basement storage to provide for acquisitions. Crowding and improvisation can probably provide essential book shelf space in the immediate future, but the limits to which they can be continued are narrow.

Government Documents of general, as opposed to scientific, interest have been consolidated in the Humanities Library where, arranged for easy reference, they occupy about 250 running feet of shelving.

The data collected in the inventory and in the survey of shelving serve both their obvious immediate purpose and as part of the program for a new library building. Figures now are available on the size and rate of growth of each divisional and departmental library, and compilation of other essential information is in progress, including a file for the systematic collection of all kinds of information about college library plans and structures.

The Library is now prepared to act as Custodian for the Institute Archives. With the exception of material stored in safes, the archival collection is now assembled in a single room, located in the subbasement of Arms, instead of being scattered among various campus organizations and offices. The Library has planned a program to fill the gaps in the collections of Institute publications, and to insure collection of all current material. In addition to administrative and student publications, the archives include publications of the staff as well as pictures and objects of historical interest.

As part of its program for improved service to faculty and students, the Library plans several innovations for the coming year. Mr. Paul J. Monroe, the latest of four professional librarians appointed to the staff, will be Librarian for the Division of Humanities and General Reference Librarian for the Institute. Another librarian will divide her time between the Biology and Chemistry Libraries. Dr. Oliver Dunn will offer graduates and undergraduates a short elective course, without credit, in the uses of the library. A much-needed publication, entitled *A Guide To The Libraries*, will be ready for distribution at the beginning of the Fall term.

Other activities planned for the coming year are to continue the program for a new library, to survey the subject of catalog revision in order to determine the Library's policy on the subject and then to continue revision as fast as possible, to develop a plan of library

service for the Industrial Associates of the Institute, and to find and prepare additional space for immediate growth.

The Library is fortunate to have acquired the services of Associate Director, Dr. Oliver Dunn, and of Cataloger, Mrs. Julia Chesny, who have assumed their responsibilities with vigorous competence. It is with sincere regret that the Library parts with Mrs. Jack McLaughlin who has been largely responsible for the orderly and accelerated growth of the periodical collections.

In closing, it should be said that the Library is constantly aware of its primary activity, namely, to develop a Library worthy of the California Institute, and constantly to increase its usefulness.

Respectfully submitted,
ROGER STANTON, *Director of Libraries*

THE DIRECTOR OF PLACEMENTS

To the President:

In the Fall of 1949, the placement outlook for men expecting to receive degrees in June 1950 was poor. It appeared that industry had almost satisfied its war-time deficiency of engineers and scientists and there would be a surplus of men applying for positions. These conditions were reflected in a marked decrease of reservations for interview dates by industrial concerns. Some companies stated that they would do no recruiting in the year 1949-50; others indicated that they would be more selective and would make fewer offers. There was some indication that starting salaries might be a little lower than in previous years. This situation prevailed until about March or April, 1950, and then placement conditions began to improve in some fields. By the date of Commencement, the demand had nearly reached that of the preceding few years. So far as can be determined, not less than 3 per cent of the men who received degrees in June 1950 were unemployed. The industrial organizations who have interviewed on campus have indicated eagerness to employ Institute graduates, but they can take only a small portion of their quota from one institution.

Recognizing the problems which face seniors in looking for employment, a series of discussion meetings was arranged with the assistance of a committee of the Alumni Association. This series of discussions was started in October and continued into March, with a total of 15 meetings held in the evening at the Student Houses. Outstanding men from industry and government agencies led these discussions covering the general aspects of seeking employment, where industry and government use engineers and scientists, and

the opportunities in specific fields. These discussions were excellent and provided students with valuable information and an opportunity of talking on an informal basis with men in the field.

The action of the Faculty creating a plan of counseling undergraduates, to begin with the year 1950-51, should prove to be very helpful on matters of placement. Heretofore the discussion of placement problems between students and Faculty has been, in many cases, lacking. This was shown by individual interviews of all seniors with the Director of Placements in the Fall.

The Alumni Placement picture was similar to that described for men graduating in June. The number of alumni who registered for a change of employment was somewhat greater in 1949-50 than in the preceding year. The applications of about 400 alumni were handled during the year. About 800 requests for men were received, which is approximately the same number as in the previous year. A large proportion of the requests were for men of considerable experience.

Respectfully submitted,
DONALD S. CLARK, *Director of Placements*

Part IV

ACTIVITIES OF THE DIVISIONS

THE DIVISION OF BIOLOGY

To the President:

Since World War II many outstanding advances in biology have been made in laboratories all over the world. To mention only a few of these: Bacteriology has been revolutionized by a group of young investigators using the methods of genetics, cytology, and biochemistry. Our knowledge of viruses has been greatly increased, particularly from the biological point of view. Through a growing interest by physicists and physical chemists in biological problems, biophysics has grown rapidly. It has made extensive use of the electron microscope, the preparative and analytical centrifuges, the Tiselius electrophoresis apparatus and other techniques completely unknown to the biology of a few years ago.

Through its Divisions of Biology and Chemistry, the Institute has made its fair share of contributions to the new biology. During the year under review many specific accomplishments have been recorded. Part of these are mentioned in this report of the Division of Biology and part in the account of the activities of the Division of Chemistry. The convention of separate reports from the two divisions, desirable as it may be from a purely administrative point of view, is unfortunate in so far as it fails to develop an adequate picture of the joint chemistry-biology program at the Institute.

During 1949-50 the activities of the Division were carried on by a staff of 12 professors, 10 research associates, 5 associate professors, 9 senior research fellows, 1 assistant professor, 53 postdoctoral research fellows, 23 graduate fellows and assistants, 14 graduate students, and 138 non-academic personnel in offices, laboratories, library, stockroom, shops, greenhouses, gardens, marine station, animal annex, etc.

Several staff members received special awards or honors.

Albert Tyler was granted leave of absence for the winter quarter to accept an appointment as Walker-Ames Visiting Professor in the Department of Zoology of the University of Washington.

Arthur W. Galston was awarded a Guggenheim Fellowship to work in the laboratory of Hugo Theorell of Stockholm, Sweden.

Arie J. Haagen-Smit was given the Fritzsche Award by the American Chemical Society for "outstanding achievement in analysis, research, and new applications of essential oils."

William M. Hiesey, with two fellow staff members of the Carnegie Institution of Washington, shared in the award of the Mary Soper Pope Medal by the Cranbrook Institute of Science for "distinguished accomplishment in botany during 1949."

Warren P. Spencer was awarded the Leidy Medal by the Academy of Natural Sciences of Philadelphia "for his distinguished studies . . . . . and for his stimulating undergraduate teaching that has inspired able young men to go on to scientific careers."

James Bonner was elected to the National Academy of Sciences.

FELLOWSHIPS AND SCHOLARSHIPS

The program of the Division of Biology, like the programs of other divisions at the Institute, puts strong emphasis on graduate work and postdoctoral training. The latter is evident from the fact that during the year 1949-50, 53 postdoctoral research fellows worked in the division. Almost all of these held fellowships or scholarships, some from Institute funds and others from outside agencies.

Gosney Fellowships. Five men held Institute Gosney Fellowship appointments:

Barry Commoner, Associate Professor of Botany, Washington University, St. Louis, Missouri.

Charles B. Metz, Assistant Professor of Zoology, Yale University, New Haven, Connecticut.

Donald F. Poulson, Associate Professor of Zoology, Yale University, New Haven, Connecticut.

Warren P. Spencer, Professor of Biology, College of Wooster, Wooster, Ohio.

Marshall R. Wheeler, Instructor, Department of Zoology, University of Texas, Austin, Texas.

McCallum Graduate Fellowship. Through the Nutrition Foundation and the McCallum Foundation, Mr. Arthur McCallum established a graduate fellowship for work in chemical genetics, biochemistry, and other fields related to nutrition. The first award of this was made for the academic year 1950-51 to Mr. George L. Ellman, graduate student working toward a Ph.D. degree in chemistry with Professor H. K. Mitchell.

Thirteen persons carriod on postdoctoral research in the Division under fellowships awarded by agencies other than the Institute. These were as follows:

Rockefeller Foundation Fellows	3
Merck Fellows of the National Research Council	3
National Research Council Fellow in the Natural Sciences	1
American Cancer Society Fellow	1
Commonwealth Fund Fellows	2
Atomic Energy Commission Fellow	1
University of London Fellow	1
University of Nebraska Johnson Faculty Fellow	1

In connection with nationally awarded postdoctoral fellowships, it is a fact of interest that of 24 Merck Fellowship awards made during the three years 1947, 1948, and 1949, four were to men from the Institute and nine were to men who elected to work at the Institute. This is a record of which the Institute can with good reason be proud.

Graduate Fellowships. The Lucy Mason Clark Fellowship in Plant Physiology, established last year, was awarded for the first time in 1949-50 to Mr. Jean Nitsch, who is completing work for a Ph.D. degree with Professor Went.

Five graduate students held nationally awarded predoctoral fellowships as follows:

Atomic Energy Commission Fellows	2
U. S. Public Health Service Fellows	3

Undergraduate Scholarships. The Seeley W. Mudd Scholarship, established by Doctor Seeley G. Mudd for students interested in medicine and medical research, was held during 1949-50 by Mr. Wheeler North. Mr. North will work toward a Ph.D. degree at the Scripps Institution of Oceanography at the University of California with the ultimate goal of investigating aging from a biochemical standpoint.

The first award of the Thomas Hunt Morgan Scholarship, established by friends of the late Professor Morgan, was made for 1949-50 to freshman Robert Wood.

VISITING LECTURERS

During the year seventeen seminars were given by visiting lecturers. In many instances travel assistance was provided these lecturers by the Eversole Lecture Fund.

VIRUS SYMPOSIUM

Through a generous grant from the James G. Boswell Foundation, the division is in a position to strengthen greatly its research program in virology. As a means of summarizing the present state of

knowledge of plant, animal, and bacterial viruses and of seeking effective ways of gaining new knowledge about these important disease-producing agents, a special three-day virus conference was held at the Institute in March, 1590. Professor Max Delbrück was largely responsible for planning and managing this conference. It was attended by 20 leading virologists, representative of the major research groups throughout the country. In addition, 15 staff members of the Institute participated. The conference was found to be so valuable to those who took part in it that at the last moment it was decided to publish the proceedings. This has now been done in a 150-page volume entitled *Viruses 1950*. With this conference as a background, plans are now being made to extend the Institute's virus research program to include work on animal viruses.

LECTURE SERIES ON PSYCHOANALYSIS

The Hixon Committee, with financial assistance from the Hixon Fund, sponsored a series of five lectures on the general subject, "The Scientific Basis of Psychoanalysis." These were as follows:

Professor Ernest R. Hilgard, Stanford University, "Experimental Approaches to Psychoanalysis." (Two lectures)

Doctor Lawrence S. Kubie, New York City, Yale University School of Medicine, "Problems and Techniques of Validation in Psychoanalysis." (Two lectures)

Doctor E. P. Mindlin, Veterans Administration, Los Angeles, "The Position of Psychoanalysis in the Biological and Social Sciences."

This series of lectures was so well received that it was decided by the Hixon Committee that it should be published. On concurrence of the participants, plans for publication were made, and Doctor Mindlin has consented to serve as editor.

RESEARCH ACTIVITIES

It is not an easy task to summarize briefly the activities of over 130 researchers working in more than a dozen branches of biology. All that one can hope to do is give a general impression with perhaps a highlight here and there.

In comparative and mammalian physiology Professors C. A. G. Wiersma and Anthonie Van Harreveld with a group of collaborators are adding to our knowledge of how the nervous system works—how animal reactions may depend on a pattern of nerve impulses, how nerve impulses are transmitted from one nerve cell to another, and a host of related problems. They are also interested in the effects of drugs on blood circulation, the mechanism by which pain sensations

are perceived, the manner in which functional improvements may occur through nerve regeneration in muscles that have been denervated experimentally or through such diseases as poliomyelitis, and the patterns of brain activity under the influences of drugs, oxygen lack, or such diseases as epilepsy.

