California Institute of Technology

Annual Report

1950-1951

Annual Report

1950-1951

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

Published by

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*Resigned November 5, 1951.

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 1950-1951.*

The Institute and National Affairs

As was foreseen in the President's Report for 1949-1950, the Institute has been called upon during the current year to assist the Federal government in many aspects of its program directed toward national security. The Institute has responded generously to these calls though they have frequently meant serious sacrifices to our normal program of education and research.

Though such sacrifices are gladly made, we must remain cognizant of the fact that our normal program of education and research is also essential to national security. The education of first-quality scientists and engineers is of more critical importance today than ever before. It would also be disastrous to the nation for it to abandon basic research programs in institutions such as this.

On the other hand, the military services also need immediate help. Fortunately, there is no central agency to tell us how we should balance our effort between these "normal" and "emergency" activities. We must make such decisions ourselves, using our own best judgment of the relative value of the Institute contributions in these two areas, basing our judgment on our own knowledge of the national and international situation. This is a grave responsibility, indeed, and must be approached with farsighted and patriotic unselfishness.

Fortunately, many members of the faculty, the administration and the Board of Trustees are in close touch with military and other national problems and can assist greatly in reaching wise decisions. And if your President seems rather frequently absent from his desk on trips to Washington, it can at least be hoped that his activities there will also help cast light on important Institute decisions.

The largest Institute activity directly related to national defense is the operation of the government-owned Jet Propulsion Laboratory. The increasing tempo of mobilization has naturally meant a substan-

*This report covers, officially, the fiscal year ending June 30, 1951. Since the annual meeting of the Board of Trustees was not held until November 5, 1951, a few items and events of the Summer and Fall of 1951 have been included.

tial increase in activity there, with increased emphasis on the more immediate as against the long range developments.

Similarly, the Cooperative Wind Tunnel, operated by the Institute for a group of aircraft companies, has been exceptionally busy. Plans for enlarging the tunnel to make supersonic tests possible are well along.

Of more immediate concern to the campus was the initiation of a special project known as Project Vista. The name derived from the fact that quarters to house this project were provided by the Army in what was once the Vista del Arroyo Hotel, later the Army's McCornack Hospital, in Pasadena. The name of the project is about the only feature of it which can be made public. A large fraction of the senior faculty members of the Institute have participated and also a number from other universities. The project is sponsored jointly by the Army, Navy and Air Force, and the work is of far-reaching importance. The program will be completed on January 1, 1952. Professor W. A. Fowler is performing a superb job as research director of the Vista Project.

Members of the faculty continued to be called upon to serve on military advisory committees in many fields. Professor H. P. Robertson was persuaded to extend his year's leave of absence to two years to serve as Scientific Director of the Weapons System Evaluation Group of the U. S. Joint Chiefs of Staff. Your President's services to various government agencies are typical of those of other faculty members. In addition to his regular service on the Naval Research Advisory Committee and the General Advisory Committee of the Atomic Energy Commission, he has also been appointed by the President of the United States to serve on the Advisory Committee on Scientific Manpower of the National Securities Resources Board (a short term committee), the Scientific Advisory Committee of the Office of Defense Mobilization, and the National Science Foundation Board. These are mentioned only to illustrate that practically no major national scientific group is any longer established without at least one—sometimes several—representatives of Caltech. The Institute's high achievements in science and engineering have made it a critical national asset, but have also brought attendant obligations and responsibilities.

Faculty

The Institute suffered a major shock in the sudden death on December 7, 1950 of Dr. Chester Stock, Professor of Vertebrate Paleontology, and Chairman of the Division of the Geological Sciences. Chester Stock was beloved by all who knew him, both on and off the campus. He had been for 25 years one of the most distinguished

members of the Institute faculty. Only a few days before his death he had been elected national president of the Geological Society of America. To replace him is next to impossible, for he was a unique figure in his field.

The vacancy created by Professor Chester Stock's death has, however, been most illustriously filled by the appointment of Dr. Harrison Brown, formerly of the University of Chicago, as Professor of Geochemistry. For some years the Division of the Geological Sciences has been anxious to extend its interests further in the fields of the physics and chemistry of the earth and of earth processes. Professor Brown, who during the war was a chemist with the atomic energy project, has since 1945 turned the new techniques of physics and chemistry into a brilliant attack on earth-science problems. This Institute offers an ideal site and atmosphere for the furtherance of such studies. We welcome him most warmly to our campus.

Dr. J. G. Kirkwood, Professor of Chemistry, resigned on July 1, 1951 to become Sterling Professor of Chemistry and Chairman of the Chemistry Department at Yale University. Though the loss of Professor Kirkwood was a serious blow, we at the same time are proud to congratulate him on his new and most distinguished appointment.

As usual, the report of the Dean of the Faculty lists many honors which have been bestowed on Institute staff members during the past year. These include membership in the National Academy of Sciences bestowed on James Bonner, Professor of Biology; the award to Professor Linus Pauling of the Gilbert Newton Lewis Medal of the California Section of the American Chemical Society; membership on important government committees assigned to Professors Robert Bacher and Charles Lauritsen among others.

As in prior years the Institute has welcomed to its laboratories for short or long periods a large group of visitors, visiting professors, and research fellows from all over the world. They have brought much to us. Most of them take special pains to insist that they have gained much from this sojourn here.

Many of our own staff have had the opportunity this past year to visit other institutions in this country and abroad to study or participate in scientific gatherings.

Student Life

The academic year 1950-51 was a difficult one for students at all colleges and universities. The Korean war and the attendant calls for draftees and for reserves left most students uncertain as to their future. The long debates in Congress over draft policies accentuated the confusion. At the same time, the insistent calls for more scientists and engineers made it clear to Caltech students that they were also

serving their country by continuing their education in these critical fields.

A few were called as draftees or reserves, a few enlisted. But the majority remained. The administrative officers of the Institute have urged all students to continue their studies as long as possible on the ground that their services as scientists and engineers will be more desperately needed than as soldiers. Even military leaders agree on this point, and the President and the Defense Department have urged Congress to include in Selective Service legislation adequate provisions to insure the flow of well trained scientists and engineers.

It was largely to ease this situation and to give our students the opportunity of finishing their education before being called to military service that the Institute applied for an Air Force Reserve Officer's Training Corps unit to be established on the campus. Though the number of institutions applying for such units greatly exceeded the number of units authorized, our application was approved and the unit was activated at the opening of the Fall term. One hundred and fifty freshmen or three-fourths of the freshman class enrolled in the unit. Special provisions for the enrollment of sophomores also were made, bringing the total size of the unit to nearly 200.

Those who elect, after completing the first two years of work, to enter the advanced R.O.T.C. course for the last two years of college will graduate with commissions as second lieutenants in the Air Force Reserve. According to present plans, such officers will be called to active duty for two years, though the possibility for some to pursue graduate work is not excluded.

Needless to say there is extended discussion among students, faculty and parents as to the relative advantages and disadvantages of R.O.T.C. enrollment. Because neither the international situation nor the future selective service policy can be predicted, there can clearly be no final answer to this question. But one thing is clear—if this country finds it necessary to maintain a military force of 3,500,000 men for a number of years to come, it will be necessary to ask practically every able-bodied young man as he comes of age to serve his country for approximately two and a half years. That is simple arithmetic. But because a modern military establishment needs great numbers of technically trained officers, it is also desirable for those with such talents to complete their training before they serve. The R.O.T.C. plan offers one means of achieving this goal.

Last spring's dire predictions about reduced enrollments in colleges and universities this fall have not materialized. At Caltech the enrollment at the opening of the fall term was 1023—about four per cent lower than a year ago but about four per cent higher than for the spring term of last year. An unusually large freshman class of 199

—resulting from an unexpectedly small number of summer withdrawals—is largely responsible. This large class required scheduling of an extra freshman section and some last-minute rearrangement of laboratory and recitation periods. Also, the Student Houses are again filled to capacity—with a waiting list—although there were a number of vacancies last spring.

As the "G.I." scholarship plan is being terminated, the number of students seeking scholarships from other sources has rapidly mounted. Our scholarship funds, in spite of a number of recent most generous gifts, are quite inadequate to provide for able but needy students.

As the nation witnessed with concern the evils arising from overemphasis on big time athletics by a few universities, Caltech took pride again in its wholesome program of intercollegiate and intramural athletics—a program conducted solely to provide exercise, relaxation and fun for *all* students. Sixty-seven per cent of the entire undergraduate student body participated in some intercollegiate or intramural competition. Forty-four per cent of the 1951 senior class had played on at least one intercollegiate team, and 28 per cent had won varsity letters. Of the eleven seniors who had won three or more letters, five had also been elected to Tau Beta Pi, national honorary scholastic society. The fact that Caltech football teams often end at the bottom of the conference is given more publicity than the fact that this year the water polo, soccer and cross country teams finished second and the baseball team tied for second place. But the important fact is that the athletic program provides for a majority of the students, most of whom have had no previous athletic experience, a much needed relaxation from their heavy study programs.

The 60th Anniversary

In the fall of 1891 Throop University was chartered and opened its doors to its first students. Though this event caused no national stir, it was a matter of great interest to the then 5000 residents of Pasadena. The Hon. Amos G. Throop, the founder, was a leading figure in the community, and his plan of providing opportunity for manual and technical training from the grade school through the college level attracted much interest. In 1892 the enrollment of the new institution was already close to 150 students, mostly in the "Preparatory" Division.

The early catalogues of Throop Polytechnic Institute (the name was changed in 1892) are replete with woodcuts of girls in sewing, cooking and typing classes and boys in the wood shop and laboratories. These pictures seem quaint today, but the foundation of a new experiment in education was being laid. As time went on

Throop grew, and, though frequently in financial troubles, it prospered. In 1910 it was moved from the downtown campus to what was then described as a "spacious site at the southeastern edge of Pasadena." At the new site the single building "Pasadena Hall," now Throop Hall, was devoted solely to college level work with the announced aim of making Throop College of Technology (its new name) an institute of technology "second to none in the country."

Those were brave words, indeed, in 1910! The miracle is that this aim was achieved in so short a time. Within 20 years—by 1930—the California Institute, the new name which "Old Throop" took on in 1920, was achieving nation-wide recognition. (Caltech has at least probably had more names than any other college in the country!) By 1951 only one other institution *in the world* was even in the same class with Caltech as a great center of education and research in science and technology.

It is fitting on this 60th anniversary that we pay tribute to the company of great men who founded this institution and who have guided its destinies on a path of ever higher achievement down through the years. A series of events to celebrate this birthday is being planned during the fall and winter of 1951-52. One of the most heartwarming events of recent years was the magnificent Caltech "birthday" dinner sponsored by the Pasadena Chamber of Commerce at the Huntington Hotel on November 9, at which time the community's tribute to Caltech was most effectively expressed.

Curriculum

A recent visitor to the Institute from Oxford wrote back (reports Professor Hallett Smith) "I felt at Caltech as I did not feel in other universities I visited, that the humanities were a social and intellectual force in the life of the undergraduates, not imposed from above but freely accepted as a part of a liberal education." This certainly has been the goal of the Division of the Humanities at Caltech and this external assurance that the goal is being achieved is most gratifying.

Notable advances in the program have been made possible by the Carnegie Corporation grant announced last year. A new attempt is now made throughout the history courses of the freshman and sophomore years to bring into sharper focus the development of political philosophy and to throw into clearer contrast the differences between the philosophy of the western nations and the philosophies espoused by Hitler and Stalin. In the senior course in current public affairs this conflict between the East and the West is even more intensively treated along with the consequences of the struggle on American economy, American institutions and the American way of life. In the new Public Affairs Room newspaper and magazine comment on

these issues from all over the free world is promptly available via air mail delivery. Thirty-five foreign and 60 American periodicals are received, plus the Congressional Record and scores of pamphlets issued by many government and private agencies. There is no excuse for any Caltech student not having a keen appreciation of the basic issues in current domestic and world affairs.

Finances

The total net assets of the Institute, including plant assets, stood at $47,580,131 on June 30, 1951, a rise of $2,434,094 for the fiscal year. This figure includes endowment funds of nearly $24,000,000, a plant investment of over $17,000,000, trust funds of just under $3,000,000 and surplus and unexpended income of $2,600,000.

The expenditures for the year amounted to $11,363,984 and this amount was slightly less (by $95,647) than the total income. Of the income about $7,200,000 was received as reimbursement for research carried out under government contracts, the Jet Propulsion Laboratory being the major item. Endowment income amounted to $1,547,939, and current gifts totaled $855,111. The Institute's investments in marketable securities (excluding real estate, trust funds, etc.) yielded an income of 5.3 per cent of the average book value, or 4.6 per cent of the current (June 30) market value. The Institute portfolio now consists of about 27 per cent bonds, 19 per cent preferred stocks, 51 per cent common stocks and 3 per cent real estate.

It is gratifying to note that during the past five years the total capital assets of the Institute have increased by about $10,000,000—an average increase of $2,000,000 per year. Assets will probably pass the $50,000,000 mark during this coming year.

Fifty million dollars seems like a lot of money—in nongovernment circles. But measured by Caltech's needs and opportunities it is distressingly inadequate. Faculty salary scales are in urgent need of revision; facilities for education, research and for student life are desperately needed. The thoughtful donor will find here many fine opportunities for a gift that will pay dividends forever.

Activities of the Divisions

It is impossible, of course, in the space of a very brief report to convey any adequate idea of the nature and extent of the many important research activities being carried on at the California Institute. As an example of the great magnitude of the research effort, it might be mentioned that the Division of Biology for special reasons prepared during the year a complete catalogue of all the research enterprises

in progress within that division, with one or two descriptive paragraphs relating to each project. When completed, this report turned out to be a volume of 140 pages.

As in previous years, therefore, it is necessary to confine our attention in this report to a few random samples of research projects of general interest in various fields of current activity at the Institute.

Astronomy. Regularly scheduled observations with the 200-inch Hale Telescope have continued throughout the year. Most of the observations on moonless nights have been devoted to the cosmological program. This is a systematic step-by-step program planned to extend our knowledge of the distances, dimensions and structural features of the extragalactic nebulae. These are vast stellar systems similar to our own Milky Way, each nebula being made up of millions or even billions of stars.

As a first step in this program, hundreds of photographs have been taken of the Andromeda and other nearby nebulae. Studies of these plates have already indicated that the increased resolution of the 200-inch telescope will make possible the elimination of most of the uncertainties in the earlier determinations of the distance and size of these objects. Another group of plates of more distant nebulae has shown that this same type of direct distance measurement can be extended to several times as many nebulae as could be reached with the 100-inch telescope.

The accurate determination of the absolute sizes and luminosities of a large sample of nebulae will in turn permit a survey with greatly increased accuracy of the distribution of these objects out to the extreme range of the 200-inch telescope, that is, throughout a sphere some 2,000,000,000 light years in diameter.

Another important part of this program has been the study of the spectra of the nebulae which are so distant as to be beyond the range of the 100-inch telescope. An examination of these spectra enables one to determine the velocity at which these nebulae are receding into space. Previous observations have shown that the more distant a nebula is from the observer the greater is its velocity of recession. Recent observations have extended this relation out to new limits. For example, one nebula estimated to be at a distance of 360,000,000 light years from the earth shows a velocity of recession of approximately 38,000 miles per second. This is a speed exceeding 1/5 the velocity of light. New techniques for improving the precision of the measurements of distance and recession velocities will enable astronomers to make far more accurate determinations of the relation between two quantities, and the precise nature of this relation is an important method of testing various cosmological theories.

On the campus, work in astrophysics was continuing its develop-

ment. Further light on the nature of nuclear reactions in the stars emerged from the joint efforts of physicists and astronomers.

Biology. During the year 1950-1951 a number of important advances were made in the research and teaching activities of the Division of Biology. An extensive project on radiation genetics, supported largely by the Atomic Energy Commission and the Office of Naval Research, added significantly to our knowledge of the effects of higher energy radiation on living systems.