In biochemistry Professors Henry Borsook, A. J. Haagen-Smit and a group of coworkers have been investigating the manner in which proteins are made by animals. These giant molecule compounds are essential constituents of all living things—viruses, bacteria, plants, animals and man. They are of many kinds, all made from a common set of some 20 building blocks compounded end to end to form long chains. The component parts are known as amino acids. Their structures are relatively simple and well understood by chemists, but the way in which they are built up to form proteins remains one of biology's unsolved problems. This is a problem of fundamental importance because proteins are key substances in growth, in the processes by which organisms reproduce their kind, in heredity, in the structure and function of enzymes, and in many other aspects of the normal functioning of organisms. In fact it can be said that the problem of protein synthesis impinges in one way or another on every branch of biology. By tagging individual amino acid building blocks with radioactive carbon atoms in strategic positions, and allowing these marked smaller molecules to be put together by living cells or suitable preparations made from living cells, the Borsook team is able to recover the resulting proteins marked in certain of their component parts. By carefully degrading such proteins, much as one would break a pattern of dominos into sidechains and subgroups, the researchers are finding it possible, by following the distribution of radioactive carbon, to learn a great deal about how the original amino acids were put together to form large and complete protein molecules.

In the field of bio-organic chemistry, Professor Haagen-Smit and his associates have not only collaborated with Borsook's group in the protein synthesis project, investigated a series of natural chemical substances including the essential oils, examined chemically the flavor constituents of grapes and wines, and studied milk proteins, but in addition have added notably to our knowledge of the source and properties of certain harmful constituents of Los Angeles smog. The plant-damaging effects of natural smog can be duplicated by organic peroxides produced from the interaction of hydrocarbons of gasoline with ozone. This work is so promising that the Los Angeles Air Pollution Control District has persuaded Professor Haagen-Smit to join its research staff on a three-quarter-time basis for a year.

Professor Albert Tyler and his collaborators have continued to study physiological and chemical aspects of the process of fertilization in certain marine invertebrates and in the trout.

In the field of genetics, which the Institute has emphasized strongly from the time the late Thomas Hunt Morgan first organized the Division of Biology, there are several groups of workers approaching the basic problems of gene transmission and gene function from many directions. One group working with the fly Drosophila—Professors A. H. Sturtevant and E. B. Lewis, plus a number of research fellows, graduate students, and research assistants—is concerned with such problems as the genetic composition of populations, the mechanisms by which chromosome rearrangements are produced and affect chromosome distribution, the relation of gene position to gene function, and the mechanisms by which genes control morphological traits. The corn group, under the general leadership of Professor E. G. Anderson, is investigating the genetic, cytological, and biochemical characteristics of gene mutations and chromosome aberrations induced by laboratory-controlled and atomic bomb high energy radiation. A third group, represented by Professors Sterling Emerson, N. H. Horowitz, and H. K. Mitchell and working with the red bread mold Neurospora, has continued to emphasize the chemical aspects of genetics—the relations of genes to enzymes and to specific chemical reactions. Finally, in the work of Professor R. D. Owen and his associates we see an attack on genetic problems through the use of the tools of serology. As an example of this approach Doctor Clement Markert, Merck Research Fellow, and Professor Owen have investigated the enzyme tyrosinase in a series of mutant strains of the mold Glomerella. Through injection of mold material into rabbits, antibodies directed against the enzyme are elaborated in the rabbit's blood serum. These are detected through their ability to precipitate and inactivate the enzyme tyrosinase which catalyzes the formation of melanin pigment from the amino acid tyrosine and closely related compounds.

In the field of plant biochemistry, headed by Professor James Bonner, research activities continue to center around the plant growth hormones, their synthesis, their enzymatic conversion to compounds without growth-promoting properties, and their roles in chemistry and physiology of the plant. In this direction a significant advance has been made by Doctor Galston and his collaborators, who have shown that vitamin B_2 is the receptor pigment in the photooxidation of the growth hormone indoleacetic acid. This appears to be the key mechanism in phototropic responses in higher plants, that is, to explain why plants grow toward light. The plant biochemistry group has also investigated such phenomena as the flowering of higher plants in

response to particular periods of light and dark, the growth of plant tissue cultures, the hormonal control of fruit growth, and the biosynthesis of rubber in the guayule plant.

A notable event of the year in the Biology Division was the inauguration of the recently completed Earhart Plant Research Laboratory. The operation of this unique laboratory is under the general direction of Professor Frits Went. Among numerous projects now under way are those on the identification of plant-damaging smog constituents and their manner of action on plants, the effects of day and night temperatures on the growth, flowering and fruiting of such plants as the tomato, a determination of conditions favorable for the growth of the plant Veratrum and production by it of alkaloids useful in the treatment of hypertension, and an investigation of factors influencing growth and sugar formation by the sugar beet.

In virology two groups have been active during the year. The Delbrück group has continued a series of investigations concerning the nature of bacterial virus, the manner in which it invades its host cell, and its mode of multiplication after invasion. A second group, including Doctor Samuel Wildman, Professor Owen, and others, has investigated higher plant viruses from the standpoint of how virus formation in an infected plant is related to normal protein constituents. A method of diagnosing plants for virus disease before external symptoms appear has been developed by Wildman and coworkers, using the Tiselius electrophoresis apparatus.

Respectfully submitted,
G. W. Beadle, *Chairman, Division of Biology*

THE DIVISION OF CHEMISTRY AND CHEMICAL ENGINEERING

To the President:

The past year has been a year of steady progress of the Division of Chemistry and Chemical Engineering in its program of teaching and research. The vigor of the research programs in physical chemistry, inorganic and analytical chemistry, organic chemistry, immunochemistry, and chemical engineering is indicated by the continued increase in the number of post-doctoral research fellows, who have come to the Institute to carry on their work from all over the United States and from many foreign countries. The number of these post-doctoral research men, working with the 28 members of the senior staff, has increased to 40, and the research group in-

cluded also during the past year 18 research assistants and 45 graduate fellows and assistants.

The scientific work of the Division has been supported by generous grants from the National Foundation for Infantile Paralysis, the Rockefeller Foundation, the Office of Naval Research, and the United States Public Health Service. Substantial financial aid was also furnished by the Eli Lilly Company, the DuPont Company, the Carbide and Carbon Chemicals Corporation, the Research Corporation, and the American Petroleum Institute. In addition, a number of foundations and industrial firms provided support for special fellowships.

RESEARCH IN PHYSICAL CHEMISTRY

Although it had been clearly recognized for more than a century that the properties of crystals strongly indicated that these forms of matter are composed of atoms arranged in regular, repeating manner, it first became possible to determine the actual arrangements of the atoms in crystals in 1913. In this year the two Braggs, father and son, making use of a discovery by Max von Laue the year before, determined the structure of a number of simple crystals by the interpretation of the X-ray diffraction photographs of the crystals. Within two years the technique of X-ray diffraction was being applied at the California Institute of Technology (then called Throop College of Technology) by two early workers in the chemistry department, Burdick and Ellis. The work was then continued by Professor Roscoe G. Dickinson and his students, and in recent years by Professors Linus Pauling, J. H. Sturdivant, and Robert B. Corey, and by many other workers in the Gates and Crellin Laboratories. A considerable part of our knowledge of the solid state has been obtained through the efforts of the investigators in the Institute, and the Gates and Crellin Laboratories are now recognized as one of the world's greatest centers in crystal structure research.

During the past year the investigation of the structures of the amino acids, the basic constituents of proteins, has been effectively continued through the very detailed investigation of DL-threonine, and progress has been made in the attack on hydroxy-L-proline and DL-serine also. Dr. E. W. Hughes and his collaborators have continued the study of peptides, including alpha-glycylglycine, gamma-glycylglycine, beta-glycylglycylglycine, NN′-diglycyl-L-cystine, and several others. An interesting investigation has been made of arsenobenzene. This substance, which is closely related to the important drug salvarsan, has been found to consist of a six-membered puckered ring of arsenic atoms, with a benzene ring attached to each. It is probable that salvarsan itself has a similar structure, rather than the structure commonly ascribed to it by organic chemists, in which

there is a double bond between two arsenic atoms. A new series of investigations dealing with the crystal structure of antibiotics has been begun. Dr. J. D. Dunitz had made good progress toward a complete structure determination of chloramphenicol (Chloromycetin), and has also begun work on aureomycin and terramycin. Information about the nature of addition compounds has been obtained from the determination of the structure of the compound of manganous chloride with hexamethylene tetramine by Dr. You-Chi Tang, and of the compound of urea and oxalic acid, by Dr. Adam F. Schuch and Professor Lynne L. Merritt, Jr.; and a number of other problems in inorganic chemistry and organic chemistry have been attacked during the year by the X-ray method.

The new cold room, designed for operation at temperatures as low as -40°C, has been completed, and equipped with X-ray facilities. This room will be used in the effort to obtain information about the structure of proteins through X-ray diffraction at low temperatures. It is hoped that the information obtained from the investigations of the structure of amino acids and peptides will assist in the interpretation of the very complex diffraction patterns provided by the proteins, and that in this way a solution to the riddle of protein structure will ultimately be obtained.

Professor R. M. Badger and his associates have continued their spectroscopic investigations in the infrared region. Infrared studies of several gases having unusual spectra have been made and interpreted. Among the gases studied are nitrous acid and hypochlorous acid, which cannot be isolated in the pure state, and which are, for this reason, not easily susceptible to structural study except by spectroscopic methods. Infrared investigations of the carbohydrates, amino acids, and related substances have been continued with the support of the Bureau of Ordnance through the Office of Naval Research. The capacity of the infrared method of structural investigation has been considerably extended by the development of a special microscope which makes it possible to obtain spectra on samples as small as one millionth of a gram. Spectra of single micro crystals can be obtained in this way, and with the use of polarized radiation information about the structures of several crystalline substances has been obtained.

Another very important technique of structural chemistry in which the California Institute of Technology has been a leader is that of the determination of the molecular structure of gas molecules by the diffraction of electrons. During the past year Professor Verner Schomaker, Dr. Kenneth W. Hedberg, Dr. Otto Bastiansen (from Norway), Dr. Edgar Heilbronner (from Switzerland), and a number of other investigators have studied several interesting substances.

One of these substances is the blue hydrocarbon azulene, which has been found to be planar, the seven-membered ring of the molecule to this extent therefore resembling the six-membered rings of the aromatic series, such as benzene, rather than the eight-membered ring of cyclooctatetraene, which is puckered. It has also been found that the molecule trisilylamine has a planar arrangement of the three silicon atoms about the nitrogen atom, whereas analogous compounds of nitrogen have a pyramidal structure. It has been confirmed that in molybdenum hexafluoride the six fluorine atoms are not all at the same distance from the molybdenum atom; the reason for this difference in nature of the bonds between molybdenum and fluorine is not known. Studies have been made of a number of boron hydrides and related compounds.

Professor Linus Pauling, Dr. David Shoemaker, and Dr. F. J. Ewing have continued their investigations of the structure of alloys, in an effort to develop a theory of the relation between composition and mechanical properties of these important materials. In the course of this work the structures of several complex intermetallic compounds have been determined, and further progress has been made in the formulation of a system of metallic valence.

The program of research in statistical mechanics being prosecuted by Professor J. G. Kirkwood has been continued vigorously, with the support of a contract from the Office of Naval Research. A rigorous derivation of the equations of transport of hydrodynamics from the laws of molecular mechanics has been formulated. A numerical solution of the integral equation for the radial distribution function in liquids has been found, and several other problems have been satisfactorily treated during the year.

Dr. Oliver R. Wulf, working as a member of the United States Weather Bureau at the Institute, has continued his research on the variations of the earth's magnetic field in their relation to variations of solar activity and of the large-scale circulation of the atmosphere.

INORGANIC AND ANALYTICAL CHEMISTRY

Professor Don M. Yost and his students have continued their attack on problems of inorganic chemistry, with use of modern methods. A microwave spectrograph has been constructed, and used in determination of the structure of hydrocyanic acid and tetrafluoromethyl acetylene. An improved technique of dating archeological specimens by the determination of the content of carbon-14 has been developed, and applied to some specimens. Other problems being investigated are the properties of the manganese-indium alloys, the nature of the photochemical reaction between water and bivalent europium ion, the magnetic properties of europium and samarium

amalgams, exchange reactions involving tritium, and the use of nuclear resonance phenomena in inorganic chemistry and chemical analysis.

Professor Norman Davidson has continued his study of the interesting phenomenon of the intense coloration shown by compounds containing the same element in two different valence states. This work has been extended to compounds of copper, manganese, platinum, and palladium. The electronic mechanism underlying the phenomenon continues to be puzzling. The techniques used in this work are those of spectrophotometry and the use of radioactive tracers. These techniques have also been applied in the investigation of rates of reactions and the nature of photochemical processes at high intensities of light.