Another of the noteworthy research activities of the division is that having to do with viruses. One group with Professor James Bonner has investigated higher plant viruses. Others working in Professor Max Delbrück's laboratory have continued study of bacterial viruses. Doctor André Lwoff of the Pasteur Institute of Paris spent two weeks working with this group and was to a large extent responsible for stimulating research on the interesting and important phenomenon of "lysogenesis." This term is used to describe the condition in which bacterial cells carry viruses in a latent condition without harm to the host cells. The special contribution of Lwoff to an understanding of this relation was the discovery that treatment of lysogenic strains of bacteria with ultraviolet radiation under suitable condition brings about liberation of active viruses capable of infecting sensitive bacterial cells. With assistance from the Boswell Foundation for Virus Research, Doctor Renato Dulbecco and associates are attempting to develop a new type of animal virus assay fashioned after the now classical "plaque count" technique widely used in bacterial virology. If this is successful, a serious bottleneck in animal virus research will have been opened up. In order to obtain desired background and the best available advice on this project, Dulbecco spent two months during the early part of 1951 on a trip to various animal virus and tissue culture laboratories. Since his return, active work has been under way with the virus of equine encephalomyelitis in a newly equipped and modernized virus-tissue culture laboratory suite.

As in the past several years, many activities of the division have been performed in close collaboration with members of the Division of Chemistry and Chemical Engineering as a part of the joint Chemistry-Biology Research Program. This program is generously supported by a special seven-year grant from the Rockefeller Foundation. An example of an area of research in which the activities of the two divisions come close together is found in the various investigations on proteins and protein structure. Professor Linus Pauling and Professor Robert Corey have recently increased our understanding of the molecular structure of proteins in a truly remarkable way. Since proteins are the key molecules of all living systems, the impact of this work on the biological sciences is indeed very great.

Geology. The Division of the Geological Sciences has continued to advance in many fields in spite of the severe shock caused by the death of Professor Chester Stock. For example, there was progress in the improvement of its earthquake recording instruments and the multiplication of its Southern California seismic stations, in fundamental studies on the nature of the earth's core, in studies of past glaciations in California and of the dynamics of desert dunes, and in the development of a fundamental and comprehensive hypothesis on the origin of pegmatites. In addition to many continuing investigations of important industrial minerals, significant studies were completed during the year on mica deposits in the southeastern United States, talc deposits in southeastern California, and gypsum deposits in the Palen Mountains, California.

Much thought and planning on the part of the division staff have been given throughout the year to the relatively new field of geochemistry in anticipation of the arrival of Professor Harrison Brown, under whose leadership an important and far-reaching program in this field will be initiated.

Chemistry. Many important advances in a number of chemical research programs were made during the year. For example, a penetrating investigation of the nature of enzymes has been under way for some time by Professor Carl Niemann and his associates. This study has involved especially the enzymes that are responsible for the breakdown of proteins and amino acids in the animal body. Important progress has been made toward determining the mechanism of the action of these enzymes and its relation to their structure.

Fifteen years of work by Professors Linus Pauling and Robert B. Corey and their many colleagues on the problem of determining the structure of protein molecules culminated in important and new results. Protein molecules are known to consist of chains of amino acids, but a chain may contain several hundred amino acid residues, and at least 24 different kinds of amino acids are known to occur. The problem of finding the precise way in which these amino acids are arranged in a protein molecule is thus a formidable one. However, new X-ray studies have enabled Pauling and Corey to propose a detailed structure of several important protein molecules and to show that these proposed structures are apparently consistent with all known X-ray data and also to show that previous models of protein structure are inconsistent with the new X-ray data. If further work confirms these findings, this will be an advance of great importance in a field which has occupied the attention of chemists and biologists for many years.

During World War II, Drs. Dan H. Campbell, Linus Pauling and J. B. Koepfli conducted a search for a substance which could be used

as a satisfactory substitute for human blood plasma and which could be manufactured in large quantities and stored for long periods and be adaptable to use on the battlefield. A material was developed by chemical treatment of gelatin with glyoxal and hydrogen peroxide and was given the name of oxypolygelatin. Clinical tests indicated that the material might be an exceedingly satisfactory plasma substitute. Because of the recently renewed interest in this field, additional investigations have been undertaken and extensive clinical tests are under way in the various medical centers of the U. S. Armed Forces. All of the results so far are exceedingly promising.

Work on the problem of the crystal structure of metals has attracted the attention of physicists, chemists and metallurgists for many years. Recently Dr. David P. Shoemaker and Dr. B. Gunnar Bergman have been able to work out the structure of the important so-called sigma phase which occurs in certain alloys such as stainless steel. Many previous attempts to determine the structure of this phase have been unsuccessful but these workers have now succeeded. The structure turns out to be a most unusual one and the success of this work will cast light on many of the problems of the structure of metals and alloys.

Physics and Mathematics. A major effort during the year was devoted to the construction of the new synchrotron. Preliminary operation was achieved at very low power levels, showing that no serious problems existed in ejecting electrons into the proper orbits. The new power supply for high power operation was installed and tested and construction was fairly well complete by the fall of 1951. Operation at the initial level of one-half billion volts may be expected by the middle of 1952.

A new cosmic-ray laboratory, built as a wing to the Norman Birdge Laboratory, was completed and Professor Carl D. Anderson and his colleagues are installing new equipment which will make possible a major addition to the Institute's important cosmic-ray program. Professor Anderson's group has added important new information to the nature and behavior of the most puzzling new neutral particle—the "V-particle," which apparently disintegrates into a proton and a negative meson.

Professor Victor Neher and his colleagues made cosmic-ray studies during the summer at Thule, Greenland—the nearest accessible point to the north magnetic pole.

Professor J. W. M. DuMond has continued his astonishingly precise measurements of the wave lengths of gamma-ray lines from various radioactive isotopes. He has also put into operation a new type of X-ray monochromator which makes possible "X-ray microscope" studies.

Work in the Kellogg Radiation Laboratory on the properties of light nuclei continued to yield a stream of new information, in spite of the disruption during the spring and summer of 1951 caused by participation of many staff members in the Vista Project.

Engineering. The past year was the first full year of occupancy of the new engineering building. This has given greatly improved facilities for instruction and research in civil and mechanical engineering. A similar building for chemical and electrical engineering is badly needed to relieve overcrowding in those areas.

In civil engineering a new study of water purity problems was initiated by Professor J. E. McKee. Professor F. J. Converse reported important progress on a new vibrational method of compacting soil. Further studies of resistance of structures to shocks and earthquakes have been reported by Professor George Housner. A study of the wind-induced vibration problem in long pipe lines has been initiated.

In electrical engineering Professor G. D. McCann and his colleagues have obtained new data on the characteristics of high-power arcs in air, which are of interest to the three electrical companies sponsoring the work. Applications of the electric analogue computer to many types of engineering problems have rapidly expanded to the point where the Institute Analysis Laboratory can no longer handle the load which industry would like to place on it. Hence the Institute is assisting a number of companies in building their own computers and in training computer personnel. Aircraft vibration problems can be handled in such an effective manner that most major aircraft companies are finding computers of this type to be essential equipment. The Institute will continue the basic research on computer design and application to new types of problems.

Basic studies in hydrodynamics continued to yield information of value to the Navy, to designers of pumps and turbines. In mechanical engineering new metallurgical studies by Professor Pol Duwez of titanium alloys provided new data of value in developing additional applications of this important metal, whose usefulness has only recently come to be recognized.

In the Guggenheim Aeronautical Laboratory basic research continued on many problems in fluid mechanics, the properties of air flow at hypersonic speeds (5 to 10 times the speed of sound) and in elastic and vibration problems encountered in aircraft structures. In the hypersonic wind tunnels the expansion of the air stream necessary to attain these extremely high speeds is accompanied by extremely low temperatures. Thus, rather surprisingly, new information on the liquefaction of air under these conditions is being obtained.

The very large Cooperative Wind Tunnel was built before supersonic speeds were of such importance—or could be attained. A

$6,000,000 modification program now under way will bring this tunnel to the supersonic range, thus vastly increasing its value.

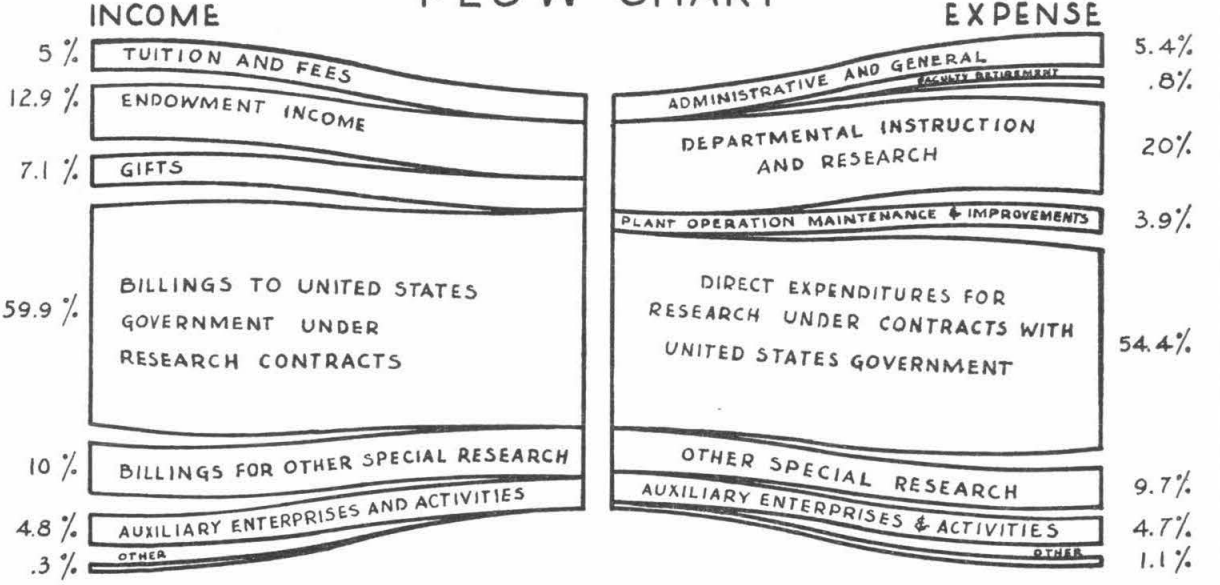
Acknowledgment

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 $12,000,000
1950-1951
FLOW CHART



Part II

THE 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, 1951, 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, 1950 and 1951:

	1950	*1951*
Bonds, stocks and other investments	$26,356,690	$27,819,180
Plant and equipment	16,661,412	17,111,937
Cash	1,752,846	2,819,566
Receivable from U. S. Government	1,036,180	1,900,704
Other assets—books and supplies, student loans, miscellaneous receivables, etc.	632,171	758,301
	$46,439,299	$50,409,688
Deduct—		
Advances by U. S. Government for certain research contracts	$ 772,500	$ 1,840,693
Current accounts payable and other liabilities	520,762	988,864
	$ 1,293,262	$ 2,829,557
Net assets	$45,146,037	$47,580,131
Representing capital of:		
Current fund—		
Surplus:		
Unappropriated	$ 761,141	$ 769,651
Appropriated	423,623	458,758
Unexpended gifts and endowment income	1,600,612	1,428,220
	$ 2,785,376	$ 2,656,629
Loan funds	98,053	100,983
Endowment funds	23,219,877	23,888,572
Plant funds—		
Invested in plant	16,647,912	17,098,437
Unexpended	412,424	277,610
Trust funds	1,620,058	2,880,475
Agency funds	362,337	677,425
As above	$45,146,037	$47,580,131
Net increase during the year		$2,434,094

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).

Set forth below is a summary of the transactions for the year which resulted in a net increase of $2,434,094 in Institute surplus and capital.

Current income (particulars on the following page)		$11,459,631
Gifts received:		
Endowment—		
Allan C. Balch	$ 19,875	
Janet Jacks Balch	19,875	
Alumni Association	18,527	
Trust (income distributable to beneficiaries)—		
Richard C. Tolman	753,040	
Arthur H. Fleming	436,508	
Others, excluding gifts treated as current income	184,271	
		1,432,096
Unexpended investment income (not included above in current income)		109,463
Profit on disposal of investments (net)		269,242
Agency funds received, less disbursements		312,885
Other additions (net)		8,809
		$13,592,126
Current expenditures (particulars on the following page)	$11,363,984	
Less—Expenditures for plant added to plant capital	246,242	
	$11,117,742	
Other expenditures charged to reserves, etc.	40,290	
		11,158,032
Net increase during the year		$ 2,434,094

CURRENT FUND

There follows a condensed comparative summary of current income and expenditures in the two years ended June 30, 1950 and 1951:

	1950	*1951*
Income:		
Tuition and fees	$ 660,464	$ 604,592
Endowment income	1,451,493	1,547,939
Gifts	678,379	855,111
Billings to United States Government under research contracts	4,787,468	7,199,952
Billings for other special research	1,248,750	1,207,059
Auxiliary enterprises and activities (net)	17,365	12,139
Other	43,020	32,839
	$ 8,886,939	$11,459,631
Expenditures:		
Administrative and general	$ 617,215	$ 638,425
Departmental instruction and research	2,251,531	2,347,867
Plant operation, maintenance and improvements	394,707	461,114
Direct expenditures under contracts with United States Government	4,186,673	6,491,226
Other special research	1,226,806	1,154,332
Other	224,423	271,020
	$ 8,901,355	$11,363,984
Excess of income or (expenditures)	$ (14,416)	$ 95,647

Income from endowment investments used for current purposes totaled $1,547,939 during the year ended June 30, 1951, as compared with $1,451,493 in the year ended June 30, 1950, as summarized below:

	1950	*1951*
Income received from investments in:		
Marketable securities (see following page)	$ 1,145,383	$ 1,272,352
Real estate	222,654	229,385
Beneficial interests in—		
Eudora Hull Spalding trust	340,000	176,040
Other trusts and estates	7,160	5,711
Receivables and other investments	25,735	30,715
	$ 1,740,932	$ 1,714,203
Portion of income from certain investments applied in reduction of their carrying value in recognition of depreciation and depletion	(55,417)	(56,801)
Net investment income	$ 1,685,515	$ 1,657,402
Less—Income retained and added to unexpended income balances of endowment and other funds (net)	234,022	109,463
Remainder applied as current income	$ 1,451,493	$ 1,547,939

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, 1950 and 1951 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*	
	1950	*1951*	*1950*	*1951*
Bonds:				
United States Government	$ 102,360	$ 92,334	2.1	1.9
Municipals	6,381	4,920	4.8	3.7
Canadian and foreign	14,034	18,646	2.5	2.9
Utilities	31,778	25,921	3.4	3.1
Industrials	10,940	11,065	2.7	3.2
Rails	8,000	8,000	7.2	7.2
Others	6,682	6,700	10.3	10.3
	$ 180,175	$ 167,586	2.5	2.4
Preferred stocks:				
Utilities	$ 72,122	$ 64,454	4.7	4.6
Industrials	113,302	103,425	4.4	4.5
Rails	7,116	6,705	4.8	4.5
Banks and other financial	10,069	9,177	1.8	1.0
	$ 202,609	$ 183,761	4.2	3.8
Common stocks:				
Utilities	$ 182,915	$ 260,478	6.4	6.5
Industrials	448,062	511,469	8.5	10.2
Rails	30,215	33,018	6.7	6.7
Insurance	11,077	14,164	4.4	4.5
Banks and other financial	90,330	101,876	4.3	4.7
	$ 762,599	$ 921,005	7.0	7.7
	$1,145,383	$1,272,352	5.0	5.3

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

Division	*Expenditures 1950*	*1951*
Engineering:		
Administration	$ 31,724	$ 39,913
Civil engineering	44,784	46,930
Mechanical engineering	122,660	149,616
Electrical engineering	85,658	97,443
Applied mechanics	27,952	27,477
Aeronautics	104,840	113,546
Jet propulsion	20,151	28,410
	$ 437,769	$ 503,335
Physical sciences:		
Physics	$ 186,897	$ 184,145
Astronomy	15,414	16,158
Mathematics	84,646	82,542
	$ 286,957	$ 282,845
Chemical sciences:		
Chemistry	$ 503,415	$ 515,822
Chemical engineering	88,897	93,680
	$ 592,312	$ 609,502
Geological sciences	$ 203,451	$ 192,104
Biological sciences	389,136	419,865
Humanities	152,331	171,517
Palomar Observatory	105,796	85,377
Physical education	52,915	58,292
Industrial relations	30,864	25,030
	$ 2,251,531	$ 2,347,867
The total expenditures in the two years were for:		
Salaries	$ 1,774,254	$ 1,852,429
Materials, supplies, etc.	340,801	337,302
Equipment added to plant capital	136,476	158,136
As above	$ 2,251,531	$ 2,347,867

Expenditures for research under contracts with the United States Government in the two years ended June 30, 1950 and June 30, 1951, are summarized below:

	1950	*1951*
Departments of the:		
Air Forces	$ 394,776	$ 428,841
Army	2,772,291	4,614,333
Navy	936,715	1,020,381
Others	82,891	427,671
	$ 4,186,673	$ 6,491,226

Billings under these contracts were $4,787,468 in 1950, and $7,199,952 in 1951.