Professor Ernest H. Swift has continued work on the development of a new method of quantitative analysis, the coulometric method. In this work he has had as a collaborator Dr. Paul S. Farrington, who during the year held the Merck Graduate Fellowship in Analytical Chemistry. Dr. Farrington was the first recipient of this fellowship, which is to be awarded annually. It is open to young analytical chemists anywhere in the United States.

ORGANIC CHEMISTRY

During the year the members of the staff and their associates in the field of organic chemistry have made contributions to a number of important problems.

Professor H. J. Lucas and his students have continued the study of the mechanism of organic reactions, including especially the hydrolysis of esters and the rate of addition of acids to unsaturated hydrocarbons. In addition Professor Lucas has shown that cyclic chlorophosphites can be made by the reaction of phosphorus trichloride with glycols, and used in the synthesis of cyclic phosphite esters. These substances are useful for resolving glycols into their geometrical isomers.

Professor L. Zechmeister has continued his study of the stereoisomeric carotenoids. In collaboration with Professor Harry J. Deuel, Jr., of the University of Southern California some of these isomers have been tested for their provitamin A activity. The results of earlier work had indicated that the isomers which have a bent configuration about a double bond are less potent in satisfying the need for vitamin A than the all-trans molecule, which has the straight form. The new studies show that the poly-cis compound pro-gamma-carotene is as potent as its all-trans isomer both in rats and in chicks.

With the support of the Office of Naval Research Professor Zechmeister has been studying fluorescing compounds contained in marine organisms. A surprising result of this investigation is that the fluorescent substance phytofluene, which he had shown to be extremely widespread in land plants, seems not to exist in marine organisms.

The problem of the nature of enzyme action is under investigation by Professor Carl Niemann and his collaborators, who have been studying in detail the reactions catalyzed by chymotrypsin, urease, and papain. It has been known for a long time that an enzyme may cause a certain substance to undergo reaction, and not be able to cause another substance to react which is composed of molecules that are mirror images of those of the first substance. Professor Niemann has now found that the molecules of the enzyme alpha-chymotrypsin are able to combine with the mirror-image molecules, and that they combine with these molecules more strongly than with the molecules which they cause to undergo reaction. The continued study of this phenomenon should provide a better understanding of enzyme action. Other problems under investigation include the determination of hexoseamines in polysaccharides, the synthesis of optically active azlactones, the synthesis of amino acid inhibitors involving replacement of a hydrogen atom by a fluorine atom, and the synthesis of the amino acid hydroxytryptophan.

Professor Niemann, Dr. J. B. Koepfli, and Dr. Seeley G. Mudd have continued to work on the isolation and characterization of the mouse tumor necrotic agent formed by the bacterium E. coli. Dr. Koepfli and his collaborators, who in 1946 isolated a highly potent antimalarial agent, febrifugine, from a Chinese drug, have now proposed structures for this unique alkaloid and its isomer, isofebrifugine. This work represents the culmination of an investigation that was started seven years ago, at the request of the Committee on Medical Research of the Office of Scientific Research and Development.

Dr. Edwin Buchman and his collaborators have continued work on the chemistry of compounds containing one or more rings of four carbon atoms. A very interesting molecule has been synthesized, which contains five of these four-carbon rings attached together in a chain by having carbon atoms on opposite sides of each ring common to adjacent rings. The compound which has been synthesized is an acid, with a carboxyl group at each end.

IMMUNOCHEMISTRY AND MEDICAL CHEMISTRY

Professor Dan H. Campbell and his associates have carried out a number of investigations dealing with the nature of serological phenomena, including the improvement of methods of purification of antibodies, the study of antigen-antibody complexes by electro-

phoresis and ultracentrifugation, the isolation of allergenic antigens from egg white and house dust, the isolation of Rh antigen, and electrophoretic studies of serum from normal and hibernating arctic squirrels and bears and from humans exposed to arctic conditions.

Professor J. G. Kirkwood and Drs. J. R. Cann and R. A. Brown have continued investigations of protein fractionation by the method of electrophoresis convection. Fractionation of human immune anti-pertussis gamma-globulin has been carried out, and it has been demonstrated that the protective activity is concentrated in the fractions of low mobility. Several Rh antisera have been fractionated, and the blocking antibody has been found to be concentrated in the gamma-globulin fractions of lowest mobility, while the agglutinating antibody is distributed with maximum titre in the intermediate mobility range between the gamma and beta globulins.

Dr. Harvey Itano, Dr. Walter Schroeder, Dr. Ibert C. Wells, and several other workers have continued the investigation of sickle cell anemia, which was shown last year to be a molecular disease. Complete quantitative determinations of the amino acid composition of the hemoglobin of normal negroes and the hemoglobin of negroes suffering from sickle cell anemia have been made, and it has been found that only small differences in composition exist. The ratio of normal hemoglobin to sickle cell anemia hemoglobin in individuals with sickle cell trait has been studied. This ratio has been found variable, over a range from about 24 per cent to 44 per cent of the abnormal hemoglobin. A study of familial relations indicates that genetic factors are involved in determining the ratio of the two hemoglobins in individuals with sickle cell trait.

In the course of this work a new abnormal form of hemoglobin was discovered by Dr. Itano, in collaboration with Dr. Neel of the University of Michigan Medical School. This third form of adult human hemoglobin is associated with a new disease, which previously had not been differentiated from sickle cell anemia. The individuals suffering from this disease have in their red cells a mixture of two kinds of abnormal hemoglobin, sickle cell anemia hemoglobin and the third variety. This disease seems to result from the inheritance of the sickle cell anemia allele from one parent and of the allele causing the formation of the new kind of abnormal hemoglobin from the other parent.

A study of the magnetic properties of human fetal hemoglobin was begun during the year by Dr. Hans Zinsser. The hemoglobin molecule contains four iron atoms, which contribute to the magnetic properties of the substance. An investigation of these properties may throw light on the problem of the special role played by fetal hemoglobin.

CHEMICAL ENGINEERING

An extensive program of research in special fields of chemical engineering was carried out during the year with the support of funds from the American Petroleum Institute, the Office of Naval Research, the Jet Propulsion Laboratory, and the California Institute of Technology. These studies include the thermodynamic properties of paraffin hydrocarbons and their mixtures with gases such as carbon dioxide and nitrogen at pressures up to 10,000 pounds per square inch, which are comparable to those found in the deeper petroleum reservoirs. A monograph covering the results of these investigations was published by the American Petroleum Institute. Studies have also been made of the behavior of hydrogen sulfide associated with water and paraffin hydrocarbons at high pressures and temperatures, on the thermodynamic properties of the oxides of nitrogen and their mixtures, the viscosity of liquids as influenced by changes of temperature and pressure, the volumetric and phase behavior of a ternary hydrocarbon system, and the measurement of the heat capacity of hydrocarbon liquids.

The program of basic investigations of the relationships of momentum and thermal transfer has been continued. Measurements which have been made with air as a working fluid have added to the experimental background of transfer processes in turbulent flow. Other studies that have been carried out relate to the evaporation of water drops and the combustion of natural gas-air mixtures under conditions of turbulent mixing.

The work in chemical engineering has been carried on by Dean W. N. Lacey, Professor B. H. Sage, Dr. David M. Mason, as instructor in chemical engineering, and Dr. Warren G. Schlinger, as research fellow.

Respectfully submitted,

LINUS PAULING, *Chairman, Division of Chemistry and Chemical Engineering*

THE DIVISION OF ENGINEERING

(CIVIL, ELECTRICAL AND MECHANICAL ENGINEERING AND AERONAUTICS)

To the President:

During the past year much engineering attention has been focused on the construction of the new building, which is to be ready for occupancy by the Fall Term and which should do much in improv-

ing the general operations and research program of the Division of Engineering. An additional engineering facility completed during the past year is the Merrill Wind Tunnel, installed in space made available over the archway between the Astrophysical Optical Shop and the Central Shop Facilities building.

Sponsored research in the Division of Engineering has continued at about the same dollar volume as previously, but the number of contracts and the diversity of subjects have increased.

Student enrollment in engineering fell off slightly from previous years, because of the gradual return of Institute classes to normal size. No significant trend in enrollment has appeared, and the relative sizes of the Engineering Options, Civil, Electrical and Mechanical, have remained the same. Applications for graduate work in engineering were this year greater in number and better in quality than in the preceding year, although the number of applicants who indicated ability to come for graduate work without financial assistance has become very small.

Aeronautics*

During the past year the number of students in this post-graduate department was reduced by careful screening of applicants to 89, about a third less than the previous year. However, over a third of these were candidates for the Ph.D. and a still larger number were working towards the sixth year engineer's degree. Thus the staff continued to carry a very heavy load of thesis research supervision. It is hoped that this load may be reduced next year by still more careful screening and selection of candidates. The Armed Forces again sent a number of officers for advanced training and indicate that this practice will be continued.

RESEARCH ACTIVITIES

(1) *Experimental Fluid Mechanics.* Experimental investigations of viscous effects in high speed flow continue. The instrumentation for these investigations has been further improved by the construction of an interferometer for use with the transonic wind tunnel and by the development of methods for direct measurement of skin friction. The interferometer was used in measurements of pressures on simple wedges in transonic flow. These measurements, together with very recent theoretical results, lead to a determination of the drag curve of wedges through the whole transonic region. Isotropic and non-isotropic fields of turbulent flow have been further investigated, using hot wire anemometry.

*This section of the report was prepared by Professor Clark B. Millikan.

(2) *Theoretical Fluid Mechanics.* Several long range investigations of fundamental problems in fluid mechanics continue, in particular studies of viscous compressible fluids and transonic flow. While the basic physical principles in these fields are known, the mathematical obstacles are great. Theoretical work entails investigations of partial differential equations which are either non-linear or of high order. This research is correlated with experimental research carried out in the Guggenheim Laboratory. A new course in "Statistical Problems in Gas Dynamics" was given, necessitated by the growing importance of this field. This course was correlated with the GALCIT turbulence research.

(3) *Elasticity, Mechanics of Solids, Structures.* The Air Force-sponsored research on design methods for thin, swept wings for high speed aircraft and missiles was continued with fourteen reports on the subject either submitted or in preparation. A fundamental program of investigation into the mechanism underlying the fatigue of metals has been started. In addition to the above, research into the problems of thin walled beams, vibration and buckling of trusses, and photoelastic materials led to four Ph.D. and four engineering degree theses.

(4) *Aerodynamics.* A number of problems connected with the design and operation of supersonic aircraft were studied theoretically. In several cases these studies were carried out in cooperation with aircraft companies. The ten foot wind tunnel was used both for low speed experimental researches and for tests of models under development by industry and government agencies. A small wind tunnel primarily for instruction and student research was installed in a new laboratory constructed for the purpose near the Guggenheim building. This will be completed during the summer of 1950 and dedicated as the Merrill Wind Tunnel in honor of A. A. Merrill, one of the early pioneers in aviation and for many years a member of the Institute staff.

COOPERATIVE WIND TUNNEL

The Cooperative Wind Tunnel has continued to serve the aircraft industry and government agencies in connection with their programs for the development of high speed aircraft and missiles. Researches in high subsonic speed aerodynamics were also pursued by the staff. Engineering studies were made of possible modifications to the tunnel to permit supersonic operation. These will be continued during the coming year.

Respectfully submitted,

CLARK B. MILLIKAN, *Director,*
Guggenheim Aeronautical Laboratory

Civil Engineering

Research in engineering seismology is continuing under the auspices of the Office of Naval Research. This study is a systematic investigation of the response of typical buildings to actual earthquakes, records of which are supplied by the U.S. Coast and Geodetic Survey. This work the Institute has done largely with the analog computer of the Analysis Laboratory.

APPLIED MECHANICS

The investigations of a year ago into soil compaction by vibration were brought to a satisfactory conclusion in both the theoretical and experimental effects for the scale of sample and vibration apparatus being used. The work has now been extended to include the design and construction of a larger vibration machine. With this machine it will be possible to obtain field data which should clarify the question of extrapolating the small scale results to larger compaction units and larger masses of soil material.

Electrical Engineering

The electrical engineering teaching load, both undergraduate and graduate, has continued to be heavy. The electrical engineering staff, in addition to directing and taking a major part in the program of the Analog Computer Laboratory, has conducted research in areas of electronics, permanent magnet alternators, knowledge concerning removal of aerosols from the atmosphere, and design problems relating to high-voltage electrical power transmission.

The addition of new personnel has included Dr. Myron H. Nichols, who, during his first year with us, has completed facilities for conducting research in physical electronics, and has begun the study of thermionic emission from single crystals of tungsten and tantalum. This work has been supported by the Research Corporation of America and will be continued largely under the sponsorship of the Office of Naval Research.