ENDOWMENT FUNDS

The following is a comparative classified summary of the Institute's investments (excluding investments of trust funds) at June 30, 1950 and 1951:

	Market value of securities		*Carried at*		*Per cent of total*	
	1950	*1951*	*1950*	*1951*	*1950*	*1951*
Marketable securities:						
Bonds—						
U. S. Govt.	$ 5,080,910	$ 4,635,277	$ 5,119,004	$ 4,743,576	20.7	19.2
Municipals	129,070	124,250	133,995	130,484	.5	.5
Canadian and foreign	679,820	581,480	701,520	597,020	2.8	2.4
Utilities	978,499	680,980	955,547	709,699	3.9	2.9
Industrials	397,585	288,161	395,450	298,540	1.6	1.2
Rails	163,000	160,500	111,588	111,588	.4	.4
Others	133,730	144,235	64,887	64,887	.3	.3
	$ 7,562,614	$ 6,614,883	$ 7,481,991	$ 6,655,794	30.2	26.9
Preferred stocks—						
Utilities	$ 1,439,458	$ 1,349,121	$ 1,401,799	$ 1,401,799	5.7	5.7
Industrials	2,336,576	2,050,517	2,434,042	2,130,397	9.8	8.6
Rails	112,000	126,080	147,539	147,539	.6	.6
Banks, etc.	933,300	974,250	930,900	970,650	3.8	3.9
	$ 4,821,334	$ 4,499,968	$ 4,914,280	$ 4,650,385	19.9	18.8
Common stocks—						
Utilities	$ 3,379,032	$ 5,299,694	$ 3,092,136	$ 4,871,135	12.5	19.7
Industrials	7,154,372	8,292,922	5,259,469	4,741,626	21.3	19.1
Rails	388,580	411,495	495,935	495,936	2.0	2.0
Insurance	350,082	378,688	314,193	314,241	1.3	1.3
Banks, etc.	1,914,964	2,028,767	2,159,039	2,187,305	8.7	8.8
	$13,187,030	$16,411,566	$11,320,772	$12,610,243	45.8	50.9
Total marketable securities	$25,570,978	$27,526,417	$23,717,043	$23,916,422	95.9	96.6
Stocks and bonds without market quotations			37,842	37,844	.2	.1
Notes and contracts receivable			18,091	4,574	.1	
Real estate and leasehold			945,553	810,161	3.8	3.3
Beneficial interests in estates and trusts (carried at nominal amounts)			29	31		
Total investments			$24,718,558	$24,769,032	100.0	100.0
Comprising:						
Consolidated portfolio			$21,082,439	$21,125,985	85.3	85.3
Separate investments			3,636,119	3,643,047	14.7	14.7
			$24,718,558	$24,769,032	100.0	100.0

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

Estates of:	
Allan C. Balch	$19,875
Janet Jacks Balch	19,875
Mrs. Henry M. Robinson	7,688
Henry M. Robinson	7,688
Alumni Association	18,527
Others	10,880
	$84,533

PLANT FUNDS

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

	At June 30 1950	*Net additions*	*At June 30 1951*
Campus, buildings and equipment:			
Land	$ 688,182	$ 17,818	$ 706,000
Land improvements	194,400	11,184	205,584
Buildings	6,260,021	125,956	6,385,977
Equipment	2,930,788	255,274	3,186,062
	$10,073,391	$ 410,232	$10,483,623
Construction costs of Palomar Observatory and related buildings and equipment	6,588,022	40,292	6,628,314
	$16,661,413	$ 450,524	$17,111,937

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 $1,024,612 as compared to $738,081 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	$127,299
Aeronautics:	
Hughes Aircraft Company	6,700
Douglas Aircraft Company, Inc.	2,700
Biology:	
American Cancer Society	8,082
Herman Frasch Foundation	10,000
John Simon Guggenheim Memorial Foundation	2,850
International Minerals and Chemical Corporation	19,005
Eli Lilly and Company	14,400
County of Los Angeles	14,154
McCallum Foundation	4,600
Merck & Co., Inc.	4,000
National Foundation for Infantile Paralysis	30,000
Nutrition Foundation, Inc.	9,500
Pioneer Hi-Bred Corn Company	1,500
Riker Laboratories, Inc.	6,000
State of California	10,000
Elbridge and Mary Stuart Foundation	5,500
United States Public Health Service	14,234
University of California	10,000
Williams-Waterman Fund	4,000
Others—8	2,400
Chemistry and Chemical Engineering:	
Allied Chemical and Dye Corporation	1,800
American Academy of Allergy	3,000
American Cyanamid Company	10,000
American Petroleum Institute	40,800
California Research Corporation	1,850
Carbide and Chemical Corporation	15,000
Children's Hospital Research Foundation	2,300
Dow Chemical Company	6,000
E. I. DuPont de Nemours & Company	12,800
Ethyl Corporation	1,500
Fluor Corporation	3,500
General Petroleum Corporation	4,000
John Simon Guggenheim Foundation	7,500
National Foundation for Infantile Paralysis	30,000
Parke, Davis and Company	5,000
Research Corporation	5,976
Shell Oil Company	7,116
United States Public Health Service	94,253
United States Rubber Company	2,200
Others—5	1,586

Engineering:	
Daniel and Florence Guggenheim Foundation	35,000
Miehle Printing Press & Manufacturing Co.	2,500
Shell Oil Company	1,949
A. O. Smith Corporation	10,000
Department of Water and Power—The City of Los Angeles	4,000
Kelman Electric and Manufacturing Co.	4,000
State of California	9,425
Westinghouse Educational Foundation	2,000
Others—2	275
Geology, Paleontology and Seismology:	
Standard Oil Company of California	1,350
Stanolind Oil and Gas Company	1,700
Others—2	700
Humanities:	
Carnegie Corporation of New York	30,000
John Randolph and Dora Haynes Foundation	2,300
Pasadena Music and Art Association	1,198
Industrial Relations:	
American Potash and Chemical Corporation	1,000
Consolidated Vultee Aircraft Corporation	2,000
General Petroleum Corporation	2,500
Joyce, Inc.	1,000
Lockheed Aircraft Corporation	2,000
Richfield Oil Corporation	2,500
Signal Oil and Gas Company	1,000
Southern California Edison Company Ltd.	1,500
Standard Oil Company of California	2,500
Union Oil Company of California	2,500
Other—30	5,970
Palomar Observatory:	
National Geographic Society	25,000
Physics:	
Otto Beeck Memorial Fund	2,545
Dow Chemical Company	3,000
E. I. DuPont de Nemours & Company	2,200
William E. Hale Fund	1,500
Hughes Aircraft Company	6,500
Research Corporation	4,360
Shell Oil Company	5,000
Standard Oil Company of California	1,350
Other	450
Other Restricted Purposes:	
Alumni Association—California Institute of Technology	1,165
Carnegie Foundation for the Advancement of Teaching	1,800
Others—2	379

General or undesignated purposes:		
J. G. Boswell Company	1,000	
C. F. Braun	1,000	
California Institute Research Foundation	5,000	
California Institute Associates	64,402	
Douglas Aircraft Company, Inc.	20,000	
General Petroleum Corporation	20,000	
Grumman Aircraft Engineering Corporation	10,000	
Eli Lilly and Company	10,000	
Lockheed Aircraft Corporation	10,000	
Glenn L. Martin Company	10,000	
North American Aviation, Inc.	10,000	
Keith Spalding	26,400	
Standard Oil Company of California	25,000	
Stanolind Oil and Gas Company	10,000	
Union Oil Company of California	10,000	
Others—5	1,300	
		$ 983,323
Auxiliary enterprises and activities:		
Athenaeum—California Institute Associates	$ 7,980	
Health Center—Emergency Hospitalization Fund	5,310	
Other—	350	
		13,640
Non-educational purposes:		
Anonymous	$ 9,000	
General Petroleum Corporation	2,250	
Harriet Graham	2,000	
Amie S. Kennedy	1,000	
Lasker Award	1,000	
George H. Mayr Educational Foundation	5,200	
Donald L. Shepard Memorial	1,795	
Others—7	5,404	
		27,649
		$1,024,612

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

PRICE, WATERHOUSE & CO.

Exhibit 1

530 WEST SIXTH STREET
LOS ANGELES 14

September 28 1951

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 1951 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 1951 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		$ 387,225.06
Receivables:		
United States Government		1,900,703.66
Advances to trust fund		20,707.40
Tuition and fees, fully reserved	$ 13,681.90	
Other receivables		87,333.78
Supplies, food and books, at cost		157,954.56
Deferred charges		145,537.00
		$ 2,699,461.46
Restricted—		
Cash	$ 1,261,540.40	
Advances to current unrestricted fund	1,275,024.07	
Share in endowment fund assets	1,191,105.78	
		3,727,670.25
		$ 6,427,131.71
LOAN FUND ASSETS:		
Cash	$ 20,705.05	
Share in endowment fund assets	28,500.00	
Loans receivable	58,890.89	
		108,095.94
ENDOWMENT FUND ASSETS:		
Cash	$ 497,329.65	
Receivables	169.24	
Investments carried at	24,769,031.68	
		25,266,530.57
PLANT FUND ASSETS:		
Invested in plant—		
Campus buildings and equipment	$10,483,622.55	
Palomar observatory	6,628,314.14	
	$17,111,936.69	
Uninvested cash	155,910.82	
Share in endowment fund assets	121,698.90	
		17,389,546.41
TRUST FUND ASSETS:		
Cash	$ 72,180.63	
Investments carried at	3,050,148.16	
		3,122,328.79
AGENCY FUND ASSETS:		
Cash	$ 424,673.88	
Receivables	268,094.96	
Share in endowment fund assets	36,653.85	
Prepaid insurance	40,321.45	
		769,744.14
		$53,083,377.56

—BALANCE SHEET—JUNE 30, 1951

Exhibit 2

CURRENT FUND LIABILITIES AND CAPITAL:		
Unrestricted—		
Accounts payable		$ 416,332.71
Accrued salaries and wages		197,882.62
Deposits and advance collections		40,570.80
Payable to current restricted fund		1,275,024.07
		$ 1,929,810.20
Unappropriated surplus (Exhibit 3)		769,651.26
		$ 2,699,461.46
Restricted—		
Advances from United States Government for expenditures under certain research contracts	$ 1,840,693.01	
Appropriations of surplus for current purposes (Exhibit 3)	458,757.70	
Unexpended gifts for current purposes	882,863.06	
Unexpended endowment income	545,356.48	
		3,727,670.25
		$ 6,427,131.71
LOAN FUND LIABILITIES AND CAPITAL:		
Loan fund returnable to donor	$ 7,112.59	
Loan fund capital	100,983.35	
		108,095.94
ENDOWMENT FUND LIABILITIES AND CAPITAL:		
Share of other funds in endowment fund assets	$ 1,377,958.53	
Endowment capital	23,888,572.04	
		25,266,530.57
PLANT FUND LIABILITIES AND CAPITAL:		
Invested in plant—		
Deferred liability due in 1957	$ 13,500.00	
Plant capital	17,098,436.69	
	$17,111,936.69	
Unexpended plant funds	277,609.72	
		17,389,546.41
TRUST FUND LIABILITIES AND CAPITAL:		
Payable to creditors, including $178,762.78 interest	$ 210,962.78	
Payable to current fund	20,707.40	
Undistributed income	10,183.15	
Trust capital	2,880,475.46	
		3,122,328.79
AGENCY FUND LIABILITIES:		
Accounts payable and accrued expenses	$ 92,319.09	
Agency funds	677,425.05	
		769,744.14
		$53,083,377.56

	Total surplus	*Unappropriated*	*Appropriated*
Balances at June 30, 1950	$ 1,184,763.19	$ 761,140.52	$423,622.67
Current income and expenditures for year ended June 30, 1951:			
Income (Exhibit 4)	12,025,842.30	12,025,842.30	
Expenditures (Exhibit 5)	(11,930,195.27)	(11,930,195.27)	
Reversal of surplus appropriations made in prior years to cover expenditures included above		13,427.17	(13,427.17)
Appropriations for:			
Current purposes		(45,515.96)	45,515.96
Additions to plant	(55,047.50)	(55,047.50)	
Allocation of profit on disposal of investments of consolidated portfolio (Income of $20,094.46 allocable to appropriated balances invested in the consolidated portfolio was included in current fund income—see Exhibit 4)	3,046.24		3,046.24
Balances at June 30, 1951	$ 1,228,408.96	$ 769,651.26 (Exhibit 2)	$458,757.70 (Exhibit 2)

APPROPRIATED FOR				
Aeronautics research	*Income stabilization*	*Biology*	*Chemical engineering*	*Scholarships*
$199,212.25	$160,082.69	$51,918.67	$2,740.72	$ 9,668.34
				(13,427.17)
22,693.25	17,208.58			5,614.13
1,106.93	1,400.50	454.22		84.59
$223,012.43	$178,691.77	$52,372.89	$2,740.72	$ 1,939.89

Exhibit 4

CURRENT INCOME—YEAR ENDED JUNE 30, 1951

Educational and general:		
Tuition and fees		$ 604,592.28
Endowment income—		
For restricted purposes	$991,429.05	
For general purposes	495,951.63	
		1,487,380.68
Gifts—		
For restricted purposes	$619,969.98	
For general purposes	220,501.70	
		840,471.68
Billings to United States Government under research contracts		7,199,951.89
Billings for other special research—wind tunnel tests, etc.		1,207,059.00
Income from investments allocable to appropriations of current surplus		20,094.46
Sales and services of educational departments		4,985.00
		$11,364,534.99
Auxiliary enterprises and activities:		
Bookstore	$ 99,054.56	
Cafeteria	68,286.00	
Student houses—		
Campus	216,848.73	
Arcadia	18,358.45	
Athenaeum	124,259.88	
Dormitory	8,200.52	
Health center	36,108.85	
Student athletic fees	7,233.47	
		578,350.46
Other noneducational income:		
Endowment income—		
For annuities, scholarships, fellowships and prizes	$ 60,558.12	
Gifts—		
For scholarships, etc.	14,639.48	
Rentals	5,290.16	
Miscellaneous	2,469.09	
		82,956.85
		$12,025,842.30

(Exhibit 3)

Exhibit 5

CURRENT EXPENDITURES—YEAR ENDED JUNE 30, 1951

	Salaries and wages	*Materials, supplies, etc.*	*Equipment added to plant capital*	*Total*
Educational and general:				
Administrative and general	$ 425,307.16	$ 192,078.57	$ 21,039.73	$ 638,425.46
Departmental instruction and research	1,852,428.97	337,302.07	158,136.40	2,347,867.44
Operation and maintenance of academic plant	298,543.80	106,116.74	6,119.17	410,779.71
Expenditures for campus land and improvements	1,214.87	11,546.92	37,572.70	50,334.49
Direct expenditures under contracts with United States Govt.	3,804,945.40	2,685,896.41	384.32	6,491,226.13
Expenditures for other special research	763,243.98	371,913.50	19,174.74	1,154,332.22
General library	30,656.79	2,593.33	1,811.32	35,061.44
Retirement allowances, federal old age benefit taxes and annuity premiums		100,937.61		100,937.61
	$7,176,340.97	$3,808,385.15	$244,238.38	$11,228,964.50
Auxiliary enterprises and activities:				
Bookstore	$ 10,783.26	$ 82,688.21	$ 518.96	$ 93,990.43
Cafeteria	25,554.70	43,838.16	800.92	70,193.78
Student houses—				
Campus	91,002.66	124,250.28	324.47	215,577.41
Arcadia	4,590.00	5,357.97	115.12	10,063.09
Athenaeum	55,075.99	69,581.90	229.42	124,887.31
Dormitory	5,205.86	2,593.34		7,799.20
Health center	28,151.59	15,533.87	14.83	43,700.29
	$ 220,364.06	$ 343,843.73	$ 2,003.72	$ 566,211.51
Other noneducational expenses:				
Scholarships		$ 122,543.70		$ 122,543.70
Annuity payments		10,010.20		10,010.20
Other		2,465.36		2,465.36
	$7,396,705.03	$4,287,248.14	$246,242.10	$11,930,195.27 (Exhibit 3)

NOTE—Approximately $570,000 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:

The California Institute suffered a grievous loss during the past year through the sudden death of Dr. Chester Stock, Professor of Paleontology and Chairman of the Division of Geological Sciences. Dr. Stock had served the Institute for 25 years as a professor and administrator and had greatly enhanced its reputation through his research. His death, which came without warning, was a great shock to all, for he was still in his prime and had just been inaugurated as President of the Geological Society of America, an especially great honor for a paleontologist. He will be impossible to replace, and his passing will necessitate a complete revision of the geological program at the Institute.

Another serious, though not tragic, loss to the Institute came about through the resignation of Dr. John G. Kirkwood, Arthur Amos Noyes Professor of Chemistry. Dr. Kirkwood, who is one of the outstanding theoretical chemists of his generation, resigned to accept appointment to one of the most distinguished professorships in the country, the Sterling Professorship of Chemistry at Yale University. He will also serve as Chairman of the Chemistry Department at Yale.

Honors and awards continue to come to members of the Institute Faculty as a result of their scientific attainments. President DuBridge, already a member of the Scientific Manpower Advisory Committee of the National Security Resources Board, was appointed in April to a special committee of 11 scientists to advise President Truman and Mobilization Director Charles E. Wilson in matters relating to research and defense. In April also he accepted the invitation of General Dwight D. Eisenhower to serve as a member of the new National Manpower Council established at Columbia University. Earlier in the year he was appointed a member of the Board of the National Science Foundation.

To Theodore von Kármán, Emeritus Professor of Aeronautics, came during the year the Kelvin Gold Medal for 1950, one of the highest engineering science awards in the world. This medal is awarded in

London by a committee composed of the presidents of the eight major engineering societies of Great Britain.

George W. Beadle, Professor of Biology and Chairman of the Division of Biology, received during the year the 1950 Lasker award of the Public Health Association for his "outstanding and fundamental contributions to the understanding of genetic control of metabolic processes."

Howard P. Robertson, Professor of Mathematical Physics, was elected to membership in the National Academy of Science. He is the twenty-fifth member of the present Institute staff to receive this recognition—one of the highest scientific honors in the country.

Donald S. Clark, Professor of Mechanical Engineering, and Pol E. Duwez, Associate Professor of Mechanical Engineering, were awarded the Charles B. Dudley Medal of the American Society of Testing Materials. This, the highest award of the society, is made for a paper of outstanding merit constituting an original contribution to research on engineering materials.

Changes in the Faculty

(a) administrative officers

1. Ian Campbell replaces Chester Stock as Chairman of the Faculty. H. Frederic Bohnenblust will serve as Vice-Chairman.
2. Because of the death of Chester Stock, Ian Campbell is acting as Chairman of the Division of Geological Sciences.

(b) promotions

1. *To the rank of Professor:*

   V. Hugo Benioff (Seismology)
   Donald S. Clark (Mechanical Engineering)
   Robert P. Dilworth (Mathematics)
   Milton S. Plesset (Applied Mechanics)
   Rodman W. Paul (History)

2. *To the rank of Associate Professor:*

   Charles R. DePrima (Applied Mechanics)
   W. Duncan Rannie (Mechanical Engineering)
   Arthur W. Galston (Biology)

3. *To the rank of Assistant Professor:*

   Julian D. Cole (Aeronautics and Applied Mechanics)
   Yuan-Cheng Fung (Aeronautics)
   Alfred C. Ingersoll (Civil Engineering)
   Caleb W. McCormick, Jr. (Civil Engineering)
   Lloyd C. Pray (Geology)
   George K. Tanham (History)
   David F. Welch (Engineering Drafting)
   Max L. Williams (Aeronautics)

(c) NEW APPOINTMENTS

1. *Visiting Professors:*

Hans A. Bethe, of Cornell University (Physics)
Enrico Fermi, University of Chicago (Physics)
Felix G. Gustafson, University of Michigan (Earhart Laboratory)
Ernest Hadorn, University of Zurich (Biology)
Edward O. Holmes, Jr., Boston University (Chemistry)
Massimo Simonetta, University of Milan, Italy (Chemistry)
Polydor Swings, University of Liege, Belgium (Astrophysics)

2. *Research Associates:*

Fritz Borgnis, Federal Institute of Technology, Zurich (Physics)
Walter G. Cady, Wesleyan University (Physics)
David M. Dennison, University of Michigan (Physics)

3. *Lecturers:*

Richard B. Beaman, University of Redlands (Humanities—Art)
Ross Lee Finney, University of Michigan (Humanities—Music)
Alfred H. Joy, former Staff Member, Mount Wilson Observatory (Astronomy)
Joseph Levy (Hydrodynamics)

4. *Associate Professors:*

Austin Phelps (Biology) (summer only)

5. *Senior Research Fellows:*

S. J. Singer (Biology and Chemistry)
Jerome Vinograd (Chemistry)

6. *Assistant Professors:*

Francis S. Buffiington (Mechanical Engineering)

7. *Instructors:*

Seba Eldridge, Jr. (Mechanical Engineering) (part-time)
Donald Norris (Invertebrate Paleontology) (part-time)
R. R. Solverson (Aeronautics) (part-time)
Calder T. Williams (English) (part-time)

8. *Research Fellows:*

Adolph Abrams (Biology)
Jack L. Alford (Engineering)
William C. Ashby (Biology)
Irving S. Bengelsdorf (Chemistry)
Sidney A. Bernhard (Chemistry)
Guiseppe Bertani (Biology)
Wan-Chen Chiu (Meteorology)
George H. Cleland (Chemistry)
George C. Dacey (Engineering)
E. E. Dale (Biology)
Robert B. Day (Physics)
Daniel H. Deutsch (Chemistry)
Helen Garman (Biology)
Charles E. Harrold (Biology)
Henry Hellmers (Biology)
Chang-Pen Hsu (Electrical Engineering—Analysis Lab.)
Torben Huus (Physics)
Anton Lang (Biology)
Victor A. Lewinson (Chemistry)

Cheng W. Li (Physics)
Margaret Lieb (Biology)
F. W. Lorenz (Biology)
Milton Madoff (Chemistry)
Richard E. Marsh (Chemistry)
David E. Muller (Physics)
Alfred Novak (Biology)
Axel Nygren (Biology)
J. Howard Pinckard (Chemistry)
Derrick Rowley (Biology)
Edwin E. Salpeter (Physics)
Pierre A. Schaeffer (Biology)
Richard Schweet (Biology)
John D. Seagrave (Physics)
Tsu-Chia Sheng (Biology)
Alberto Soriano (Biology)
Harrison D. Stalker (Biology)
Tsuneo Y. Tenabe (Biology)
Dudley Thomas (Chemistry)
R. G. Thomas (Physics)
Serge N. Timasheff (Chemistry)
Kiyoo Wadati (Seismology)
Emanuel Windsor (Biology)
Katerina Zarudnaya (Biology)

(d) RETIREMENTS

Ralph E. Wilson, Staff Member, Mt. Wilson and Palomar Observatories, retired May 1, 1951, after a long and distinguished career.

(e) RESIGNATIONS

William C. Kinard, Assistant Professor of Business Economics.

John G. Kirkwood, Arthur Amos Noyes Professor of Chemistry.

Myron H. Nichols, Associate Professor of Electrical Engineering.

Richard O. Sensor, Assistant Professor of Industrial Relations.

(f) LEAVES OF ABSENCE

Arthur W. Galston, Associate Professor of Biology, was granted leave of absence for the year to enable him to carry on research in Sweden under a Guggenheim Foundation Fellowship.

Horace N. Gilbert, Professor of Business Economics, returned about the middle of the year from a two-year tour of duty on the staff of the U. S. High Commissioner for Germany.

Samuel Karlin, Assistant Professor of Mathematics, was granted a leave of absence for the year to enable him to carry on research at Princeton University.

Joseph B. Koepfli, Research Associate in Chemistry, took leave of absence in January to accept the newly-created post of Science Advisor to the Secretary of State.

Charles W. Merriam, Associate Professor of Invertebrate Paleontology, was on leave from July to January completing a project in the Inyo Mountains for the U. S. Geological Survey.

Howard P. Robertson, Professor of Mathematical Physics, was on leave of absence in order to serve as Deputy Director of the Weapons Systems Evaluation Group of the Department of Defense in Washington.

(g) DEATHS

William H. Clapp, Professor Emeritus of Mechanism and Machine Design.

Chester Stock, Professor of Paleontology and Chairman of the Division of Geological Sciences.

Respectfully submitted,

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

THE DEAN OF GRADUATE STUDIES

To the President:

Graduate enrollment at the beginning of the academic year 1950-51 was only sligthly less than that for the year before, but during this period a decrease occurred which brought the number of graduate students at the Institute below 400 for the first time since 1946. Prior to 1945, the number was always less than 300. The loss during the past year was caused by the unsettled national conditions and the completion of requirements for advanced degrees before the final term by a number of students. Of the graduate students in attendance, one-half were married, well over one-half were veterans, nearly 10 per cent held commissions in the military forces on active or inactive status, and 15 per cent were citizens of some 22 foreign countries. There was almost an equal division of students between science and engineering. More than half of the total number were working toward the doctorate.

Doctor's degrees were granted to 68 students, this number being only slightly lower than the peak reached in 1949-50. Engineer's degrees were awarded to 17 candidates; and Master of Science degrees to 113. These latter numbers are lower than those for the preceding year.

Scholarship aid given to graduate students was 18 per cent greater than that for the year before. This increase was needed because educational assistance being provided by the government for veterans of World War II was declining rapidly as individual allotments became depleted. This trend is to be expected also in the following year.

Fellowships were made available to 25 outstanding graduate students by industrial corporations, 13 by governmental agencies, 9 by educational foundations, and 3 by special endowment funds given to the Institute for this purpose. These helpful educational gifts were granted mostly to students who had made gratifying progress toward the Ph.D. degree. The Institute chapter of the Society of the Sigma

Xi awarded a number of one-term grants to men who were in the last stage of completion of doctoral requirements. Graduate Assistantship appointments were held by 167 students.

The Committee on Graduate Study gave attention to several specific problems during the year. It proposed, and the Faculty ratified, the creation of a small supervising committee for each student at the beginning of his work toward the Ph.D. degree, to follow his studies throughout their course and to serve as the nucleus of his final examining committee. A statement of policy was formulated as a guide regarding the nature and scope of examinations for the doctorate. A study was made of methods which might assist in encouraging enrollment of more graduate students of the very highest caliber. As a result, a program was instituted to offer travel aid to a limited number of outstanding candidates to permit them to come to the institute from distant points.

Several academic departments of the Institute made thorough studies of their graduate curricula during the year. As an outcome of these investigations, a number of changes in graduate course offerings were made, departmental degree requirements were modified in some cases, and procedures for administering graduate study were improved.

During the latter part of the year, uncertainty about personnel requirements of the armed services made planning for the next year particularly difficult. Possible decreases in the undergraduate student body would have a direct effect upon the number of graduate assistantships which could be filled, and thus upon the total financial aid available to graduate students. The conservative budget decided upon did in fact result in some decrease in number of graduate students and left some departments with a shortage of graduate assistants as the 1951 fall term brought a full undergraduate enrollment after all.

Respectfully submitted,

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

THE DEAN OF STUDENTS

To the President:

The college year 1950-51, which it had been anticipated would closely approximate a "normal" year, developed as one beset with much initial distraction for our students while discussions preceded the determination of national policies pertaining to manpower of the armed forces. Stabilization of attitude was aided by the fact that

you were a member of the Advisory Scientific Manpower Committee of the National Security Resources Board. Thus the students were enabled to receive directly authoritative information which impressed them with the importance of continuing with their training in the scientific or engineering fields. Such a realization is essential in view of the estimates of the Engineering Manpower Committee of Engineers Joint Council that 60,000 engineers were needed this year to supply the additional requirements of the country, exclusive of the needs of the military. To meet this need, the prospective output of the engineering colleges of the nation was 1951, 38,000; 1952, 26,000; 1953, 17,000; 1954, 12,000. Statistics available indicate corresponding shortages of personnel in other scientific fields.

The number of veterans in the undergraduate student body declined to 147 or 23 per cent during the past college year, compared with thirty-nine per cent during the previous year. Fifty-five or thirty-seven per cent of the veterans were married. Veterans numbered 67 or forty per cent of the 167 seniors, but only ten per cent of the freshman class.

The Student Houses were occupied during the past year by a more homogeneous group of residents, with less diversity of age, than in any year since 1942-43 preceding the Navy V-12 period. Under this favorable situation, and with the counsel of Professor George Tanham, Master of the Student Houses, progress has been made in the direction of group responsibility administered by the student officers for wholesome conditions and internal discipline. A problem which confronts the administration of the Houses is that of occupancy. At the beginning of the year, the Houses were completely filled with 365 residents and there was a waiting list of twenty. At the end of the year, there were forty vacancies. It is believed that such variation is non-recurrent, since the past year was marked by an unusual number of withdrawals for scholastic and other reasons.

In December of the past year the new residence for the YMCA Secretary was completed and occupied. Located on South Holliston Avenue, near the campus, it provides an unusual and advantageous facility for an important phase of student interests. The project represents a direct investment of $26,000 for the lot, building, and furnishings, with an additional $16,000 of endowment for maintenance expenses. The whole constitutes a fine demonstration of support by friends of the Y.M.C.A.

The first "Parents' Day" last fall inaugurated by Dean Foster Strong for families of new students proved to be so successful that its continuation as a regular event is very desirable. It provided an exceptionally favorable occasion for acquaintance between parents

of students and members of the faculty, as well as for observation of the facilities of the Institute.

In many ways the Caltech Service League has provided facilities and valued assistance to both groups and individuals of the student body during the year. In addition to a large number of continuing activities, some special undertakings have been the redecoration of the Throop Club lounge for non-resident students and provision of a recreation area with equipment for families of married students living at the housing project. It is particularly gratifying that close coordination of the program of the Service League is maintained with the office of the deans.

The usefulness of this office is greatly dependent upon the cordial relations and mutual confidence existing between Dean Paul C. Eaton and Dean Foster Strong and their respective constituents, the upper classmen and the freshmen. Appreciation is expressed for their unusual interest and cooperation.

Respectfully submitted,

FRANKLIN THOMAS, *Dean of Students*

THE ASSOCIATE DEAN FOR UPPER CLASSMEN

To the President:

The outstanding aspect of undergraduate life during the past year was the reflection, in the affairs of individual students, of the national emergency. Superficially, academic "business as usual" was carried on, but in varying degrees everyone was aware of external pressures.

Fortunately, in comparison with certain other campuses, we maintained a pretty stable condition. No wave of enlistment hysteria broke over us; good scholastic averages were maintained and generally improved; athletic, social, and other extra-curricular programs were continued in their entirety. Such counsel as this office and other Institute agencies gave to students, concerned by long uncertainty over their academic or military future, was to wait and see, always stressing the value to the individual and national interest of as much uninterrupted college training as was possible to obtain. Nevertheless, attrition figures are larger than in the previous four years. A breakdown of losses during the year from 25 September 1950 through 1 July 1951 in the three upper classes follows:

	Soph. (1953)	*Junior (1952)*	*Senior (1951)*	*Total*
Withdrawals (military)	6	5	1	12
" (financial)	1	1	0	2
" (academic) ...	1	0	0	1
" (health)	2	1	1	4
Academic failure (denied reinstatement)	1	4	1	6
(no petition)	4	1	2	7
Transfer to other college....	1	1	1	3
Disciplinary suspension	2	1	0	3
	18	14	6	38

The military withdrawals were distributed as follows:

	Soph. (1953)	*Junior (1952)*	*Senior (1951)*
Enlisted	3	5	0
Called to active duty (delay denied or not requested)	2	0	1
Drafted (no postponement or deferment)	1	0	0
	6	5	1

The effect of the National Emergency was noticeable in other areas. The Departmental Adviser System, in its second year of operation, worked well, but additional obligations of some staff members in the national interest naturally limited their availability. An informal poll on the desirability of establishing an ROTC unit showed about 75 per cent of undergraduate students favorably interested. When in April, 1951 the Air Force unit was assigned, gratification was general. Some curriculum revision was necessary to adjust to the Air Force requirement that 12½ per cent of the total unit load be made up of courses in Air Science and Tactics.