Dr. Nichols also continues his interest in upper atmosphere research. Together with Dr. Pickering, he assisted in bringing to the Institute Dr. Sydney Chapman of Oxford, England, for the year 1950-51. Dr. Chapman is organizing and directing a program on a comprehensive study of properties of the upper atmosphere. This study, which is under the sponsorship of the Signal Corps, is of general interest as well as importance to the Institute's jet propulsion program. The Division of the Geological Sciences also has an interest in this program.

The moving of the Testing Materials Laboratory to the new Engineering Building has made available space in Throop Hall which is being converted to a Servomechanisms and Control Laboratory. These laboratory studies in control systems will supplement analytical course work which has been given for several years. A servomechanism, or follow-up control system, may involve electrical, mechanical, and hydraulic elements in any combination and is thus an ideal example for unifying the several forms of engineering thinking.

Electrical engineering graduate student collaboration with the Jet Propulsion Laboratory continues on problems involving missile control and guidance and the telemetering of various types of information from a missile in flight to observing stations. From these investigations have come a number of fundamental studies, such as one completed this past year on microwave transmission near the earth surface and the resultant signal phase shifts which may occur.

Mechanical Engineering

The research in the rapid loading of materials continues under the sponsorship of the Office of Naval Research, with emphasis on the search for the causes of yielding and a possible explanation of the mechanism of yielding in materials. The experimental work has been done with steel samples which had carefully controlled carbon and nitrogen content.

Metallurgical work has been increasing during the year. Two studies of particular interest are phase transformations in titanium, in which extremely rapid cooling rates are employed; and crystal structure studies of the sigma phase of the iron chromium molybdenum system.

HYDRODYNAMICS

During the year the various activities in the Hydrodynamics Laboratories have received somewhat greater financial support from government agencies than during the previous year. The harbor studies conducted at Azusa have been in general terms and constitute basic work in the mechanics of wave motion in arbitrarily confined basins.

The U.S. Department of Agriculture, Soil Conservation Service reactivated a portion of the former Soil Conservation Laboratory on the campus with an experimental contract on hydraulic structures, in particular, channel revetments.

The Hydrodynamics Laboratory study of flow in rotating channels has progressed well, with an outstanding feature in experimental technique—the use of three-dimensional, high-speed motion picture

photography for tracing the flow of particular markers or cavitation bubbles in the flow which occurs in the transparent rotating channels. This same photographic technique has been applied to the turbulence and diffusion studies which are a part of the ONR-sponsored research on fluid transport of particulate matter.

With both the Free-Surface Water Tunnel and the High-Speed Water Tunnel, increased effort has been directed toward basic problems in cavitation and cavitation formation. This work has broad implications in all hydraulic machinery and other hydraulic devices. A high level of supporting theoretical work has been maintained throughout the year.

ANALYSIS LABORATORY

During the past year the activities of the Analysis Laboratory were considerably expanded. The facilities of the Digital Computing Group, built around the IBM 604 calculator, were placed in service in December, 1949. Since that time, the group has been engaged in fundamental research on digital computing methods and has acted as a computing service for various Institute research programs. A cooperative research program has also been set up with Northrop Aircraft Inc., for the operation of their new high-speed analog computer, the BINAC.

The demands of local aircraft companies and government research agencies on the use of the Analog Computer facilities has been very great in the past year. This has been due primarily to a new computing technique developed for the general vibration analysis of aircraft and guided missiles. This permits, for the first time, the rapid and comprehensive design analysis of complete aircraft structures under various types of aeroelastic or landing shock conditions.

This development was described at a symposium sponsored by the Division of Engineering and held at the Institute in May, 1950. At this symposium, which was attended by invited engineers from all aircraft companies and interested government agencies, five formal papers were presented by Institute staff members and engineers of the Douglas Aircraft Co., Inc. These covered the application of the Caltech Electric Analog Computer to the structural, aeroelastic and control problems of aircraft.

Respectfully submitted,

F. C. LINDVALL, *Chairman, Division of Engineering*

ANNUAL REPORT

THE DIVISION OF THE GEOLOGICAL SCIENCES

To the President:

The energetic pursuit of field problems by staff and graduate students is clear demonstration that the field in geology continues to offer ample important raw materials to warrant the vigorous effort of investigators. While the major activities in geologic research are expended in the conduct of investigations in the field, laboratory techniques are applied when needed and as they become available with acquisition of the necessary facilities. With application of laboratory methods and instrumentation it is possible to utilize the results obtained in the field in the formulation of fundamental laws and processes of geological change and the operation of this change in time. It is also of interest to note that what might be regarded as strictly geological problems continue to range widely over the face of the North American continent.

Within the structure of the regular teaching program the field courses continue to play an important role. These include the summer field camp, held in 1949 again in the Zuni Mountains, New Mexico. During the past year courses in petroleum geology were offered in the regular curriculum.

SEISMOLOGY

During 1949-50 the Seismological Laboratory continued its research program, including the cataloging of earthquakes, issuing of reports and the exchanging of data with other seismological stations. In addition to the Seismological Laboratory in Pasadena, the California Institute network of stations now consists of seven permanent auxiliary stations and four temporary installations. At the latter the recorders have been changed over from paper to film. This reduces cost and partially alleviates the very serious problem of storage space for seismograms.

The Laboratory now participates in the tsunami or sea-wave warning network which has been inaugurated by the United States Coast and Geodetic Survey. Upon telegraphic request our Laboratory reports arrival times of seismic waves in strong earthquakes to the warning center near Honolulu. Data for all distant earthquakes recorded here are sent daily by teletype to the U. S. Coast and Geodetic Survey offices in Washington, D. C.

The Laboratory staff has been frequently consulted in matters of earthquake damage, as well as regarding the risk and safety of structures.

The project on microseisms was continued for an additional year, and the new building and most of the equipment on Palomar Mountain have been completed. The project was supported by the Air Force.

A new type of seismometer has been developed by Dr. Hugo Benioff, using a capacity transducer and frequency modulation circuit. This instrument is suitable for recording with galvanometers, pen writing systems, and on magnetic tape. Improvements on the standard variable reluctance instruments have been carried on.

Studies of strain release on all great earthquakes since 1904 have indicated that shocks of this magnitude are not independent events. They are related in some form of world-wide stress system. This research is carried on by Dr. Benioff.

A large quarry blast near Corona, California, was recorded on all stations of the network. It was also recorded at several locations specially chosen for the occasion by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, aided by some of our students. Observations on this blast leave no doubt that former interpretations of seismograms of nearby earthquakes were in part incorrect. Studies on different groups of earthquakes by different methods have been carried on independently by Professors Beno Gutenberg and C. F. Richter with concordant results leading to a revised interpretation of seismograms and revised wave velocities and structure in the upper continental crustal layers in southern California. This revision, which was completed by Richter and J. Nordquist, has eliminated previously outstanding discrepancies, including some encountered in the study of the Manix, California, earthquake of 1947.

Instruction in seismology and research by graduate students continued on a normal schedule. Investigations on waves transmitted through or reflected from the earth's core formed the subjects of doctoral theses completed this year. Valuable results were obtained which raised many new questions. Similar problems are raised by a thesis on reflection at the surface of the earth of waves from deep focus earthquakes, which was also completed this year. The direction of the initial motion in shear waves from nearby earthquakes was also investigated. The results contribute to our knowledge of the mechanism of local earthquakes.

Our seismograms of the earthquake of November 17, 1949, which took place at Terminal Island, California, indicate that the motion at the source was unusually slow and occurred at an unusually shallow depth.

GEOPHYSICS

The following activities were conducted by Professor Potapenko:

(1) Supervised graduate research work on the electrical properties of drilling fluids.

(2) Supervised graduate research on the interpretation of experimental data relating to the magnetic properties of sedimentary rocks. Experimental work was carried on in part at the laboratory of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, D. C.

(3) Participated with Professor Robert Sharp in the electrical prospecting of Cima Dome, Mohave Desert, California. (See report of Dr. Sharp's project in desert geomorphology.)

(4) Published, in collaboration with D. Wheeler, Jr., of Lehigh University, a paper on the "Extension of the Slatis Theory of Drude-Coolidge Method of Measuring Dielectric Constant."

A study of the upper atmosphere, under the sponsorship of the Signal Corps, is being directed by Dr. Sydney Chapman, Sedleian Professor of Natural Philosophy at Oxford University. Professor Chapman will spend the year 1950-51 at the Institute as Research Associate in Geophysics, organizing and directing this research program.

GEOLOGY

The following represent research problems under investigation in geology:

Professor Albert Engel has been occupied with the mineralogy and petrology of the Archean Rocks of the Grenville series in northeastern United States and southeastern Canada, thus bringing to light the nature of some of the oldest known rocks on the American continent. He has likewise conducted X-ray, spectroscopic and related studies of amphiboles, serpentines and talc, with a view to determining the specific changes involved in the process of alteration of this suite of minerals. Professor Engel has continued his investigations on rock weathering, having practical application to problems presented for study and possible solution by the Rock of Ages Corporation, Barre, Vermont.

Professor Ian Campbell is continuing to pursue his studies on rocks that have a high magnesia content (magnesium metasomatism) at two localities: (1) the area at Chewelah, Washington (the largest producer of refractory magnesia in the United States), and (2) in Lucerne Valley, California. A preliminary report of the latter occurrence was published by the 18th International Geological Congress. Professor Campbell has likewise completed a study of an unusual dike occurrence near Boulder Dam. This permitted drawing

some conclusions as to the rate of growth of crystals in magma—a subject on which geologists as yet have very little information. The results of this study will be published in the November issue of the *Journal of the Mineralogical Society of America.* It should be indicated likewise that Professor Campbell has directed research carried on by graduate students on talc, gypsum and vermiculite. While these investigations will probably not result in important commercial developments, it is significant to recognize that currently the "Industrial Minerals" are contributing far more to the wealth and capital growth of southern California than are the metalliferous minerals.

The activities in the Mohave Desert of Dr. D. Foster Hewett, research associate of the Institute and staff geologist of the United States Geological Survey, have brought to light important mineral deposits having both scientific and commercial significance. While much of the effort devoted to these deposits is being expended under the auspices of the U. S. Geological Survey, the men and facilities at the Institute are contributing to the program of investigation. Thus, deposits of the rare mineral bastnasite were discovered in the vicinity of Mountain Pass, Spring Mountains, San Bernardino County, California, early in 1949. This mineral contains oxides of rare metals (cerium, lanthanum, neodymium, praseodymium). Heretofore it was known sparsely only in a few places in the United States, but large quantities are being found at this new locality. This deposit has added importance in that it contains several per cent of thorium and is therefore radioactive. Mr. Lloyd Pray of the geology staff has mapped the locality in cooperation with the U. S. Geological Survey. It is being commercially exploited at the present time. In addition, at least two other occurrences of radioactive minerals have recently been discovered in the Mohave Desert, one in the Cady Mountains, 40 miles east of Barstow, and a sound at the eastern end of the San Bernardino Range. These focus attention on the possibility of an even greater distribution of radioactive minerals in the desert area than was known heretofore.

A long-term project on muscovite mica by Professor Richard H. Jahns is still underway in the Institute laboratories. We now have the most complete collection in existence of commercial muscovite from domestic pegmatites, and the availability of this material will probably furnish much additional information leading to a more complete correlation of chemical and physical properties with geologic occurrence. As a matter of fact, most of the data are already in hand; the principal problem is concerned with the compilation of the facts.

As time permits, Professor Jahns, with Professor Engel, is conducting a field investigation in the Avawatz Mountains in the region

south and southwest of Death Valley. They are particularly concerned with problems relating to the chaotic breccias, curious types of sediments that occur in that area, and which some geologists ascribe to tectonic activity, but which Jahns and Engel regard as of wholly different origin. Much areal mapping and detailed field work in selected localities over a broad region are planned.

Through an arrangement with the California State Division of Mines, important results of graduate student work are being published. For example, a report on the "black granites" of San Diego County is now in press. Other contributions shortly to be published are the stratigraphic relations in the southern ridge basin, north of Mint Canyon, California; the geology of the Jurupa Mountains, near Riverside, and the structure and stratigraphy of an area southeast of Grapevine station at the north end of the ridge basin. The paper by Dr. John Lance on the pyrophyllite deposits near Escondido, San Diego County, will also be published by the California State Division of Mines.