Two general matters, indirectly related to the international situation, might be mentioned. One is the matter of undergraduate scholarships. Although both the tuition and student house charges have been raised since 1947, the budgetary provision for scholarships, as of this writing, has remained practically constant. With all other costs up and the number of those students entitled to Federal assist-

ance by reason of military service down, it is hoped that additional funds may be provided. There have been several gratifying gifts from individuals and organizations. A full-tuition scholarship provided by the Caltech Management Club was especially appreciated.

The second matter is that of geographical representation in the undergraduate body. In 1949-50, 73.8 per cent of entering freshmen came from California. To maintain and, hopefully, to increase the percentage representation from preparatory and high schools in the East, the undersigned has for the past two years made a round of visits to schools in the New England-New York area during the summer. Results are difficult to evaluate, but the number of well-trained boys potentially available is remarkably high. Also remarkable is the extent to which recent and accurate information about the opportunities at the California Institute has *not* penetrated. Remedial measures like the above have been undertaken by the Dean of Admissions, whose own visits and whose distribution of information by mail have done much to stimulate interest in this important area. The North- and South-West have been similarly cultivated by other staff members. Here again, more scholarship funds and increased alumni participation would be welcomed to enhance our competitive position for the ablest students.

The importance of the student-operated Honor System was recognized this year, when the retiring chairman, Oliver H. Gardner, '51, was selected by the undergraduate deans as the recipient of the Hinrichs Award, a distinction earned in large part by him and his fellow Board of Control members for effective administration.

Respectfully submitted,

P. C. EATON, *Associate Dean for Upperclassmen*

THE ASSOCIATE DEAN FOR FRESHMEN

To the President:

One hundred and seventy-six freshmen registered in September 1950 and went to New Student Camp. As before, the camp served as an excellent medium to introduce to the new students most of the major aspects of their future life on this campus. Also as before, but fortunately to a lesser extent this time, the excitement and drama self-generated at camp regarding the future possibilities on campus

acted to obscure in the students' minds the fact that all campus life is based on a core of hard, thorough academic work. Thus, when the students return to campus and start their class schedule there still remains, and probably always will remain, the problem of getting the new students over the hump of their discovery that college means hard work and constant self-discipline.

In its efforts to anticipate and solve this problem, the Deans' Office has received excellent and sympathetic cooperation from the faculty. It should be particularly recorded that most effective interest and help on this problem has been received from the Master of the Student Houses, and from the Resident Associates and upper class student leaders in the houses. This increase of effectiveness at the working level of the students, whereby an increasing sense of responsibility is being shown by upperclassmen for the academic success of their younger colleagues, is especially promising.

In October 1950, another attack on the problem of student morale was made by the inauguration of a Parents' Program. It was felt that if parents could attend a meeting on campus, and could there be told what the Institute was like, what demands were being made on the students, and how the students were helped to respond to these demands, a greater background of intelligent support could be generated for the students. A day-long program, supplied partly by the Institute and partly by the Caltech Service League, was planned, and all parents of new students were invited. One hundred and eighty-seven parents or relatives, representing families of 104 students, attended. Many of the parents came from out of state, even from as far away as Washington and New York.

Judging by the comments of the parents at the time and from the letters received afterward, the parents considered the program a success and thought it should be repeated every year. An unexpected dividend came from the students in the number who commented at some time later in the year that their rapport with their parents had increased subsequent to Parents' Program. It is proposed to repeat the Parents' Program in future years.

During recent years we have received prophecies from those in close touch with high school students that year by year we would find that our entering freshman class would be weaker academically. In spite of our efforts to anticipate this possibility and to increase freshman counseling, our experience with this year's freshman class gives substance to this prediction. This year the loss from the freshman class was 43, the highest so far, and was made up as follows:

Failed scholastically	14	
Withdrew to avoid scholastic failure	7	
Total of those academically deficient		21
Reinstated to repeat freshman work next year		8
Withdrew for financial reasons		1
Withdrew to change vocation		3
Known to be doubtful returnees, but not yet formally withdrawn		5
Military leave (reservists recalled to active duty)		5
		43

This represents an attrition of 24 per cent. The significant figures above are the 21 students we admitted who were found incapable of doing acceptable academic work, and the eight students who are believed to be capable of doing acceptable work on the second try. It is believed that the number of students who require two attempts at the freshman work in order to get up sufficient momentum for the Caltech curriculum will increase in future years.

One additional statistic may be interesting. This year, on the basis of need and estimated scholarship potential, the Admissions Committee awarded 45 scholarships to incoming freshmen. Of these, only 13 attained sufficiently high grades during the year to become eligible for scholarship consideration the following year. This drop in scholarship eligibility underlines the difficulty of correlating pre-registration information with subsequent performance.

Respectfully submitted,

FOSTER STRONG, *Associate Dean for Freshmen*

THE DEAN OF ADMISSIONS AND REGISTRAR

To the President:

Enrollment figures for the last two years and an estimate of registration for September, 1951 are given below. The estimate shows a decrease of 25 students as compared with September, 1950; these are men who did not pre-register in June, 1951, most of them because they expected to be called into military service. It must be emphasized that the September, 1951 estimate is subject to far greater inaccuracy this year because of the uncertanty regarding the number that will be taken by selective service or will enlist in order to enter the military branch of their choice. The figure of 620 is predicted for Sep-

tember because of the belief that not many will be drafted during the summer and that most of those not drafted will return in the hope of further deferment. What the policy of the Selective Service System in general, and local draft boards in particular, will be with regard to deferment of college students it is impossible to predict. We will undoubtedly lose a number in the course of the year. Last year all students called for induction during the year had their inductions postponed until the end of the year. In the coming year no student whose induction was postponed in 1950-51 is eligible for another postponement unless he can secure an actual change of classification and deferment.

Registration Figures

	September 1949	*September 1950*	*September 1951 (estimated)**
Undergraduates	697	645	620
Graduates	444	425	400
	1141	1070	1020

Figures on Veterans' Enrollment

	No.	*Per cent of Total*	*No.*	*Per cent of Total*	*No.*	*Per cent of Total*
Undergraduate veterans	272	39	147	23	79	12.7 (estimated)
Graduate veterans	267	60	264	62.1	information not now available	
	539	47	411	38.4		

* The total registration for the Fall term, 1951, proved to be 1023; 412 graduate students, 611 undergraduates.

The decrease in undergraduate veterans is, of course, to be expected.

With the present limitation of 180 on the freshman class, a normal undergraduate enrollment would be about 675. The drop from this figure in 1950 and 1951 is caused partly by the present military situation and partly by the fact that for the past three years the freshman class has numbered around 170 instead of the anticipated 180. Cancellations during the summer from among those admitted have been unusually large, and most of these cancellations were received from men who had to be denied scholarships for which they had applied. The Admissions Committee each year makes an allowance for cancellations, but it is impossible to predict such things with accuracy. The penalty for exceeding 180 is overcrowded laboratories and lec-

ture rooms. This year, because of the generally unsettled conditions which prevail, the Admissions Committee made an unusually large allowance for cancellations. Cancellations ran below normal, and we ended with a freshman class somewhat larger than the optimum figure. Thus, there will be some undesirable overcrowding in the first year, but in view of possible future inroads on enrollment because of voluntary or required military service, it would seem advisable that we either make provision for a larger number of freshmen or encourage more applications for transfer with advanced standing. These matters are now under consideration.

In the fall of 1951 the Institute inaugurated a unit of the Air Force Reserve Officers Training Corps. The basic course is open to all freshman students who do not have obvious physical defects. At the end of the sophomore year these students must pass the physical examination required of all Army officer candidates, and if they are otherwise qualified as well they may enter the advanced course. After satisfactorily completing four years of AFROTC, they will be commissioned as second lieutenants in the Air Force Reserve and will probably be called to active duty for a period of two years. Membership in the unit is optional. Those who join are exempted from the draft as long as they remain in good standing. Since four years of AFROTC training are required, students may join only at the beginning of the freshman year. It is expected that those who complete the course at the Institute will become ground officers. No flight training will be given. However, those who desire to do so and who can pass the flight physical examination may apply for flight training after graduation.

For the academic year 1950-51 a total of $48,600.00 was awarded in undergraduate scholarships to 110 individuals in amounts ranging from $100 to $1000. The average grant was approximately $450. Recipients had demonstrated need, and in the three upper classes all recipients ranked in the top quarter of their respective classes. This means that 17 per cent of the undergraduate body required some financial aid in order to complete the year. This figure does not include those to whom loans were made, although a number, even including some who received scholarships, were forced to borrow from the Institute loan funds in addition in order to meet expenses. In 1949-50, 8 per cent of the undergraduates received scholarships. The large increase this year is the result of the decreasing number of students receiving veteran's aid and of the increasing cost of living, including an education. Scholarships for 1951-52 have not yet been awarded to the three upper classes. Awards to freshmen entering this September total $24,250 as compared with $21,400 awarded to freshmen who entered in September, 1950. Approximately 25 per

cent of the entering class will receive scholarships, and this is the same as the percentage for last year.

Applications for freshman admission in 1951 were 16 per cent higher than in 1950 in spite of a general drop throughout the country for colleges as a whole. It is possible that this is a reflection of the school visiting program carried out locally by undergraduates and at a distance by members of the Admissions Committee. Students' Day, an open house for high school students and teachers which was held last fall, undoubtedly contributed to the increase. However, the competition between colleges for the best men graduating each year from high school continues to be keen and must be met by maintaining and increasing our contacts with the high schools in every possible way.

The geographical distribution of our students is of importance if we are to guard against becoming too provincial. As of the date of writing this report, 66.5 per cent of the freshmen entering this September are from California; 29.7 per cent are from other states; and 3.8 per cent are from Territories and foreign countries. Twenty-six states, Hawaii, and the Canal Zone, and four foreign countries, are represented. These figures show an increase over last year in the number coming from states other than California and from foreign countries.

Respectfully submitted,

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

THE DIRECTOR OF STUDENT HEALTH

To the President:

Continued progress has been made toward the improvement of the Student Health Center. The clinical laboratory has functioned to the great benefit of the student and employees. The Service League has helped in many ways in the operation of the Health Center, including gifts of funds for equipment and furnishings and the provision of special foods and reading material for Infirmary patients. 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 and we may add psychiatric and dental attention to our services.

Respectfully submitted,

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

THE DIRECTOR OF LIBRARIES

To the President:

Acquisitions for the year 1950-51 and a summary of holdings are as follows:

	Total 1949-50	*Added 1950-51*	*Total 1950-51*
Books	47,631	3,533	51,164
Periodicals	28,121	2,312	30,433
	75,752	5,845	81,597

In addition to single volumes presented by numerous donors, the Library gratefully acknowledges gifts of books from Mr. G. P. Klaas, Mr. and Mrs. Frederick Springer, and the Mount Wilson Observatory. The books from Mr. and Mrs. Springer were part of the library of their son Richard, class of 1951, who died shortly before Commencement. Books from the Observatory, numbering 20, were part of the Hale Collection. The Scott Fund, established last year in memory of Oliver B. Scott, enabled the Division of Biology to purchase eight valuable books for their collection.

The Library has subscribed to three noteworthy works of general interest, *The Papers of Thomas Jefferson* edited by Julian Boyd, *The Letters of Theodore Roosevelt* edited by Elting E. Morrison, and *The Great Soviet Encyclopedia*. Each of these works is being published serially.

The Catalog Department, in addition to cataloging 542 books more than were cataloged last year, is making steady progress with the long, slow process of revising the catalog. As the result of excellent team work and close coordination of the numerous processes which comprise cataloging, many new books clear the department the same day they arrive; and all acquisitions find their way to the shelves much faster than ever before. Gradually, the books in the mathematics and engineering collections are being supplied with pockets and circulation cards. Thanks to an appropriation from the Department of Physics, it has been possible to have reclassified approximately 2,400 volumes in the Physics Library and to supply each one with a pocket and circulation card.

The Periodicals Department this year acquired 1,264 fewer bound volumes than last year, when a spectacular number of long-standing gaps were filled. To fill remaining gaps—many of them single issues and volumes—is requiring time-consuming search. High prices also are retarding the buying program, although patient shopping offers rewards. At the same time that new material is being acquired unwanted material is being weeded out and offered for sale or trade. The Department has reshelved all periodicals in mathematics and

engineering, removed little-used runs to basement storage, and has posted visible indexes to help patrons locate titles in both collections. About mid-year, the Periodicals and Catalog Departments, working jointly, completed a union catalog of all periodical holdings. It is difficult to exaggerate the usefulness of this new catalog.

The Order Department has increased its efficiency by concentrating book orders with two firms—one specializing in scientific, the other in general subjects—and by adopting a specially-designed, multiple-order form, which reduces eleven typing operations to a single one. The reduction is distributed among three departments—Central Accounting, and the Library's Order and Cataloging Departments, although the latter benefits most. The setting up of an active closed-orders file is another innovation which has increased the efficiency of the department.

Until 1948-49, no count ever had been kept of Inter-Library Loans, but it became clear in 1949 that the Institute was lending more books than ever before. The number has been mounting steadily; 812 in 1948-49, 893 in 1949-50, and 1,181 in 1950-51. The largest borrower is the Jet Propulsion Laboratory; second is the Pacific Aeronautical Library, which serves several of the Industrial Associates; third is the Naval Ordnance Test Station. The Institute, in its turn, has borrowed from other libraries during the past three years an average of 500 volumes annually.

Within the year, the Library has either initiated or participated in several special projects. Brief comment on each appears below.

As part of the archival function of the Library, a new plan went into effect January first whereby the Library maintains a Central Publications File, listing all books and papers published by members of the Institute Staff. This Central File becomes the official source of information for a bibliography of staff publications prepared quarterly as a service to the Industrial Associates who find it useful to keep abreast of current research at the Institute. Incidentally, the Library offers the Industrial Associates the same privileges and services it extends to faculty and students.

The Institute this year became an Institutional Member of the Special Libraries Association. With other members of the Los Angeles Chapter, the Institute Library is cooperating on a project to create a union list of all periodicals held by special libraries in Southern California, and has submitted to the project, on cards, a list of all its periodical holdings. The Special Libraries' Union List, also on cards, is now almost completed, and a set is on file in the General Library, where it will expedite the periodicals service, especially to Faculty and Industrial Associates. Frequent revision by all participants will keep the Union List up to date.

The Library has prepared a new edition of *Instructions and Suggestions for the Preparation of All Graduate Theses.* The Librarian continues to act as consultant to graduate students who request information about format, about presentation of unusual material, or about other technical details.

In collaboration with the department of mathematics, the Library has assisted in setting up a periodicals exchange program. As a sponsor of the new *Pacific Journal of Mathematics,* the California Institute receives, free, copies of each issue for the purpose of exchange. Thus, in effect, the Library will acquire runs of several desired foreign journals in mathematics, subscription free.

The Office of Naval Research is publishing on microcards, and on an experimental basis, all unclassified reports on sponsored research for the period January-June, 1951. The Library is receiving many of these reports, which have been requested by the Guggenheim Laboratory and the Division of Biology. A rented microcard reader is installed in the Aeronautics Library for the convenience of patrons.

In the year to come, the Library proposes to offer again for students a course on library uses and to solicit a wider response to fill an acknowledged need. Work will continue upon the revision of the catalog, the weeding out of unwanted material, and upon the collection of data for a program for a new library.

Respectfully submitted,

ROGER STANTON, *Director of Libraries*

THE DIRECTOR OF ATHLETICS AND PHYSICAL EDUCATION

To the President:

An increased interest was evident in the athletic and physical education program during 1950-51, as 67 per cent of the undergraduate enrollment entered in to some phase of the intercollegiate or intramural program. This represents an increase of 9 per cent in participation over the preceding year and has been exceeded only by two pre-war years. The record of the freshman class was particularly outstanding. Seventy per cent of the class entered into competition, while 54 per cent of the class represented the Institute in intercollegiate contests. Of the 159 members of the 1951 graduating class, 44 per cent played on intercollegiate teams during their undergraduate days, and 28 per cent of the class won varsity letters.

With a full and competent staff, the Institute policy of three periods of supervised physical training reached a new post-war peak this year. The only persons excused from the required training were those over 24 years of age or those who, because of some physical impairment, were unable to pursue the required work. During 1950-51 only 14 per cent of the students were excused, compared with 34 per cent the preceding year, when war veterans also were excused.

The Institute is a member of the Southern Intercollegiate Athletic Conference together with Occidental, Pomona, Whittier and Chapman colleges, and the University of Redlands. This small, compact conference enjoys a national reputation for high standards in competition and sportsmanship, and is one where intercollegiate athletics is merely an adjunct of a well-balanced collegiate education.

A regular varsity and freshman conference program is carried on in football, basketball, baseball, track, tennis, swimming, golf and cross country. The Institute also sponsors teams in soccer, water polo and skiing; and contests are scheduled with numerous non-conference schools. During the year, 121 varsity and 49 freshman contests were played with the five conference and 21 near-by non-conference schools.

As few of our students have ever competed in sports while in high school, most of those turning out for intercollegiate sports here are doing so for the first time. All men are encouraged to engage in sports as their time permits; no attempt is made to exclude the inexperienced; and a great period of practice sessions are devoted to individual instruction. While the rigorous academic schedule does not permit as much time for practice as is available at other schools, Institute teams nevertheless always make a creditable showing, and student interest in intercollegiate competition is high. While we do not win many championships, our teams are held in wholesome respect by all of our opponents, and we are proud of the records of our teams and the achievements of our players. This year the Varsity finished second in water polo, soccer, and cross country, and tied for second in baseball. Many individuals on these teams were recognized for their ability; and on the All-Conference teams selected by the Conference coaches three Institute men were selected in football, three in baseball, one in track, one in basketball and one in water polo.

During Commencement week, special recognition was given to the eleven seniors who had won three or more letters in one varsity sport. These were outstanding men, not only in athletics, but in student body and campus activities. Eight men were team captains, and five were members of Tau Beta Pi, honorary scholastic society.

The Wheaton Football trophy, awarded annually to the outstanding football player for achievement in scholarship, sportsmanship

and moral influence, was awarded to team co-Captain Dallas Peck, senior from Seattle, who not only was an inspirational leader and fine player, but also held the highest scholastic record ever attained by a football player at the Institute. Other awards include the Vesper Basketball Trophy to Norman Gray, junior from San Diego; Goldsworthy Track Award to Peter Mason, senior from Waterbury, Vermont; and the Alumni Baseball Trophy jointly awarded to Richard Karasawa, junior from Woodstock, Illinois, and team co-Captain Walter Pfeiffer, senior from Little Rock, Arkansas.

Fleming House for the ninth consecutive year won the Varsity Rating Trophy, which is presented annually to the Student House having the greatest number of men participating on intercollegiate teams. Fleming had 51 per cent of its membership on these teams.

A strong intramural program supplements the intercollegiate program, and offers competition to all students who are not on the intercollegiate squads. Regular contests are scheduled throughout the year in baseball, cross country, basketball, tennis, softball, track, swimming, touch football and volleyball. This provides an opportunity for the less skilled and experienced men to participate and develop. Teams representing the four Student Houses and Throop Club (the latter composed of students who do not live on the campus) played 65 contests in which 55 per cent of the undergraduate enrollment participated—an increase of nine per cent over last year. The Intramural Trophy, awarded annually to the house accumulating the most points for the year in the nine-sport program, was won by Throop Club. The honors had previously been won by Fleming House for 14 consecutive years.

During the winter, two new concrete tennis courts were built at the Athletic Field, supplementing the six existing asphalt courts. This much needed addition was received with much enthusiasm by the great number of students who use the courts daily for instruction and practice.

The Alumni are making steady progress in their fund-raising program for the construction of a swimming pool and gymnasium on the Athletic Field. During the year, cash contributions amounting to $19,203 were received, bringing the total to $84,577. Included in this is a $500 contribution from the 1951 graduating class, which matches contributions of the 1949 and 1950 classes. Plans are now being drawn for the pool and dressing quarters to be constructed as soon as finances and governmental restrictions permit.

Respectfully submitted,

H. Z. MUSSELMAN, *Director, Athletics and Physical Education*

THE DIRECTOR OF PLACEMENTS

To the President:

The year 1950-51 has been one of great activity in all phases of placement. The shortage of engineers and scientists and the tremendous demand of industry and government for personnel have created a serious problem. Moreover, the confusion in the minds of students resulting from the uncertain Selective Service policy has further complicated the situation.

To counteract the confused state of mind of students, most industrial and government organizations gave assurance of their serious need for engineers and scientists and their policy of considering men for employment regardless of Selective Service or reserve status. These firms or agencies held to their stated policy and made definite offers to students. It is expected that a large portion of these men will be deferred because of the character of work in which they are employed. The future supply of engineers and scientists will be inadequate for the demand of even normal peacetime activities for several years.

The number of organizations who sent representatives to the campus to interview men receiving degrees increased about fifty per cent over the preceding year. About sixty per cent of the B.S. and M.S. graduates who accepted employment were placed through the campus interviews. These contacts between industry and government agencies and the Institute are of great value. The faculty are extremely cooperative in assisting the interviewers to evaluate students in terms of their demands.

In spite of the great employment opportunities, forty-five per cent of the men receiving B.S. degrees in June 1951 expect to continue their education in graduate schools. A smaller proportion of those who received the M.S. and engineer's degrees expect to continue graduate work. The balance of the group are employed in a wide variety of organizations. The men with B.S. degrees are mostly employed with industrial organizations, while a larger proportion of the men with higher degrees are employed with research institutes and laboratories.

With students deferred from draft to permit continuance of their education, the hope was expressed that as many students as possible should take work for the summer with organizations engaged in defense operations. A special committee of the faculty made a survey of the past experience of the students in summer work. The survey showed that the students had held summer positions of a varied character. The committee urged students to work during the sum-

mer and requested the Placement Office to give every possible assistance. Hence, the Placement Office gave special attention to the summer placement problem. By 1 July, practically all students who indicated a desire for summer work had obtained employment.

During the past year, many students were assisted in procuring part-time work to help pay their college expenses. More calls for men to fill part-time jobs were received than the number of men registered with the Placement Office. This indicates that all students who required assistance were cared for.

The demand for alumni during the year 1950-51 was approximately three times the demand of the previous year, while the number of alumni who applied for placement assistance was about fifty per cent of the number who applied in the preceding year. Beyond a doubt, this demand will continue for some time.

The importance of placement activities as a part of the Institute program should not be overlooked. In many cases, contact between alumni and the Institute is maintained through the Placement Office. Therefore, every effort is made to give alumni the most effective service possible as far as present facilities will permit.

Respectfully submitted,

DONALD S. CLARK, *Director of Placements*

Part IV

REPORTS OF THE DIVISIONS

THE DIVISION OF BIOLOGY

To the President:

The year 1950-1951 has been one of gratifying progress for the Division of Biology. In collaboration with the Division of Chemistry, the joint Chemistry-Biology Program has been substantially advanced, particularly with respect to our understanding of the chemical and biological properties of proteins and related highly specific large molecules.

The range of activities within the Division of Biology has been great—involving, for example, the day-to-day chore of providing facilities for some four-score researchers; the preparation of requests for research grants; the reporting of progress from time to time to some two dozen research-sponsoring agencies; the building of equipment, such as an automatic machine for determining the radioactivity of a hundred samples; and the pursuit of varied research programs, such as a determination of the chemical nature of Los Angeles smog and its influence on plant growth and development, and studies on the mechanism of gene action.

During 1950-51 the activities of the Division were carried on by a staff of 12 professors, 3 visiting professors, 9 research associates, 7 associate professors, 9 senior research fellows, 57 research fellows, 32 graduate fellows and assistants, 9 graduate students and 132 non-academic personnel in offices, laboratories, library, stockroom, shops, greenhouses, gardens, marine station, animal annex, etc.

Several staff members received awards or honors:

Arthur W. Galston was promoted from Senior Research Fellow to Associate Professor.

Albert Tyler was awarded a special Guggenheim Foundation Fellowship for two years for work on the nature of fertilization in marine eggs.

Sterling Emerson was awarded a Guggenheim Foundation Fellowship and Fulbright Travel Fellowship for work in Cambridge University.

Alfred H. Sturtevant was named Thomas Hunt Morgan Professor

of Biology at the Institute and was awarded an Sc.D. degree by Yale University.

Bernard Axelrod was given the Superior Service Award by the United States Department of Agriculture.

Philip S. Thayer received the Thomas Hunt Morgan Award for 1951.

George W. Beadle received a Lasker Award for 1951 and was given the R. E. Dyer Lectureship Award of the National Institutes of Health.

James Bonner completed a monographic book on plant biochemistry and was elected Fellow of the American Camellia Society.

FELLOWSHIPS AND SCHOLARSHIPS

Gosney Fellowships. The following held Institute Gosney Fellowship appointments:

Joseph Lein, Syracuse University, research on chemical genetics.

Thomas C. Nelson, Columbia University, research on bacterial genetics.

Warren P. Spencer, College of Wooster, research on drosophila genetics.

Tsuneo Y. Tanabe, Pennsylvania State College, research on physiology and metabolism of spermatozoa and ova.

Marguerite M. Vogt, Institute for Brain Research, Neustadt, Germany, research on bacterial virology.

Katerina Zarudnaya, University of Missouri, research on genetics of maize anthocyanins.

McCallum Foundation—Nutrition Foundation Fellowships. The first McCallum Predoctoral Fellowship, established by the McCallum Foundation through the Nutrition Foundation, was awarded to Mr. George L. Ellman, a graduate student working for a Ph.D. degree in chemistry with Professor Mitchell. During the past year a second McCallum Fellowship was established. This has been awarded to Mr. Bruce Holloway of the Waite Agricultural Research Institute, Adelaide, Australia, who is working for a Ph.D. degree in chemical genetics.

McCallum Foundation Summer Scholarships. For a long time the Division has felt a need for scholarship funds for the support of graduate students who desire to spend summers working on their thesis research programs. Institute policy encourages this by providing tuition-free registration privileges for graduate students during summer periods when there is no regular academic session. Mr.

and Mrs. Arthur McCallum appreciated the need for such summer scholarship support and generously established a fund for an experimental program for the summer of 1951. Some 15 graduate students were awarded McCallum Summer Scholarships under this program. The usual award is $100 per month for the three-month summer period. It is already clear to both faculty members and graduate students that these unique scholarships are meeting a real need.

Lucy Mason Clark Fellowship in Plant Physiology. This fellowship, established in 1949, was held during 1950-1951 by Mr. James L. Liverman, who is working for a Ph.D. degree with Professor Went.

Pioneer Hi-Bred Fellowship. Established in 1947, this predoctoral fellowship was held for the fourth year by Mr. Earl Patterson.

DuPont Fellowship. For some time the E. I. DuPont de Nemours and Company has supported predoctoral fellowships in chemistry and physics in a number of leading American universities. For the first time, here or elsewhere, one of these highly desirable fellowships has been made available in the field of biology. Mr. Paul Saltman has been awarded this fellowship. He is working in plant biochemistry with the Bonner group.

Seeley W. Mudd Scholarship. For several years, Doctor Seeley G. Mudd has made available funds for a tuition scholarship to be awarded to a third or fourth year undergraduate interested in some phase of medicine. During the past year this fellowship was held by a junior in the Chemistry Option, Mr. Milo Webber. Mr. Webber will be a member of the first class in the new medical school at U.C.L.A. and began there in the fall.

Other Fellowship Appointments. In addition to the fellowship appointments listed above there are a number of research workers who hold the title Senior Research Fellow or Research Fellow whose stipends come from grants made to the Institute in support of an area of research rather than specifically for a fellowship.

During the year 1950-1951, nine men held predoctoral fellowships awarded by an agency operating outside the Institute, usually on a national basis. These were distributed as follows:

Atomic Energy Commission Fellowships	2
Atomic Energy Commission Fellowships administered by National Research Council	4
Commonwealth Scientific and Industrial Research Organization Fellowship	1
National Institutes of Health Fellowship	1
Smith-Mundt Fellowship	1

Twelve persons held nationally awarded postdoctoral fellowships during the period. These were distributed as follows:

American Cancer Society Fellows	3
Commonwealth Fund Fellows	2
John Simon Guggenheim Memorial Foundation Fellow	1
Lalor Foundation Fellow	1
Rockefeller Foundation Fellow	1
Rose Sidgewick Memorial Fellow	1
United States Public Health Service Fellows	3

In connection with nationally awarded postdoctoral fellowships, Roderick K. Clayton and Philip S. Thayer were awarded Merck Postdoctoral Fellowships. Dr. Clayton, who completed his Ph.D. work in June, will spend a year at the Hopkins Marine Station, while Mr. Thayer, who completed his Ph.D. work in September, will work with Doctor Michael Doudoroff at the University of California, Berkeley.

THE MORGAN MEMORIAL PLAQUE

During the year Professor Albert Stewart of Scripps College completed the Thomas Hunt Morgan Plaque. A simple dedication ceremony was held in the Kerckhoff Memorial Library on February 23. At the same time President DuBridge announced the appointment of Professor Sturtevant as Thomas Hunt Morgan Professor of Biology and also presented the 1951 Thomas Hunt Morgan Award to Phillip S. Thayer. The Morgan Award is presented annually to a graduate student finishing work for the Ph.D. degree. A sum of $100 is a part of this award.

VISITING LECTURERS

During the year 19 seminars were given by visiting lecturers. In many instances travel assistance was provided by the Eversole Lecture Fund.

In March Doctor George Marmont of the University of Chicago gave a series of four lectures at the Institute on modern concepts of nerve impulse transmission. This series was sponsored by the Hixon Fund. It is hoped that these lectures will soon be ready for publication.

In April Professor Stephen W. Kuffler of Johns Hopkins University presented two lectures on neurophysiology under the sponsorship of the Hixon Fund.

RESEARCH ACTIVITIES

During the year under review researchers in the Division of Biology worked with their collaborators and assistants on 126 specific research projects. It is obvious that all of these cannot be mentioned, even by title. The interested reader is referred to the technical papers in which research results are described in detail (lists of publications of the staff are presented in a separate report) or to a detailed printed report of research activities of the Division for 1950-1951.

It is of interest to note that a number of the researches of Division staff members bear more or less directly on the cancer problem. The Laurabelle Arms Robinson Fund and two specific grants from the American Cancer Society were used in support of work in this category. It should be emphasized, as it has been in previous reports, that much of the work of the Division that bears on cancer could not be done were it not for the Laurabelle Arms Robinson Fund, which has made possible the establishment and maintenance of faculty positions in such fields as biochemistry, genetics, embryology, physiology, bio-organic chemistry, biophysics and virology.

A number of research projects are concerned with virology. These have to do with viruses that attack bacteria, higher plants, and animals. The James G. Boswell Foundation Fund for Virus Research has made possible a development at the Institute of especial interest in the field of animal virology. This involves an attempt by Dulbecco and associates to develop a new type of animal assay fashioned after the now classical plaque count assay technique widely used in bacterial virology. In order to obtain desired background and the best available advice on this project Dulbecco spent two months during the early part of 1951 on a trip to various animal virus and tissue culture laboratories. Since his return active work has been under way with the virus of equine encephalomyelitis in a newly equipped and modernized virus-tissue culture laboratory suite.

FUTURE NEEDS OF THE DIVISION

In addition to the need for additional funds for the support of research, the cost of which steadily increases from year to year, several other developments are planned for the future. Additional physical space for activities carried on as a part of the joint Chemistry-Biology Program is a continuing need. An active campaign of rehabilitation and modernization of laboratories and other existing facilities has been carried on and is being continued.

Proposed Plant Research Center. At the present time plant research in the Division is carried on in four physically separated sites,

viz., the Earhart, Clark and Dolk laboratories, the Arcadia Farm, the Orlando Road Greenhouse, and the main Kerckhoff Building. It is hoped that within the next several years a research center can be developed at the Earhart-Clark-Dolk site which will permit consolidation of much of the plant work. Such a center would clearly make for more effective and efficient use of both physical facilities and manpower. In addition, it would greatly help staff members with interests at the several sites in their various collaborative research efforts.