Professor J. P. Buwalda continued with his studies of the Pasadena area in order to make available as a text the geology of the region for use by the layman and interested student. This is possible since geologic information is now available for publication with final rendering of a decision by the Supreme Court of California in litigation regarding water rights and involving geologic formations. Professor Buwalda has likewise continued to assist the Metropolitan Water District in the solution of some troublesome water supply problems of southern California.

GEOMORPHOLOGY

Professor Robert P. Sharp and his students are carrying forward their researches in two broad fields in geomorphology.

(1) Their program of study of existing glaciers was conducted during the past year at two localities in Alaska, the Seward-Malaspina glacier system and the Juneau Ice Cap, under the auspices of, and supported by, the Office of Naval Research. This work was designed to determine the physical nature and environment of firn and ice in these areas and to contribute to an understanding of the fundamentals of glacier mechanics. Similar work is being initiated during the summer of 1950 at still another locality, the northeast slope of Mt. Rainier, Washington, and C. C. Fisher, who is coming to the Institute as a graduate student in the fall of 1950, is working this summer on the Columbia Ice Field in Canada.

The program of study on western mountain glaciation is being carried forward with projects in Colorado and the Sierra Nevada and

Trinity mountains in California. It is anticipated that this program will contribute to the chronology of the Ice Age and to an understanding of land forms produced by glaciation.

(2) The work on the geomorphology of desert regions is progressing with projects in the Mohave Desert that deal with the formation and evolution of desert domes and the mechanism of sand dune formations.

PALEONTOLOGY

Professor Charles W. Merriam continued his investigation of the Paleozoic stratigraphy and paleontology of the Great Basin with emphasis on the Devonian of central Nevada and the Carboniferous of eastern Oregon.

He also continued his studies of fusulinid foraminifera from the Great Basin, applying this information to an interpretation of the stratigraphy and geologic structure of the Inyo Mountains, California.

An extensive program of paleontological and geological exploration in Mexico by field parties of the Division of the Geological Sciences, under the supervision of Professor Chester Stock, and having its inception during the 'thirties but for a time inactive because of the last war, has been re-initiated during the past year in cooperation with the Instituto de Geologia Mexicana. The continued development of the interest arises from the fact that the great area of Mexico gave promise during the initial stages of investigation of yielding scientific results of considerable significance in the interpretation of the history of life for the North American continent. The knowledge is to be made available to educational agencies in Mexico, and to this end, as paleontological materials are prepared for exhibit and study, they are to be shared with institutions in that country. A mounted skeleton of the characteristic Pleistocene horse from San Josecito Cave in southern Nuevo Leon, prepared by William Otto, preparateur and sculptor in the Division, was recently installed at the Instituto in Mexico City.

It is a pleasure to acknowledge the financial assistance kindly given by individuals and agencies in support of the research program in the geological sciences. In addition to the support of government contracts, great thanks are due Mr. Childs Frick for his continued gift for research in vertebrate paleontology. The Rock of Ages Corporation, Barre, Vermont, has kindly underwritten the investigations of Professor Engel on rock weathering. The Southern California Edison Company has made available a research grant for the study of glacial geology in the Vermillion Valley, Sierra Nevada.

Graduate fellowships were financed by the Stanolind Oil and Gas Company, Standard Oil of California, and by the General Petroleum Corporation, for which the Division wishes to express its appreciation.

Respectfully submitted,
CHESTER STOCK, *Chairman,*
Division of the Geological Sciences

THE DIVISION OF THE HUMANITIES

To the President:

Current national interest in the role of the humanities in the education of scientists and engineers was reflected during the past year in the visits of representatives of several foundations and correspondence with many other educators and administrators. The *New York Times*, in a survey of the policies of scientific and technical schools with respect to the humanities, commented on the California Institute as one of the pioneering leaders in the recognition of the desirability of a strong program in the humanities. During the spring term the chairman of the Division made a trip, under the sponsorship of the Carnegie Corporation, to a dozen colleges and universities to study programs in the humanities. In June the Institute was invited by the Carnegie Corporation to submit plans for the expenditure of $150,000 over the next five years for the further strengthening of our work in the humanities and the social sciences.

Continued experiment and improvement in teaching methods and materials occupied the attention of members of the Division. In English courses new materials of a more literary nature were introduced; the policy governing this experiment was to train students to literary analysis and criticism at a mature level. Our experience seems to show that Caltech students have as great aptitude for this kind of study, and generally as great interest in it, as liberal arts students have. Professor Harvey Eagleson experimented with a small selected group of students in a senior elective course by giving increased freedom and responsibility to the members of the class; this type of instruction, similar to the "Honors Seminar" given in liberal arts colleges, won the enthusiastic approval of the seniors in the course.

In the field of history, one of the most important changes has been a decision to do all of the teaching in freshman and sophomore history, henceforth, in small classes of less than twenty students, thus dispensing with the rather unsatisfactory attempt to give weekly lectures before groups of 150 men. Since this change will increase the total teaching load, it has been necessary to add an additional instructor to the staff.

Of equal importance has been a gradual but extensive shift in the content of the history courses during the past two years. Recognizing that their students are primarily interested in problems that have present-day applications, the instructors have reduced the attention given to the earlier periods of history and have greatly expanded the study of modern times. As a part of this increased emphasis on our own era, several new senior elective courses have been planned. One will deal with the problem of Russia and Communism, another with England's current difficulties at home and abroad. Still another new senior course was successfully tried as an experiment during the Spring Term of the year just ended. In this an historian and an economist jointly offered a discussion course dealing with the role of the state in the modern American economy.

In all the history courses there has been a persistent attempt to cut down the amount of textbook reading in order to make room for material of a more mature sort, such as biographies, monographs, original documents, and case studies of typical historical problems.

The addition of Professor Alan R. Sweezy to the staff in economics provided the opportunity to offer greater variety in the economics electives available to fifth-year students and also to experiment with the application of economics to history at the undergraduate level. Professor Horace N. Gilbert, who was on leave of absence this year as a member of the staff of the U. S. High Commissioner for Germany, returns in the fall of 1950 to bring to his classes the benefit of his interesting experience in a currently significant area.

Dr. Alfred Stern's new course in "Contemporary European Philosophies" proved so popular that it was offered again in the spring term. Dr. Stern's eminence in the field was recognized during the year by the award to him of the Academic Palms of the French Academy.

The acquisition of a full-time instructor in speech and debating this year meant that the collaboration of the Division with other divisions of the Institute in oral English and the presentation of reports could be greatly increased. Dr. Lester McCrery has carried on this work in the departments of physics, geology, electrical engineering, civil engineering and mechanical engineering. In addition he has supervised forensic activities at the Institute; Caltech students participated in six intercollegiate speech tournaments and won a fair share of the contests.

The Division has continued to support musical interests on the campus; under the supervision of Professor Hunter Mead the undergraduate musical organization presented a very successful series of concerts in Dabney lounge during the spring term.

During the year the Division brought to the campus Professor

Elting Morison of the Massachusetts Institute of Technology. Professor Morison, who is engaged in editing the letters of Theodore Roosevelt, gave a lecture on Roosevelt as a letterwriter and another on "The Introduction of Continuous-Aim Firing: A Case Study of Innovation." The Division also arranged, in collaboration with the Dean's office, for the visit of William G. Perry, Jr., Director of the Bureau of Study Counsel at Harvard University. Mr. Perry demonstrated the Harvard Reading Films and discussed with members of the Faculty and students the possibility of work in remedial reading on our campus.

In addition to their teaching and administrative functions, members of the Division contributed significantly to research in their fields during the year. Professor Melvin D. Brockie published two articles in leading journals of economics; Dr. Kent Clark continued his researches on Jonathan Swift. Mr. Godfrey Davies edited Defoe's *Moll Flanders*, contributed revised biographies to the *Dictionary of National Biography*, and wrote many reviews of historical works. Professor Beach Langston continued his work on Elizabethan attitudes toward death as well as writing essays on international affairs and on George Fox and the peace movement. Professor Mead read a paper and presided at one of the meetings of the American Society for Aesthetics on the campus in December. Professor Rodman W. Paul edited Mark Twain's *Roughing It* and two documents in his own special field of California history: *Letters of the Gold Discovery* and *The Miner's Own Book;* in addition he has continued his work on the history of agriculture in California. Professor John Schutz edited the letters of George Bartman on the siege of Fort McHenry and published an essay on James Ramsay and the anti-slavery movement in England. Professor Hallett Smith read a paper on Milton's poetry at the University of Rochester in December, finished the manuscript of a book on Elizabethan poetry, and published an article on Shakespeare's sonnets. Dr. Stern continued to publish, both here and abroad, his studies of the contemporary situation in philosophy. Mr. George K. Tanham went to Belgium in the summer of 1950 to complete his study of the Belgian Resistance during World War II.

During the year the Division was represented at the meeting of the National Council of Teachers of English in Chicago by Professor Paul Bowerman, at the convention of the American Society for Engineering Education in Seattle by Professor William Huse, and at the Modern Language Association meeting at Stanford by Professors Bowerman, Eagleson and Smith.

Respectfully submitted,
HALLETT D. SMITH, *Chairman,*
Division of the Humanities

THE DIVISION OF PHYSICAL EDUCATION

To the President:

The athletic and physical education program during 1949-50 showed a very desirable advance toward complete student participation. The freshman class made an outstanding record, with 62 per cent of the class playing on various of the eight freshman intercollegiate teams. Thirty-four per cent of the 1950 senior class played on varsity teams during their student life at the Institute, and 25 per cent of the class made varsity letters. Teams representing the four student houses and the Throop Club (the latter composed of students who do not live on the campus) carried on a lively intramural program, in which approximately 48 per cent of the students participated. Considerably more than half of the entire student body took part in intercollegiate or intramural sports. This does not mean that intercollegiate competition was limited to a small number of men. In many cases a varsity man in one sport went out for intramural competition in another.

Both varsity and freshman teams participated fully in the program of the Southern California Intercollegiate Conference. The other members of the conference are Occidental, Pomona, Redlands and Whittier; Conference sports are football, basketball, track, tennis, golf, swimming, water polo and cross country. Our soccer and volley ball teams played both Conference and non-conference games. The total intercollegiate contests numbered 114 varsity, 63 freshman. A considerable number of these contests were with 18 non-conference colleges near by.

The Institute teams gave an excellent example of true sportsmanship through the year, though they did not win any team championships. The varsity finished in second place in three sports: track, swimming and cross country. We should be proud of the records made by our teams and by many of our individual players. The academic requirements of the Institute are rigorous, and daily afternoon laboratory work is the rule. That our students, with already crowded schedules, are willing to devote time to sports for the love of the game and the values learned on the playing field is greatly to their credit. Our team members are recognized as worthy and well-taught contestants, even though they are not majoring in physical education with the expectation of becoming professional coaches and teachers of physical education.

The 12 seniors who made three or more letters in more than one sport were also notable for their participation in other student body

activities and for their scholarship; five of them qualified for membership in Tau Beta Pi, the honorary scholastic society.

Odell Carson, senior from Tustin, California, was awarded the Wheaton Football Trophy, which is presented annually to the outstanding football player for achievement in scholarship, sportsmanship and moral influence. Team Captain Richard Karasawa of Chicago and Norman Gray of San Diego were the joint recipients of the Alumni Annual Baseball Trophy.

During the year, two new trophies were established: the Howard G. Vesper Trophy, for achievement in basketball; and the Colonel E. C. Goldsworthy Trophy, for achievement in track. The Vesper Trophy was established by Howard G. Vesper, of the Class of 1924. The first winners were team captain William Cox of Seattle and Jay Montgomery of Hollywood. The Goldsworthy Trophy was established by the alumni in honor of the late Colonel E. C. Goldsworthy, formerly Master of the Student Houses, who for many years was a prominent track official. Captain Dwight Schroeder, a senior from Santa Ana, California, was the first winner of the Goldsworthy Trophy.

Mr. Bert LaBrucherie's first year as football and track coach has been successful beyond all expectation. He has thoroughly demonstrated his knowledge of the technique of the sports he coaches and his ability and willingness to adjust the requirements of a Caltech coach to the study requirements of Caltech students.

It is a pleasure to report that the alumni are making steady progress in raising funds for the construction of a gymnasium and swimming pool on the Institute's athletic field. During the year cash contributions amounting to $25,000 were received; the fund now totals $65,000. It is to be hoped that this fund will grow rapidly, so that the students may have the stimulus of well merited and long deserved athletic facilities, as well as the pride of ownership of our own athletic field.