The development of such a plant research center would require that additional greenhouse facilities be made available at the Earhart-Clark-Dolk site to replace those at the farm and at Orlando. Smog damage is a serious problem at the Orlando Road and Dolk Greenhouses and could easily become one at the Arcadia Farm if it were necessary to grow plants other than corn there. A consolidated greenhouse group would make feasible the installation of a smog-removing filter system that would serve both the Dolk Greenhouse and the additional greenhouse and laboratory.

In addition to greenhouse facilities, space for the out-of-door growing of experimental plants is essential for the proposed development. It is hoped that eventually a small area of land can be acquired for this purpose.

Respectfully submitted,

G. W. BEADLE, *Chairman, Division of Biology*

THE DIVISION OF CHEMISTRY AND CHEMICAL ENGINEERING

To the President:

CHEMISTRY

Members of the staff of the Division of Chemistry and Chemical Engineering and their research associates and students have continued their work in many fields of chemistry. Fundamental progress has been made in inorganic chemistry, analytical chemistry, physical chemistry, and organic chemistry. Especially significant, as in recent previous years, have been the contributions to immunochemistry, medical chemistry, and other fields closely related to biology, that constitute a part of the joint program in biology and chemistry that was initiated at the California Institute several years ago.

Professor Zechmeister and his collaborators have continued their investigation of carotenoids and other substances related to vitamin A. They have also made the striking discovery that some barnacles contain strongly fluorescent substances, which have been identified as polycyclic aromatic hydrocarbons. One fraction of this material was found to be strongly carcinogenic in mice. The significance of this work to the cancer problem is being investigated.

A penetrating investigation of the nature of enzymes is being carried out by Professor Carl Niemann and a large group of associates. This study has involved especially the enzymes that are responsible for the breakdown of proteins into amino acids, in the animal body. The principal method of attack is the very careful quantitative study of the rate at which the enzymes act on pure simple substances; the proteins themselves are so complex that it is difficult to interpret observations made on the decomposition of proteins by enzymes. The goal of these investigations is the discovery of the mechanism of action of enzymes, in relation to their structure. Dr. J. B. Koepfli and Mr. Robert E. Phillips have continued their study of alkaloids febrifugine and isofebrifugine, that were isolated by Dr. Koepfli a few years ago from a Chinese drug. These alkaloids have a very strong anti-malarial effect, and their continued investigation may yield important results in connection with the malaria problem.

Investigations in other fields of organic chemistry have also been carried out by the workers in the laboratory. Dr. E. R. Buchman and his associates have continued their work on compounds containing rings of three carbon atoms or four carbon atoms. A very striking result of their work is the synthesis of the compound tetraspirohexadecane. The molecule of this substance consists of a string of five squares in which each of the three intermediate squares shares opposite corners with its neighbors. Professor H. J. Lucas and his students have continued work on the mechanism of organic reactions, and especially on the reactions between unsaturated compounds and silver ion. It has been recognized for some time that the carcinogenic activity of unsaturated hydrocarbons can be correlated in an empirical way with the amount of double-bond character of some of the carbon-carbon bonds in the molecules. The formation of compounds with silver ion is also expected to be determined by the amount of double-bond character, and accordingly Professor Lucas is looking for a possible new experimental test of carcinogenic activity of these substances, through their reaction with silver ion.

During the period 1942 to 1946 a search was made by Professor Dan H. Campbell, Professor Linus Pauling, Dr. J. B. Koepfli, and

their associates for a substance that could be made in large quantity that would be satisfactory as a substitute for human plasma for transfusions. A material was developed, made by chemical treatment of gelatin with glyoxal and hydrogen peroxide, and given the name Oxypolygelatin. Clinical tests of the material have indicated that it may be the most satisfactory plasma substitute now known. Extensive clinical investigations are under way at the present time, mainly by the armed forces. Because of the possibly great importance of a plasma substitute, the renewed inestigation of Oxypolygelatin was undertaken a year ago by Professor Dan H. Campbell, Dr. J. R. Vinograd, and Dr. I. S. Bengelsdorf. This investigation involves a search for improvements in the process of manufacturing Oxypolygelatin and in the product itself, and a study of the nature of the chemical reactions involved. Because of the great practical importance of this investigation, it is planned that it be continued with much vigor.

About 15 years ago Professors Linus Pauling and Robert B. Corey began a long-range attack on the problem of the structure of proteins. The molecules of proteins are long chains of amino acids held together by peptide bonds. There are two problems in determining the structure of proteins: that of finding the sequence of amino acids (about 24 kinds are known to occur) in the polypeptide chain, which may contain several hundred amino acid residues; and that of finding the way in which the polypeptide chain is coiled in space. Professors Pauling and Corey proposed that the problem be attacked from beneath—by determining the structures of amino acids, simple peptides, and other simple substances closely related to proteins, by the X-ray diffraction method. This work has been carried on during the past 15 years. In continuation of it, Professor Corey, Dr. Jerry Donohue, Dr. David P. Shoemaker, Professor Verner Schomaker, and their collaborators have during the past year made a complete determination of the structure of hydroxy-L-proline, DL-serine, *a*-glycyl-glycine, and some other substances. The interatomic distances, bond angles, and other structural features found in these crystals and in those that had been investigated earlier were then used by Professors Pauling and Corey for the formulation of a number of acceptable ways of coiling the polypeptide chain—it was also shown that all of the polypeptide-chain configurations that had previously been suggested were incompatible with the new results. Strong evidence for the presence of these configurations in synthetic polypeptides and in natural proteins, such as hair, muscle, and tendon, was found to be provided by the X-ray diffraction photographs of the synthetic polypeptides and proteins themselves.

Many other investigations dealing with the general problem of the structure of proteins have been carried out during the last year. Dr. Walter A. Schroeder and Dr. F. Charlotte Green, and their associates, have attacked the problem of determining the order of amino acid residues in the polypeptide chain. They have developed a new and rapid method for chromatographic separation of the dinitrophenylamino acids, designed to isolate and identify the terminal amino acid residues in proteins and peptides. So far it has been found that the terminal amino acid in the polypeptide chain of the protein lysozyme, a constituent of tears and of egg whites, is lysine, and that the adjacent amino acids are valine, phenylalanine, and glycine, in that order.

Professor Richard M. Badger has continued his spectrographic studies in the infra-red region of the spectrum, with special attention to substances related to proteins. With use of a reflecting microscope attached to the infra-red spectrograph, he has investigated the spectrum of N-acetylglycine and diketopiperazine, substances closely related to protein, in order to get information that can be used in the interpretation of the infra-red spectrum of proteins themselves. He has also continued his fundamental spectroscopic studies of simple polyatomic molecules. The apparatus for the fractionation of proteins by electrophoresis-convection invented by Professor J. G. Kirkwood has been applied by him and his collaborators in the fractionation of human immune gamma-globulin and other protein materials.

A number of investigations of hemoglobin in relation to disease in human beings has been carried out by several young medical doctors who are associated with the Division of Chemistry and Chemical Engineering. Dr. Harvey Itano, who last year discovered a second abnormal form of human hemoglobin, associated with a new disease that had not previously been recognized as a clinical entity, has now discovered a third abnormal form of hemoglobin. This third abnormal form of hemoglobin is also associated with a new disease. In this work Dr. Itano collaborated with Dr. J. V. Neel of the Medical School of the University of Michigan. Dr. Alexander Rich has studied the disease called Mediterranean anemia, and has found that the hemoglobin in patients with this disease is so closely similar in its properties to normal human hemoglobin that it cannot yet be stated with definiteness whether or not the disease is a disease involving the hemoglobin molecule. Dr. Hans Zinsser has carried out during the past year an investigation of the properties of human fetal hemoglobin. Further light on the structure of the normal hemoglobin

molecule was also provided by the investigation of Dr. R. C. C. St. George and Professor Linus Pauling of the combination of hemoglobin with alkyl isocyanides.

Since 1930 one of the principal fields of research in our laboratories has been the determination of the structure of the gas molecules by the electron-diffraction method. Work in this field has been continued during the past year by Professor Verner Schomaker, Dr. Kenneth Hedberg, and a large number of collaborators. Among the many substances whose structures have been determined perhaps the most interesting are the hydrides of boron. The molecules of these substances do not conform in their composition to simple valence theory, and their structures are found to have several extraordinary features. The molecule of pentaborane has five boron atoms that are at the corners of a square pyramid, with bonds formed along the edges of the pyramid. In this molecule, as in other boron hydrites, some of the hydrogen atoms are held jointly by two boron atoms.

Professor Ernest H. Swift and his students have continued their investigations of new methods of chemical analysis. They have studied especially a method of determining the amounts of substances in a sample by measuring the amount of electric current necessary to cause a certain reaction to proceed to completion. These methods of coulometric and amperometric analysis promise to be of great importance in the future.

Professor Norman Davidson and his students have investigated the mechanism of inorganic reactions in solution, and the kinetics of reactions that take place in extremely short times. They have been able to follow the process of recombination of iodine atoms to iodine molecules during a period of the order of one-thousandth of a second.

Dr. Oliver Wulf, a member of the United States Weather Bureau working in the Division of Chemistry and Chemical Engineering at the California Institute, has continued his investigations of the measurement of atmospheric ozone in the upper atmosphere, and the relation between solar activity, the transient variations of the earth's magnetic field, and the large-scale circulation of the atmosphere.

Work on the problem of structure of metals has been continued by Professor Linus Pauling and his collaborators. Determinations of the structure of a number of alloys have been made. The most important investigation carried out during the past year was the determination of the crystal structure of the sigma phase, by Dr. David P. Shoemaker and Dr. B. Gunnar Bergmann. The sigma phase is a

very important phase that occurs in the stainless steels and other alloys. It is characterized by unusual brittleness, and its presence in stainless steel is ordinarily undesirable. For 25 years investigators have attempted to determine the structure of this phase, but without success. Until the work of Dr. Shoemaker and Dr. Bergmann was carried out, it had not been known with certainty that the crystals belonged to the tetragonal system. By making use of minute single crystals that were separated from a preparation of the single phase provided by Professor Duwez, the investigators have succeeded in showing that there are thirty atoms in the unit of structure and have determined the positions of all of these atoms. The structure is an extraordinary one in that it involves the interpretation of two slightly distorted hexagonal lattices, to give tetragonal structure. Work on the structure of intermetallic compounds and other alloys is being continued, with the goal of developing a sound structural theory of the mechanical properties of alloys.

CHEMICAL ENGINEERING

Work in chemical engineering has been carried out on fundamental problems that are important to various fields of engineering, including petroleum engineering.

Dean W. N. Lacey and Professor D. H. Sage and their assistants and students have continued their studies of the volumetric and phase behavior of fluids. This work has included the study of binary mixtures of hydrogen sulfide with propane, water, and pentane and mixtures of methane, n-butane, and decane at pressures up to 10,000 lb. per square inch. Studies of the phase behavior of the hydrogen-propane system and of mixtures of nitrogen dioxide and nitric oxide have also been made.

Professor Sage, Dr. W. G. Schlinger and their collaborators have investigated the processes of transfer of heat and of material between phases. The principal investigations during the past years have related to conductivity due to eddies in a uniform air stream, and also the viscosity due to eddies. Dean Lacey, Professor Sage, Dr. D. M. Mason, and their colleagues have investigated the combustion of natural gas and air under turbulent conditions, the behavior of red and white fuming nitric acid, and other problems, especially of importance to the Jet Propulsion Laboratory.

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 the move into the new Engineering Building of civil engineering, mechanical engineering and applied mechanics was completed, and the consequent shift of some electrical engineering facilities into a portion of the space vacated in Throop Hall was made. As a part of these moves a Servo-Mechanisms Laboratory was created for electrical engineering instruction and research, a facility which helps to integrate some of the basic concepts of electrical engineering and mechanics.

This year has also been of note as the first year of complete operation of the Daniel and Florence Guggenheim Jet Propulsion Center with the full complement of Guggenheim Fellows and research at the three levels of graduate work. The Center has fitted very effectively into both the instruction and research work of the Engineering Division. The students registered in aeronautics and in mechanical engineering under the Jet Propulsion Option have done thesis research which has pleased both departments.

This year the Division of Engineering was pleased to have as visiting lecturers Dr. R. M. Bozarth of the Bell Telephone Laboratories, who gave a series of talks on the theory of ferro-magnetism; Professor Raymund Sänger of the Swiss Federal Technical Institute, who lectured and continued his research on problems of exterior ballistics and rocket flight; Professor J. M. Burgers of Delft, Holland, who lectured on the subject of turbulence and diffusion and aided greatly in the theoretical work of the Hydrodynamics Laboratory; and Professor Sydney Chapman of Oxford, England, who completed his residence here in charge of the program of upper atmosphere research which was sponsored at the Institute by the U.S. Army Signal Corps.

AERONAUTICS*

The post-graduate enrollment in the department has remained at approximately 90 students, of whom over two-thirds were candidates for the professional or doctorate degree.

The Navy and Air Force again sent a considerable number of officers for post-graduate training. Many of the theses of both civilian and military students were based upon investigations carried out under the various research programs outlined below.

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

RESEARCH ACTIVITIES

(1) *Experimental Fluid Mechanics.* The two long-range programs in this field, which have been pursued for some years, were further advanced. Under the direction of Dr. H. Liepmann direct measurements of skin friction in subsonic, transonic, and supersonic flow were made, and will be extended to higher supersonic speeds and to more complex flows than have hitherto been investigated. A very promising new approach to the turbulence problem was undertaken with considerable success. This involves a study of the development of a turbulent wake from the well-known Karman vortex street, and utilizes an electronic statistical analyzer designed and constructed during the past year. Both of these programs were carried out with financial support from the National Advisory Committee for Aeronautics.

(2) *Theoretical Fluid Mechanics.* The mathematical researches in this field have continued under the direction of Professor P. Lagerstrom, assisted by Professor J. D. Cole, with financial support from the Office of Naval Research. Solutions of the transonic flow equations for a wedge and a lifting flat plate have been obtained and compared with experiment. The fundamental nature of the boundary layer equations has been further explored, and the effects of viscosity have been included in studies of the linearized equations for a heat-conducting fluid. Several calculations were carried out giving the characteristics of practically important aerodynamic shapes in supersonic flow.

(3) *Hypersonic Flow.* The hypersonic wind tunnel has been in active operation under the direction of Dr. H. Nagamatsu. This project, supported by the Army Ordnance Department, has resulted in a number of reports dealing with the condensation or liquefaction of air at the extremely low temperatures which occur in flow at hypersonic Mach numbers (between 5 and 10), boundary layer and skin friction phenomena under these conditions of extreme speed, and flow disturbances originating at the throat of a hypersonic wind tunnel. Because of its interest in hypersonic tunnels the Air Force has recently joined the Army Ordnance Department in supporting this research program.

(4) *Elasticity and Aeronautical Structures.* The group in this field, under the direction of Dr. E. E. Sechler, has been strengthened by the appointment of Assistant Professors Y. C. Fung and M. L. Williams. The Air Force sponsored program on elastic problems of thin swept wings has continued to yield valuable results, as has the program on the factors underlying fatigue failure in materials of importance in aeronautics. A new investigation of low arch beams

and slightly curved shells has been initiated under sponsorship of the National Advisory Committee for Aeronautics. Increasing emphasis is being placed on the field of aeroelasticity, and the new Merrill Wind Tunnel is proving to be a useful tool in this connection. The Photoelasticity Laboratory has been reactivated and is now available for research investigations or special testing projects.

COOPERATIVE WIND TUNNEL

The national rearmament program has resulted in full capacity use of this facility by the aircraft industry and government agencies. A $6,000,000 modification program was authorized by the cooperating, owner aircraft companies, which will result in a capability for testing models at speeds well above the speed of sound. Engineering design is actively proceeding, and some major contracts have already been let. The modification is scheduled for completion by the end of 1953.

Respectfully submitted,

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

CIVIL ENGINEERING

The research program in civil engineering broadened in scope during the past year with the initiation by Professor McKee of a research project sponsored by the California State Water Pollution Control Board. This project is a study of the limiting and threshold concentration of substances in water which may affect its beneficial use. The study may otherwise be described as an investigation of water quality standards. Although the study is primarily a survey and statistical analysis, the need for further experimental investigations into some doubtful areas is already indicated.

For the U. S. Navy Bureau of Yards and Docks the earlier Institute work on soil compaction by vibration has been extended by Professor Converse to larger scale operations, including the design and construction of a suitable test machine. In order to help establish criteria for scale modelling of soil vibration effects, theoretical work has paralleled the field investigations.