Father Time has brought the Chairman of the Division of Physical Education to the retirement age set for all employees of the Institute. Since this will be his last official report, he craves the right to make a few somewhat personal comments on the program of physical education and athletic competition during the past 37 years. In 1913 President James A. B. Scherer asked him to take charge of that program, find on short notice a football coach, arrange a schedule of games, get playing equipment and otherwise make a student body athletically happy. The students were to furnish the team, but the chairman of the physical education committee must raise the money.

This was all done. A new Southern California Intercollegiate Conference was formed comprising Occidental, Pomona, Redlands,

Whittier and Throop Polytechnic Institute (as the California Institute was then called). During the years that have elapsed, these colleges have maintained an outstanding program of intercollegiate sports competition—a program free from professionalism and designed to enable all students who so desire, to participate in intercollegiate sports for sports' sake. These colleges have all conducted their intercollegiate programs on a very high level, free from college subsidies for athletes and free from the kind of alumni pressure which sometimes makes intercollegiate teams the pawns of undesirable sporting influences.

Through these 37 years the Institute has been extremely fortunate in having coaches and physical directors of high caliber. My basis for this judgment is the comment of former students. A large number frequently report that of the values they obtained as undergraduates, athletics contributed as much as any other part of their college curriculum or their life on the campus. Indeed, some men who are inclined to be "ivory tower" scientists and engineers have said that what they learned on the playing field, as taught by our coaches and by contact with team mates and opponents, has been of more value than anything else they learned at the Institute. These comments should be taken, perhaps, with a grain of salt. Even so, they establish in the mind of the writer the fact that the physical education and intercollegiate sports program as carried on at the California Institute is an important factor in developing valuable citizens.

Respectfully submitted,
R. W. SORENSEN, *Chairman*
Division of Physical Education

THE DIVISION OF PHYSICS, MATHEMATICS, AND ASTRONOMY

To the President:

At the end of the year the Division had 29 staff members in physics, 18 in mathematics, and 8 in astronomy. Of these 19 in physics, 10 in mathematics, and 2 in astronomy are professorial members and the remainder are research associates, senior research fellows or research fellows largely engaged in project research financed by government funds. During the year the Division had 71 graduate students in physics, 18 in mathematics, and 7 in astronomy. Of these about one-half hold assistantships and are either engaged in teaching activities or in research under one of the projects.

While a staff of this size is quite adequate for the instructional responsibilities of the Division, it is considerably smaller than one usually finds in these fields in a large university. With the diversity of research in physics, mathematics, and astronomy, the Division can not hope to cover adequately all of the fields in these subjects which are pursued at one place or another. With these limitations it seems wise for the Division to have certain specialties in which the Institute would be a leader in the country, but also to have a certain diversity of research interest and breadth of activity in keeping with the needs of the Institute.

In physics, the new field of high energy physics has been taken up during the past year with the plans now under way for the construction of a billion volt accelerator for electrons. For many years the Institute has been a leader in the fields of cosmic rays and elementary particle physics and nuclear physics. The new work in high energy physics, which will be aimed at a better understanding of the atomic nucleus, should join together on a united frontier the fields of elementary particle physics and nuclear physics. Together with new work to be undertaken in the theory of elementary particles and nuclear forces, the Institute should become very well represented in this fundamental subject of modern physics in comparison with many major research laboratories.

It is hoped that in the future the fields of physics which relate to astronomy and astrophysics can be more vigorously studied. In the past this connection has been obtained in spectroscopy, in nuclear physics, in cosmology, and in theory generally. It is hoped that the work in all of these fields can be augmented in the future and that possibly new fields can be found where the work in physics and astronomy can be more closely tied together. With the Mount Wilson and Palomar Observatories, the Institute has associated with it, staff and facilities which are unique. A graduate curriculum in astronomy has been established, and the scope of instruction and research by Institute staff should gradually increase. New additions to the staff of the Division in this field should be chosen so as best to augment and aid the staff of the Observatories.

While the staff in physics pursues other lines of research including electronics, X-rays, micro-optical properties of particles, low temperature physics, and magnetic effects, the work in these fields is quite restricted compared to that which can be found in many major universities. The work in solid state physics is currently on a very restricted basis, and it is hoped that this field and the others mentioned above can be encouraged and somewhat further expanded even though they may not become specialties of the Division.

In mathematics the special fields which are most actively pursued

are algebra, analysis, and geometry. All of these fields have been active at the Institute for many years and it is hoped that the staff can be augmented.

In astronomy, the responsibilities of the Division are confined to teaching, but the members of the staff of the department of astronomy are actively engaged in research at the Observatories as well as with material provided from the Observatories. The presence of the Observatories is a great attraction for astronomers, and it is hoped that as the staff of the department of astronomy gradually increases in response to the needs in the instructional program astronomers of the highest standing in research as well can be obtained.

During the past year, the Division has had a number of distinguished lecturers. Professor Bengt Strömgren of the University of Copenhagen spent the second term at the Institute and gave lectures on the "Internal Constitution of the Stars". In Physics, Dr. J. R. Oppenheimer, a former member of the Institute staff and now Director of the Institute for Advanced Study at Princeton, gave a series of lectures on "The Problems of the Interaction of Elementary Particles". Professor I. I. Rabi of Columbia University, Nobel Laureate in Physics, gave a series of lectures on "Nuclear Moments and Electron-Nucleon Interaction". Professor R. P. Feynman, a distinguished young theoretical physicist, gave a series of lectures on "Quantum Electrodynamics and Meson Theories". Many other scientists visited the Institute for shorter periods and gave lectures in a variety of subjects.

The work of the Division has been supported in part by Institute endowment income and in part by special research grants from foundations and industries, but the major support in physics comes from the research contracts jointly supported by the Office of Naval Research and the Atomic Energy Commission. These latter grants are largely responsible for the support of the research in cosmic rays, nuclear physics, gamma and beta ray spectroscopy, for the Bateman Project in Mathematics, and for a number of smaller projects. The Division is indebted to the DuPont Company for the establishment of a DuPont Fellowship in Physics and to the Research Corporation and the California Research Corporation for support of the work in part of Professor J. W. M. DuMond.

Physics

COSMIC RAYS AND FUNDAMENTAL PARTICLES

1. During the past year Professor Carl Anderson and his colleagues, Professors Robert Leighton and E. W. Cowan, have been able to obtain 34 cases of unusual forked tracks in their cloud chamber studies. These tracks are believed to be due to new types of unstable particles which are produced in high-energy nucleon-

nucleon collisions. Two examples of these tracks were found in 1947 by Rochester and Butler in England, but they have been unable to find additional confirmation. The new work of Professor Anderson and his colleagues definitely established the reality of these tracks as well as the reality of the unstable particles which produce them. To date, the information is fragmentary, but something has been learned about the properties of these particles, and their mean life has been shown to be about 2×10^{-10} seconds.

2. The detailed study of penetrating showers has been continued, and results obtained so far indicate that the penetrating shower particles consist of approximately 80 per cent mesons and 20 per cent protons. Professor Cowan has designed and constructed a continuously sensitive cloud chamber which is most successful as a demonstration equipment and which may have advantages as a research instrument.

3. Under the supervision of Professor H. V. Neher much further work has been done on the properties of the primary cosmic radiation and the reactions which it produces in passing through the atmosphere. Under Professor Neher's supervision, development work on large and small ionization chambers has been carried on. The small ionization chambers are designed for use in balloons to study high altitude fluctuations in the cosmic rays.

4. Professor R. F. Christy has developed a tentative quantitative explanation of the altitude increase of cosmic ray bursts in a shielded chamber using data obtained by Professor Neher and his co-workers. Professor Christy has continued his study of the energy loss of fast particles, a subject of particular interest in the observation of cosmic ray particles and their secondaries, in cloud chambers. He has succeeded in explaining the variation of ionization density as a function of energy for these fast particles.

NUCLEAR PHYSICS

Research in nuclear physics in the Kellogg Laboratory of Radiation, under the supervision of Professors C. C. Lauritsen, W. A. Fowler, and T. Lauritsen, has produced the following additions to the operating facilities of the laboratory and research results:

1. Two major additions have been made to the operating facilities of the Kellogg Laboratory of Radiation. The 8 ft. x 22 ft. electrostatic generator has been completely equipped with auxiliary equipment for particle analysis and detection and has been used in investigations of several nuclear reactions up to 3 Mev bombarding energy. The 16 in. double-focusing magnetic nuclear particle spectrometer has been completed and employed in the analysis of the energy and yield of the products of nuclear reactions.

2. A successful search has been made for an excited state in Be^7 at 430 Kev corresponding to the well-known state in Li^7 at 480 Kev. This is the first proof of the existence of corresponding excited states in "mirror" nuclei and constitutes very strong evidence for the charge independence of nuclear forces.

3. Additional investigations of the stellar-cycle CN nuclear reactions have been completed both at low voltages and over the available laboratory voltages, and new calculations have been made for the cross sections at stellar energies. On comparison with theoretical calculations of the direct proton-proton interaction cycle, it is indicated that the direct cycle rather than the CN-cycle may account for the energy release in the sun.

Under the supervision of Professor J. W. M. DuMond, work has been continued on the precision measurement of gamma rays and beta rays. The 2-meter curved crystal gamma-ray spectrometer has been improved and extended in its wave length range to include quantum energies well above 1 Mev. New improvements in the gamma ray detecting and measuring equipment have been made, including a robot observing device for taking data on a 24-hour basis. Precision wave length determinations of lines in the spectra of the following natural and artificial radioisotopes have been made: Co^{60}, Ta^{182}, Radon, Re^{188}, Au^{198}.

A recomputation by Professor DuMond of the "best" values of the natural atomic constants e, m and h or F, N_0, m and h and the physical conversion factors derivable therefrom, based on the recent new and greatly improved data obtained chiefly in the year 1949 by a number of different observers by atomic beam, radio frequency and microwave techniques, is now under way.

HIGH ENERGY PHYSICS

During the year plans were formulated for a high energy physics laboratory for which the central facility will be an electron accelerator designed eventually to deliver electrons of approximately one billion electron volts energy. Dr. E. O. Lawrence offered the equipment from the Berkeley Radiation Laboratory which had been used in the quarter-scale model tests of the large proton synchrotron now under construction. The plans at the Institute were developed around this equipment because of the tremendous saving in time and effort thereby. During the winter the project was approved by AEC, and in April a contract for $1,250,000 was negotiated and signed. This contract extends to June 1953, and covers both the construction and operation of the equipment.

Development work is under way on a new method of injection of electrons into such a machine at one and a half million volts. Plans

for the radio frequency system, for the vacuum chambers, for the new magnet coils which must be built, for mounts for the power equipment and the accelerator itself and for the basic detecting equipment which will be used are now under way. Initial operation will be undertaken at very low energy in order to test the principles of injection.

It is planned to use the electrons from this machine to furnish an emergent cone of X-rays. It has already been demonstrated elsewhere that high energy X-rays cause nuclear disintegrations and the production of mesons. The interaction of electro-magnetic radiation with the atomic nucleus should furnish a very good way in which to study the fundamental problems of nuclear forces and the particles which seem to be associated with these violent nuclear interactions.

This work is being undertaken under the general supervision of the Division Chairman, with Dr. R. V. Langmuir, recently appointed Assistant Professor, assuming the main responsibility for machine design, with Mr. Bruce Rule, formerly Chief Engineer at Palomar, as Project Engineer, and with Professor R. L. Walker responsible for the development of detecting equipment.

ELECTRONICS

Work on the precision determination of e/m for an electron, under the supervision of Professor W. R. Smythe, has been continued and it should become clear just how high precision can be obtained. The second edition of Professor Smythe's book, *Static and Dynamic Electricity*, has passed through the proof reading stage and is now in the hands of the printer.

Professor S. J. Barnett has continued his work on gyromagnetic effects. He has studied the effect of saturated permaloy and iron, and this work is now complete. He has also studied an electron inertia effect predicted many years ago by Maxwell. The observation of the magnetization by rotation (Barnett effect) has been used to study the gyromagnetic ratio for a number of ferromagnetic materials and alloys.

MICRO-OPTICAL PROPERTIES OF PARTICLES

Professor Alexander Goetz has continued his work on the study of micro-optical properties of particles in the size-range of micro-organisms (bacteria, fungi, etc., from 400-3,000 mu) in the earliest growth stages in order to establish the basic knowledge required for the application of physical methods for the discrimination between biotic (live or potentially alive) and abiotic (non-living) particles within a short time interval after collection of the particles from

aerosols and hydrosols. This work has been undertaken largely with funds furnished from the Chemical Corps of the U. S. Army. The molecular filters developed in the course of this work have proved to be of great use in a variety of problems in which extremely small particles are involved.

SPECTROSCOPY

In spectroscopy, under the supervision of Professor R. B. King, the absolute oscillator strengths (f-values) of several lines in the spectra of neutral nickel and of neutral chromium have been determined. These data serve to place on an absolute scale the relative f-value determinations for many lines of nickel and chromium.

Information on f-values in atomic spectra is needed in order to interpret the intensities of spectral lines measured with newly developed equipment used with the large telescopes at Palomar and Mount Wilson. The measurement of intensities of spectral lines of the stars is one of the most fertile fields for obtaining new information about stellar properties and constitution.

THEORETICAL PHYSICS

Professor H. P. Robertson continued his work in cosmology and on the study of the foundations of the relativity theory. In June 1950 he departed for Washington on leave for the coming year to accept the important post of Deputy Director and Chief Technical Officer of the Weapons Systems Evaluation Group.

Professor Paul Epstein, jointly with Professor M. S. Plesset, completed work on the study of "The Stability of Gas Bubbles in Liquids". Under the supervision of Professor Epstein and Professor Jesse Greenstein work was continued on the theory of the propagation of radio-waves in the solar corona, and as a foundation for this work Professor Epstein worked out the theory of conductivity and refractivity of highly ionized gases.

Under the supervision of Professor R. F. Christy problems concerned with the possible production and disappearance of anti-protons and anti-neutrons have been studied. The disappearance of such a particle with meson production would be a characteristic event, whereas the production of them is much more uncertain. In co-operation with the experimental work carried on in the Kellogg Laboratory of Radiation, Professor Christy has studied various nuclear reactions, including the capture of protons by deuterons and tritons.

In cooperation with Professor Jesse Greenstein of the astronomy department, Professor Leverett Davis has continued his study of the explanation of the observed polarization of starlight. Professor Davis

has taken the lead in the preparation of Part I of an extended report on *Exterior Ballistics of Rockets*. This work is now complete and Part II is in preparation.

Professor R. P. Feynman, formerly of Cornell University, joins the staff of the Institute on July 1 as Professor of Theoretical Physics.

Mathematics

Dr. T. M. Apostol has joined the department of mathematics as an Assistant Professor. He is primarily interested in number theory. Dr. Samuel Karlin has been granted a leave of absence for the next academic year. He will spend it at Princeton University as a visiting member of the staff.

Professor R. L. Wilder, of the University of Michigan, who came to Pasadena for his sabbatical year, delivered a series of five lectures on topology. These lectures were particularly interesting since this topic is not represented at the Institute. In addition, many distinguished visitors from the United States and abroad addressed the different seminars.

The research done by the members of the department of mathematics covered several fields in algebra, analysis, and geometry. Interest in applied mathematics was stimulated particularly by the constant interchange of ideas with Professors P. A. Lagerstrom and C. DePrima in the Division of Engineering. Professor E. T. Bell continued his investigation on arithmetical functions and multiplicative Diophantine analysis, whose object is to obtain complete integar solutions of certain types of indeterminate equations. In a related field Professor Morgan Ward studied the number theoretic properties of the polynomials associated with the real and complex multiplication of elliptic functions. These polynomials include as a special case the cyclotomic polynomials of Lucas and Sylvester. The results obtained are being applied to the classical problem of determining all rational points of finite order on a rational cubic curve of genus one. Professor A. D. Michal continued his investigations on the differential equations of non-numerical variables of modern functional analysis. He used some of these results in extensive analytic and geometric researches on his recent general unified theory of finite and infinite continuous groups and their invariant differential forms.

The study of the theory of games led Dr. Karlin to a reexamination of the classical moment problem in analysis. He emphasized the geometrical aspect of the problem and interpreted both known and new relations in a natural geometrical way. Together with Professor H. F. Bohnenblust a study of positive operators in a Banach space was undertaken. It is hoped to extend results on positive matrices to more general operators, and to investigate in particular how far

these results apply to the theory of integral equations with a positive kernel. Professor Robert Dilworth continued his work in the theories of lattices and of partially ordered sets. In addition to investigations in the abstract theory, several applications were considered to the completion problems of the sets of continuous and of Baire functions over topological spaces. His methods are more direct than those used by other authors and clarify the role played by the laws of distributivity in lattices.

A considerable portion of Professor A. Erdélyi's time was devoted to directing the Bateman Manuscript Project. This project is proceeding satisfactorily, and the preparation for publication of the first two volumes of the hand book of special functions is well under way. Several problems were noted and were investigated by the project staff. Professor Erdélyi obtained the most general form of hypergeometric series of two variables and reduced all series of the second order to a small number of standard types. He studied certain families of orthogonal polynomials and with Dr. W. B. Fulks analyzed the asymptotic behavior of functions which depend on two large parameters.

Professor F. Tricomi investigated the asymptotic behavior and the distribution of zeros of many important special functions. He undertook also a careful and detailed study of the incomplete gamma function. As Professor Tricomi explains in his memoirs, this subject has been strangely neglected in spite of its importance in the applications.

A team of three undergraduates entered the William Lowell Putnam examination with great success. As a team they ranked first among forty teams from universities in the United States and Canada.

Astronomy

The expansion of graduate instruction continued under Professor Jesse Greenstein, and the first postwar degrees were granted in astronomy. Members of the Mount Wilson and Palomar staffs participated in the instructional program for the first time, Doctors Nicholson, Richardson, Pettit, Merrill and R. E. Wilson giving advanced seminars. Prof. Bengt Strömgren, Visiting Professor from the Copenhagen Observatory, lectured on the internal constitution of the stars. In 1951, Prof. T. G. Cowling, Visiting Professor from the University of Leeds, will lecture on stellar electromagnetism. Dr. A. H. Joy, formerly of the Mount Wilson Observatory staff, was appointed Research Associate and took charge of the senior course in astronomy. Dr. J. J. Johnson resigned because of poor health after many years of valuable service to the Institute as teacher and as an observer with the 18 inch schmidt. Visitors and lecturers in the department

included Dr. Schwarzschild of Princeton, Dr. Aller of Michigan, and Dr. Lindblad of Stockholm.

Dr. D. R. Bates, of the University of London, served as Research Associate; he lectured on the theory of excitation by electron impact. He completed the quantum mechanical theory of the radiative capture of hydrogen by carbon in interstellar space, which is considered to be the first step in the formation of molecules and of the nuclei of interstellar dust. The capture cross-section proved so small that very high space densities are required.

Professor Strömgren completed his work on the hydrogen density in inter-stellar space as derived from photoelectric measurements of the emission lines in the Milky Way. In connection with work done in the Kellogg Laboratory on the observation and theory of nuclear capture cross-sections, he found that the proton-proton reaction may be the major source of the nuclear energy of the sun, and that the present model of the solar interior needs considerable revision.

Professor Greenstein continued his theoretical work in collaboration with Professor Leverett Davis on the origin of interstellar polarization. This remarkable phenomenon strongly suggests the existence of large-scale magnetic fields which may stretch over regions 1,000 light years in extent.

Professor Fritz Zwicky has continued his work on the theory of the physical characteristics of clusters of nebulae and derived the structural index of the best observed clusters. He is writing a book on morphological astronomy, and another on the morphology of jet propulsion and is preparing a section on the future prospects of jet propulsion for the *Squid Encyclopedia*.

Other research by members of the staff and students is described in the report of the Mount Wilson and Palomar Observatories.

Respectfully submitted,

ROBERT F. BACHER, *Chairman, Division of Physics, Mathematics and Astronomy*

INDUSTRIAL RELATIONS SECTION

To the President:

The educational and research activities of the Industrial Relations Section during 1949-50 continued to stress the original purpose which led to its establishment in 1939: to increase and disseminate a widespread knowledge and understanding of the philosophies, policies, principles, and procedures affecting human relationships in industry.

Relations between employers and employees exist in every organization and involve many different problems. Although books,

articles, and discussions may refer to "the problems of industrial relations" and may imply that they can be solved by a general political, economic, psychological, sociological, or other over-all approach, the Industrial Relations Section of the California Institute has emphasized the fact that a "grass-roots approach" must be used: a satisfactory solution of a specific problem arising between an employee and his superior must be found.

A library such as the one maintained by the Industrial Relations Section is an important tool which an educational institution can provide to help solve these specific problems. Our library has continued to assemble an ever-increasing number of books, periodicals, professional and trade journals, company magazines, union periodicals, pamphlets, and other printed materials. These describe and illustrate not merely the general approach to the solution of personnel problems but, of more importance, demonstrate the way in which specific problems have been solved under a variety of conditions. From this growing record of experience, individuals may find suggestions for the solution of their own problems.

During the past year the library has undertaken an organized effort to secure complete and up-to-date materials from the outstanding companies in the United States and has received very generous response from the companies so far approached.

Special attention has been given during the past year to a revision of the index of union agreements. At the end of the year approximately 350 current agreements had been analyzed and were ready for specific tabulation to meet the varied needs of companies and unions operating in Southern California.

The value of the library and union contract index was recognized by an increasing number of requests for information. Of the 225 inquiries received, 56 were for information on union contracts and 169 were for other information from the library. These requests came from a variety of sources: 167 from companies, 18 from unions, and 40 from other organizations and individuals. This represented an increase of approximately forty per cent over the inquiries received during the previous year.

The other activities of the Section also helped to increase and disseminate a knowledge and understanding of industrial relations and of the techniques and policies necessary for better industrial relations. During the summer of 1949 the Section conducted five special one-week conferences on the following subjects: Negotiation and Administration of Union Contracts, Employment Policies and Procedures, Training of Employees and Supervisors, National Income and Its Distribution, and Integrating a Personnel Program. These meetings, which had a total registration of 48, included representatives from 31 companies.

During the fall of 1949 and the spring of 1950 the Section conducted five series of special evening meetings which were attended by 85 persons from 49 companies. The Section also arranged a special tenth anniversary conference and dinner with a combined attendance of 755. A subsequent dinner-discussion meeting was held in January.

To reach a still wider audience, the members of the staff addressed 36 groups, including foremen's clubs, service organizations, regional conferences, and national conventions.

The Section has not concentrated exclusively upon the exchange of ideas and experiences with representatives of management, unions, government, and the public. Members of its staff have contributed to the undergraduate and graduate curricula in engineering and science. The required course in industrial management was completed by 38 Seniors in mechanical engineering. The Senior elective course in industrial relations was selected by 61 students. During the year this course was changed from a previous lecture and discussion basis to one which emphasized the solution of specific problems. The course in industrial relations for graduate students was offered for the first time since the war, and was elected by 12 students.

As part of its continuing research program the Section completed its second survey of personnel practices in Los Angeles County. Results of this large survey covering the practices of more than 700 employers were presented in tabular form showing practices in 40 specific industries. An additional tabulation stressing the personnel practices of large employers was also published.

The Section has given added attention to surveys of employee attitudes in specific companies. During the summer of 1949 it completed a resurvey in one large company which had been studied five years earlier. During the fall of 1949 it had an unusual opportunity to make a similar survey in a company with approximately 100 employees. This is the first survey conducted for such a small company. The results showed clearly that the technique is just as valuable to a small company as to a large one. It was also significant in revealing the facts that employees are interested in knowing more about their company and its problems, and that it is almost as difficult to provide such information in a small company as in a large one.

As a result of the earlier work performed by the Section in surveying the opinions and attitudes of employees, several additional surveys will be made in the future.

Any examination of personnel programs in business and industry reveals that most companies know the personnel problems of rank-and-file employees. Almost as many companies are also aware of

the problems of the first-line supervisors and are trying to solve them. Less progress has been made in recognizing and solving the personnel problems of line and staff executives in middle management, that is, those executives above the first line of supervision and below top management.

During the past year the Section has made some tentative explorations in this area. It has found an increasing awareness of the problems which exist. Solutions to the problems can not be discovered until the problems themselves have been clearly identified and analyzed. It appears that the problems involved will cover a wide area including selection and development of executives, proper compensation and incentives, benefit plans, status and symbols of status—in short, the application of sound personnel administration to this group. It is obvious that extensive research and study will be required before any publication can result.

Special attention has been given during the year to improved methods for the training of supervisory and management personnel. Interest in improved techniques of conference leading has continued. In addition the Section has experimented with methods of giving supervisors a chance to practice the use of managerial techniques. This device has been labeled in some of the current literature as "role-playing," and the general impression has been given that it is a new technique. In its approach the Section has emphasized the fact that this is not a new technique. It is merely providing in supervisory and managerial training the element of practice which has always been an important part of other training. Our analysis shows, in fact, that, except in the training for management, practice has been a regular part of all training. Even a few management training programs have provided some opportunity for practice.

The most significant development in the Section during the past year will not become apparent for another year or two. Since its establishment in 1939, the support of the Section has come as voluntary contributions from a large number of companies and individuals and from a few unions. During its first ten years, the Section has demonstrated its ability to perform specific services for many of its Sponsors and potential Sponsors. On the basis of this performance, a recommendation was made by the Committee on the Industrial Relations Section and the President and was approved by the Board of Trustees placing the Section on a definite schedule of fees and services. This method of financing recognizes the Section as an integral part of the California Institute. The details will appear in the 1950-51 catalogue.

Respectfully submitted,
ROBERT D. GRAY, *Director*
Industrial Relations Section

JET PROPULSION LABORATORY

To the President:

A balanced program of both applied and basic research has been followed throughout the year. The program of practical engineering work is a fruitful source of significant fundamental problems. A typical JPL project of the applied type was the design, construction and successful firing of the ORDCIT missile, one of the first ground-to-ground guided missiles to be entirely built and flown in the United States.

The Laboratory continues to cooperate with the educational activities of the Institute by providing laboratory facilities and lectures for students majoring in jet propulsion, as well as by supervising student theses related to jet propulsion. During the month of June, 1950, a three-day symposium on heat transfer and fluid dynamics was sponsored jointly by the Laboratory, the Institute, and several other educational organizations.

RESEARCH

The research program for 1949-1950 has included the fields of rocket propellants, materials, combustion, heat transfer, fluid dynamics and certain engineering developments.

1. *Propellants.* The investigation of the physical properties, propulsion performance, and combustion kinetics of both solid and liquid propellants continues as a major activity. The ignition parameters and burning rates of several solid propellants have been measured, and a new smokeless solid propellant has been transferred from the laboratory to the pilot plant stage. The reaction kinetics of nitric oxide are receiving detailed experimental study because of their importance to all acid-based propellant combinations. Spectroscopic studies of the radiation from flames have been extended from diatomic molecules to the more complex triatomic molecules such as CO_2 and H_2O. Investigations of accommodation coefficients for oxidation of metal surfaces are in progress which will throw light on the corrosion problems typical of rocket equipment.

2. *Materials.* The study of porous metals is no longer active as the initial laboratory phases of this program are essentially complete. Emphasis is now being placed on the measurement of the constitution diagrams of titanium and its alloys with chromium, molybdenum, and vanadium. The crystal structure, melting point, elastic properties, and similar properties are being measured, in many cases for the first time, for an extensive series of refractory alloys.

Diffusion of other metals into titanium is being studied by radio-

active tracer technique, and the investigation of ceramic oxides such as zirconia is being continued.

3. *Combustion.* The difficult problems of air-fuel combustion which are posed by ramjet-type propulsion systems are being attacked along several lines. A study of turbulence of cold gases in the wake of large-scale grids is being extended to grid configurations more nearly resembling ramjet flame-holders. A program correlating flame speed with turbulence level in Bunsen burners has just been brought to a satisfactory conclusion. Two studies of combustion in ducts are nearly complete, one in which efficiency and stability limits are observed as functions of velocity and degree of preheat of incoming air, and another in which the temperature and velocity are measured in the mixing zone around a high-speed jet in a duct.

The distribution of temperature, gas composition, and radiation from low pressure (millimeter region) flames is being measured, as well as the detail flow pattern of bases emanating from the surface of a porous metal.

4. *Heat Transfer.* Measurements of the parameters of convective heat transfer to flowing pressurized liquids have been completed for water and certain hydrocarbons, and equipment is being modified to enable measurement of typical rocket propellants such as nitric acid. Determination of the thermal conductivity of these liquids is also in process.

The phenomena of boiling heat transfer to water have been further investigated and the so-called "burnout limits" (incidence of vapor film cooling) measured as a function of velocity and temperature. Extreme heat transfer values of 4500 HP per square foot have been observed and the quantitative time history of vapor bubble diameter studied with a high-speed camera.

5. *Fluid Dynamics.* In the field of hydraulics progress has been made in the study of pressure transients occurring in hydraulic systems upon the rapid closing of valves, rupturing of burst diaphragms, and application of pressure. This information is of importance because the successful operation of a rocket motor depends strongly upon the manner in which it is started and stopped. The investigation of atomization of fluids has progressed to the point where individual droplets of specified diameter can be produced and studied under controlled conditions.

Gas dynamic problems have included a variety of theoretical problems on vehicle trajectories, flutter at supersonic speeds, and preliminary calculations on the possibility of "hypervelocity" rockets and guns.

6. *Engineering Development.* During the year the various mechanical and electronic aspects of the ORDCIT guided missile were

brought to completion, culminating in a successful firing. Further developments in autopilot design, lightweight pressure vessel construction, guidance techniques, propellant pressurizing systems and aerodynamic configuration are being pursued intensively.

FACILITIES

The fiscal year 1949-1950 has shown marked increase in the use of electronic instrumentation, with extensive use of a central data recording center and a continuation of the trend towards data of higher accuracy and higher time resolution. A Reeves Electronic Analog Computer (REAC) was installed during the latter portion of the year and is now in full operation, being particularly useful for problems involving trajectories, flight stability of test vehicles, flutter, and the like. It can also be used as a simulator in conjunction with control systems or portions thereof.

The 10x12-inch supersonic wind tunnel has seen much active service both for the Laboratory and for outside agencies. The 18x20-inch supersonic tunnel is now in operation and undergoing a three- to six-month period of calibration and adjustment.

The completion of a new permanent administration building has made it possible to convert the original administration building to an electronics laboratory, thus centralizing and expanding a previously scattered activity.

PUBLICATIONS

During the year about 100 JPL reports, comprising approximately 3,000 pages, were distributed to a mailing list of 350 agencies with parallel interests. Ninety per cent of these publications were classified. About 20 unclassified publications by JPL authors appeared in the journals of the national technical societies.

Respectfully submitted,
LOUIS G. DUNN, *Director*
Jet Propulsion Laboratory

MOUNT WILSON AND PALOMAR OBSERVATORIES

(Jointly operated by the Carnegie Institution of Washington and the California Institute of Technology)

To the President:

During the present report year, operations on Palomar Mountain have shifted rapidly from construction and testing to a normal schedule of observations. By the middle of the year both the 200-inch Hale telescope and the 48-inch schmidt-type camera had taken their place along with the 100-inch and 60-inch telescopes on Mount Wilson on the regular observing schedules of the Observatories.

At the end of the last report year the 200-inch mirror had been removed from the telescope and was undergoing the final figuring necessary to remove the slightly raised edge and other minor errors. This was completed by September 1949, and the mirror was successfully aluminized during October. Regular scheduled observations during the moonless period of each month were started on November 12, 1949.

During the Fall and Winter further tests were made of the behavior of the mirror when subjected to sudden temperatures changes. As a result of these tests thermal insulation was applied to the outer part of the mirror. This insulation and the fans installed the preceding winter satisfactorily equalized the rate of heat flow from all parts of the mirror. The final Hartmann tests showed that the mirror was focusing most of the light collected from a star in a circle whose diameter was equal to the limit of resolution of the photographic plates to be used, and consequently the mirror could be expected to give a thoroughly satisfactory performance. This was confirmed by the subsequent actual use of the telescope. In addition to the main instrument, one Ross corrector lens and the nebular spectrograph were completed during the year. Construction on the large coudé spectrograph was well advanced, and it is anticipated that this auxiliary will be in service before the end of 1950.

By June 30, 1950 a total of 510 direct photographs had been obtained with the Hale telescope. Most of these photographs have been taken as the first step in a series of detailed investigations that are part of a broad program planned to extend our knowledge of the distances and dimensions of the large-scale structures of the universe. The smallest of these structures and the one out of which the still larger structures are built are the extragalactic nebulae. Our own Milky Way system is one out of some hundreds of millions of these nebulae that can be photographed with the Hale telescope.

During the first eight months of operation a sequence of plates was obtained of the extragalactic nebulae NGC 2403, NGC 3031, NGC 5194, NGC 5457, the Sextans system, and a newly discovered member of the local group at $\alpha = 11^{h}\ 10^{m}.8$, $\delta = +22^{\circ}\ 26'$. When completed, these investigations will substantially increase the number of these nebulae whose dimensions and absolute magnitudes are accurately known. This information will in turn provide a more precise measuring stick for investigation of all of the more distant objects out to the extreme range that can be reached with the Hale telescope.

Another group of photographs has been taken to study the structure of the planetary nebulae in our own Milky Way system. The low focal ratio of the Hale telescope F 3.3. gives it so high a speed that it is particularly effective for these studies. Other exposures have been made to investigate in detail unusual objects discovered in the course of the National Geographic Society-Palomar Observatory Sky Survey.

Most of the observing time of the 48-inch schmidt telescope has been devoted to the National Geographic Society-Palomar Observatory Sky Survey. In the ten per cent of the available sky mapped before July 1950, more than 350 clusters or compact groups of nebulae, many of them near the limit of the plates at a distance of 300,000,000 light years, had been discovered. Several nearby dwarf nebulae including two additional members of the local system have been found.

1. *Solar Research.* Dr. S. B. Nicholson, Dr. R. S. Richardson, Mr. J. O. Hickox, and Mr. Paul Roques have continued the regular program of photography of the sun both directly and with the spectroheliograph on every clear day. Under the current program, small scale spectroheliograms are obtained at 1-1/3 minute intervals. Over 600 direct photographs and 110,000 spectroheliograms were taken during the year. All sunspot groups have been classified as to magnetic polarity and related phenomena. Richardson has made a statistical study of the time distribution of flares that occurred during the past 13 years. This suggests some form of coupling which causes the nearby simultaneous occurrence of flares at widely separated points on the sun more often than can be explained by chance. Tornado prominences have been investigated by Dr. Edison Pettit. Dr. Jesse Greenstein, Dr. R. S. Richardson, and Dr. M. Schwarzschild have shown that the abundance of C_{13} in the sun cannot be greater than 1/40 of C_{12}.

2. *Stellar Investigations.* The radial velocity program, to which a substantial fraction of the observations of the 60-inch telescope have been devoted for the past 40 years, was essentially brought to a close

with the publication of the radial velocities of 2111 stars by Dr. R. E. Wilson and Dr. A. H. Joy. The radial velocities and other characteristics of 175 dwarf M-type stars were investigated by Dr. R. Dyer. Further studies have been made by Dr. H. W. Babcock of the very large variable magnetic fields which are present in the spectrum variable stars. While theoretical interpretations are not yet complete, these magnetic observations are beginning to point to the explanations of the very peculiar behavior of this type of star. An extended study of late-type stars by Dr. R. F. Sanford culminated this year in the publication of a definite atlas of the spectra of stars of types R and N. Extensive observations of a large number of variable stars and stars with emission lines were made by Drs. Paul Merrill, R. E. Wilson, Joy, Sanford and Dyer. Studies of the curve of growth and of the relative abundance of various chemical elements have been made by Dr. Jesse Greenstein for γ Sag and for a group of F and G stars. The search for common novae in our own galaxy has been vigorously carried on by Professor Fritz Zwicky.

3. *Galactic and Extragalactic Nebulae.* The initial programs for the 200-inch and 48-inch telescopes outlined in the first part of this report were actively pushed by Dr. E. P. Hubble, Dr. Walter Baade, Dr. Milton Humason, Dr. Rudolph Minkowski, Dr. Albert G. Wilson and Professor Fritz Zwicky. In addition, Pettit has continued his measures of photoelectric magnitudes and colors of nebulae for which red shifts are available. Zwicky has extended his studies of intergalactic matter and of the distribution in absolute magnitude of the extragalactic nebulae. A. G. Wilson has re-examined the possibility of using the apparent diameter of extragalactic nebulae as a measure of distance. Baade has continued his studies of the structure and content of the Andromeda nebula, using plates taken with the 100-inch telescope.

4. *Guest Investigators.* The enlargement of facilities brought about by the completion of the Palomar instruments has made it possible to invite an increasing number of guest investigators from other institutions to make use of the Observatories' equipment for their observational programs. Invitations have been based primarily on the astronomical importance and the suitability for the Observatories' equipment of the programs submitted by the guest investigators. During the year more than 20 guest investigators from four foreign countries and eight American institutions have made use of the facilities of the Observatories.

Respectfully submitted,
IRA S. BOWEN, *Director*
Mount Wilson and Palomar Observatories