The analysis of strong-motion earthquakes continued under Office of Naval Research sponsorship as a joint activity of civil engineering and the analog computer group. The Earthquake Engineering Research Institute sponsored with Professor Housner an experimental program which involved vibration measurements leading toward a determination of the ability of structures to resist shock loading.

Two additional dynamics investigations of unusual interest which were made by members of the staff were a study of stresses produced by a high velocity load travelling on a beam on an elastic foundation —a part of the design study for the long high-speed test track which is being constructed by the Naval Ordnance Test Station; and a study of the vibration induced by wind in the Trans-Arabian Pipe Line undertaken to establish the characteristics of such vibrations and the appropriate remedial measures to be taken.

Electrical Engineering

Research work by Professor Nichols in physical electronics continued with studies on the growth, surface structure and thermionic properties of single crystals of tungsten, tantalum and molybdenum. Single crystals of tantalum and molybdenum have been grown in sufficient size to study qualitatively the thermionic emission and surface structure. These were found to be similar in every way to tungsten, which also has body centered cubic structure. This indicates, among other things, that the anisotropy of thermionic and field emission from these metals is a surface rather than a volume effect. A quantitative study of the thermionic emission from single crystal tungsten is nearly completed. This work was sponsored by the Office of Naval Research.

For the past five years a basic research program on the dielectric recovery characteristics of power arcs has been conducted in the High Potential Research Laboratory under supervision of Professor McCann. This has been sponsored jointly by the Department of Water and Power of the City of Los Angeles, the Kelman Electric Company and the Southern California Edison Company, with funds supplied by them. The initial phases of this program have consisted of obtaining fundamental data on the rates at which air gaps recover after passing power currents of various magnitudes and duration. During the past year a satisfactory method has been developed for obtaining time resolved spectrographs of the arcs. Analysis of these is providing for the first time accurate records of the temperature-time characteristics of arcs in air. This is supplying an essential link between quantitative analysis of the arc mechanism and empirical data.

ANALYSIS LABORATORY

Significant developments during the past few years in the application of the Institute's electric analog computer to the aeroelastic problems of the aircraft industry have led to a greater demand for its use by outside agencies than could be handled by the Laboratory staff. For this reason it was decided last summer to conduct a sym-

posium to acquaint the aircraft industry and various government agencies with the general field of application of this device and to urge them to give consideration to the establishment of their own similar computing centers. During the past year decision has finally been reached by several of the aircraft companies in this area to set up such laboratories to relieve the load on the Institute installation and also to provide sufficient computer capacity in this area for the problems best suited to this type of computer. During this current summer, the staff of the Laboratory has conducted a ten weeks' extensive training course for the personnel who are to be associated with these laboratories. These developments will enable the Laboratory to devote more of its time to basic research projects. Several are currently in progress on aircraft structural problems and on basic research in aeroelasticity. One of these, sponsored by the NACA, is a $25,000 research contract on the stress distribution in short, thin wing structures. Another is a basic research project to correlate physical tests and analytical computations of aircraft flutter being undertaken jointly with the Douglas Aircraft Company and sponsored by the Bureau of Aeronautics. Several significant papers in this field have been published by the Laboratory staff during the year.

The Digital Computing Group has recently received a $10,000 grant from the Continental Oil Company for basic mathematical research by Professor Frankel on general methods of digital computing.

A basic study of free-flight test methods was conducted under contract with the Naval Air Missile Test Center at Point Mugu. This was handled jointly by the Digital Computing Group and the Analog Computing Group of the Analysis Laboratory. One of the most significant of these studies concerned the effect of missile elasticity on its aerodynamic performance. Hitherto, aerodynamic coefficients have been calculated from free flight measurements on the assumption of a rigid air frame and somewhat simplified aerodynamics. By means of the electric analog computer a general study was made to compare the solutions, for a wide range of missile configurations, using this simplified representation and one in which the missile is treated as an elastic beam with more complete representation of the aerodynamics including down wash effects. This study determined the range in which the more complete analysis is required and the significant errors introduced by the rigid body representation.

HYDRODYNAMICS

The work of the hydrodynamics laboratories was continued actively during this year with the support of several government agencies.

Experimental studies at the Azusa Laboratory on the passage of waves through a harbor entrance showed that diffraction theory can be applied to the problem to predict wave behavior in harbors. This result is of interest not only to the Navy Bureau of Yards and Docks, the sponsor of the work, but to many municipalities and private organizations concerned with waterfront development. Other investigations at Azusa have led to a promising approach to the problem of breakwater design, which is currently the subject of intensive investigation.

The work in the Hydrodynamics Laboratory under sponsorship of ONR and the Navy Bureau of Ordnance included studies of forces on submerged bodies under a wide range of conditions, flow in rotating hydraulic machinery, cavitation, and investigations of the hydrodynamics of a number of specific military devices. In this program the investigation of the modeling laws for entry of bodies from the air into the water was continued in the launching tank, and a number of studies were made in the free surface water tunnel of underwater cavities to determine the relation between the geometry of the cavity and the pressure, velocity, and shape of the obstacle forming the cavity. As an extension of the latter study, forces were measured on simple geometric shapes in contact with cavity walls and planing on a water surface.

Good progress was made on investigations of the effect of certain propulsion systems for underwater bodies on the flow around the propelled body and of the influence of body shape parameters on the drag of stable bodies. The problem of dynamic stability of free running bodies was studied in the water tunnel and by means of a new technique which employs a small free flying, powered model with program-controlled steering. Experiments in the launching tank demonstrated that such models closely reproduce the behavior of the full-scale objects they represent.

Contributions were made to the general field of rotating hydraulic machinery through studies of velocity distribution in the passages and pressure distribution on the vanes and passage walls of rotors. Studies of the dynamics of cavitation were also continued, and some preliminary investigations were made of the effect of the scale of a system on the cavitation produced in it.

The investigation of diffusion in turbulent flows was continued in the Sedimentation Laboratory under sponsorship of the Air Force. The experimental technique involves photographic observations of the motion of flow tracers similar to those used so successfully in studying flow in rotating machinery.

Mechanical Engineering

Research sponsored by the Office of Naval Research on the mechanism of yielding in every low-carbon steel was continued by Professors Clark and Wood with the assistance of graduate students. The investigations make use of rapid loading and impact techniques which are leading to fundamental concepts of the problem.

Metallurgical work, guided by Professor Duwez, concerned with phase transformations in titanium-base alloys as affected by rate of cooling, continues under the sponsorship of the Office of Naval Research. Experimental and theoretical studies have been initiated which pertain to the kinetics of the order-disorder reaction in metals. An accurate determination of the lattice parameter of titanium solid solutions is in progress. Equipment has been developed for the measurement of specific heat of alloys in connection with transformation studies.

Investigations of the reactions of combustible mixtures in contact with hot surfaces continue under the supervision of Professor Peter Kyropoulos. Spectroscopic studies of gas and diesel engine crank case oils are in the initial stages and give promise of interesting analyses of engine component wear.

A study of possible methods of utilizing radioactive tracer techniques in the study of galvanic corrosion and the study of alloy systems continues under the sponsorship of the A. O. Smith Corporation.

Investigations of flow in axial compressors have continued under the sponsorship of the Office of Naval Research. The work has been directed by Professor Rannie toward the understanding of the complexities of flow phenomena in various types of blading and the influence on efficiency and operating range of the machine.

Investigations have begun by Professor Sabersky on boiling heat transfer, which involves phenomena closely related to those of bubble formation in cavitating fluids—a subject which is receiving intensive study by the Hydrodynamics Laboratory staff.

Daniel and Florence Guggenheim Jet Propulsion Center

The Guggenheim Jet Propulsion Center had, during this, its second year of operation, a total of 30 graduate students, six of whom were Guggenheim Fellows. An active program of research in the basic problems of jet propulsion has supported the instructional work. The Center has operated under the guidance of Professor Tsien with the aid of Professors Marble and Penner.

Some of the problems studied are the spreading of a flame from the flame holder in a uniform air fuel mixture, theoretical and experi-

mental investigations; a simple but accurate method of computing the normal flame propagation velocity by a simplification of the complex chemical kinetics; methods of computing thermodynamic functions for various compounds at the extremely high temperature of rocket motors; film cooling in terms of the concept of a critical film thickness; a complete formulation of the problem of the flow of a compressible fluid through a turbo-machine of general configuration; optimum thrust programming of high altitude rockets; thermal stress studies leading to a parameter characterizing the important property of thermal shock resistance and specifying the desired physical characteristics of ceramic and ceramel materials for applications in jet propulsion. In addition, with support from the Office of Naval Research, a study has begun on theoretical calculation of gas emissivities to permit the prediction of radiant heat transfer at high temperatures.

Respectfully submitted,

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

THE DIVISION OF THE GEOLOGICAL SCIENCES

To the President:

Despite the stunning blow resulting from the sudden and unexpected death of its chairman, Professor Chester Stock, the Division of the Geological Sciences has in the past year moved vigorously forward in all phases of its teaching and research program. From the separate headings under which these phases are described below, it might appear that the Division's program is unusually and perhaps even unwarrantedly diverse. Such is actually not the case; each phase of the program integrates with and supports the others. The central theme is, of course, a better understanding of the earth, its structure, its mechanics, its history. For such investigations we are here most fortunately situated. We are within one of the most active seismic belts of the world; we are within easy range of several important and diverse structural and stratigraphic provinces: the Tertiary coast ranges, the Sierra igneous and metamorphic block, the Basin and Range province. Small wonder that this center has attracted an outstanding group of students of the earth sciences. Nor does the fact that these investigators are on occasion found far from Pasadena belie the statement that here is the focus of their interest. Thus, to cite only a few examples: the studies of Professor R. P. Sharp on present Alaskan glaciers will make possible more accurate interpretation of

past glaciations in the Sierra Nevada. The studies of mica deposits and of pegmatites in the Blue Ridge province of the southern Appalachians conducted by Professor R. H. Jahns afford opportunity for significant comparisons and deductions with respect to mica and pegmatite occurrences in the Southwest. The studies of Professor A. E. J. Engel on the talc deposits of Gouverneur, New York (the nation's number one producer), ultimately will aid in the more intelligent development of the talc deposits of southeastern California (the nation's number two producer).

Save for the loss of Professor Stock, changes in the staff have been few. In January Professor C. W. Merriam returned from a leave of absence to resume his work in paleontology; also in January Professor C. H. Dix returned from a leave to resume, on a part-time basis, his work in geophysics. In May Mr. William C. Oke was appointed Curator of Mineralogy.

National honors and professional recognition continue to come to members of the Division. In November, Professor Chester Stock was elected president of the Geological Society of America; in January, Mr. William C. Oke was elected president of the Mineralogical Society of Southern California; in April, Professor J. P. Buwalda was elected president of the Seismological Society of America; Professor C. W. Merriam was elected president of the Pacific Section of the Paleontological Society; and Professor Ian Campbell was elected chairman of the Cordilleran Section of the Geological Society of America. Mr. Donald R. Baker, graduate in the class of 1950, was awarded a Fulbright Fellowship for study in the year 1950-51 at the Mineralogical Institute of the University of Oslo, Norway.

The research program in the Division, notably that in the Seismological Laboratory, continues to attract scholars from many lands. During the past year temporary appointments as visiting research fellows in geophysics were given to Dr. Marcus Båth, of the Meteorological Observatory of the University of Upsala, Sweden; to Dr. Kazim Ergin, geophysicist of the M.T.A. Enstitüsü, Turkey; and to Dr. P. W. Gane, Seismological Officer of the University of Witwatersrand, South Africa. The three to six months' period spent here by each of these distinguished scholars has been enjoyable and profitable to them and stimulating to our staff and students.

The Summer Field Camp, for long one of the most significant elements in the teaching program and one which affords opportunity to start the more advanced students on research, was shifted this past year to the Sacramento Mountains of New Mexico. The location was chosen by Mr. L. C. Pray, who was in charge of instruction. Although somewhat farther away than the Zuni Mountain area, where the

camp was held for the two preceding seasons, the new location proved an excellent selection. In addition to superior exposures, the new area affords a greater range and variety of rock types and stratigraphic units as well as more challenging structural problems. In this area, moreover, are found some of the finest known exposed examples of limestone "reefs"—the curious structures only recently recognized as being of great importance in the accumulation of petroleum.

Dr. Chester Stock, Chairman of the Division since 1947 and Professor of Paleontology since 1926, died suddenly from a cerebral hemorrhage on the morning of December 7, 1950. He was 58. Only the night before he had attended a meeting of the Geology Club at the Institute and had seemed in his usual good health and spirits. A few days before he had returned to Pasadena after attending the annual meeting of The Geological Society of America, where he had been honored by election to its presidency. His loss was a severe blow to the Division and to the Institute, administratively and scientifically.

Inspired by the memory of Chester Stock's devotion to research, members of the staff have joined in numerous fruitful councils looking toward the best possible continuation of the Division program of research and teaching. Out of this has come recognition of a great need for developing the field of geochemistry. This field offers not only "the challenge of the new," but just as geophysics advantageously links us with physics, so geochemistry offers the opportunity of closer association with our sister science of chemistry. In order to evaluate these possibilities, Dr. Harrison Brown of the University of Chicago, one of the country's leading geochemists, was brought to the Institute in May for conferences and for a short series of lectures given under the joint auspices of the Divisions of Geology and Chemistry.*

GEOLOGY

In geology the work of the Division went forward on many fronts. Professor J. P. Buwalda continued his studies of two significant areas, the western Tehachapis and the Pasadena-Altadena quadrangle. Two of the major structural features of California, the San Andreas and the Garlock fault zones, converge within the Tehachapi Mountains, and the Pasadena-Altadena area has great local interest for scientists and engineers, particularly in relation to our ever-aggravated ground water situation.

Professor J. A. Noble, in addition to laboratory investigations which have resulted in improved techniques for identification of opaque

*In the early Fall of 1951, Dr. Brown accepted an appointment as Professor of Geochemistry at the California Institute.

minerals in polished section, has directed a field program in the mineralized area in the vicinity of the Tropico Mine near Rosamond, California. This small mine, the only operating metalliferous mine within easy driving distance of Pasadena, not only serves as an example to show students the relations between surface and sub-surface geology but is also a good example of a special type of precious metal mineralization well developed farther east in southeastern California and Nevada.

Professors Jahns, Engel and Campbell, together with several graduate students, have continued to give emphasis to many phases of the increasingly important field of the "industrial minerals." Professor Engel, in connection with his continuing study of the talc deposits of New York state, has developed a new understanding of the rocks of the Grenville Series. These are the oldest rocks recognizable in the earth's crust and are found over some 250,000 square miles of southeastern Canada and northern New York. A major by-product of this research has been the development of criteria for determining—largely by application of geochemical principles, based on such "trace elements" as cobalt, gold and scandium—the different antecedents, igneous or sedimentary, of the puzzling rock type known as amphibolite. Professor Jahns has completed a long term project on the mica deposits of the southeastern Piedmont region and has finished a report (with L. A. Wright) on the pegmatite deposits, important as a source of lithium and semi-precious gem stones, of the Pala district in southern California. He has also undertaken a study of lithium-bearing pegmatites in the Wickenburg area, Arizona. The opportunities Professor Jahns has had over a number of years for first-hand investigation of a wide variety of pegmatites ranging from Maine to California are now being turned toward a fundamental study of the origin of pegmaties. By application of fundamental geochemical concepts, in terms of the geometric and energy properties of atoms and ions, Professor Jahns has developed a hypothesis of pegmatite genesis which shows their essential consanguinity with "normal" igneous rocks, and by the same token he has developed criteria which permit their sharp distinction from hydrothermal veins, to which many previous investigators had linked the pegmatites.

Studies were completed during the year on California talc by Dr. L. A. Wright, and on the Palen Mountains gypsum deposits by Dr. R. A. Hoppin. Dr. Wright has shown that the talc deposits of California can be grouped into three major geographic categories, which then correlate with stratigraphic and structural relationships and with distinctive mineral associations. In one of these categories, the southern Death Valley association, he has demonstrated a unique stratigraphic and petrologic control which will greatly aid prospect-

ing and development of these important deposits. Dr. Hoppin's study on gypsum not only served to delimit the potential reserves of this widely used industrial mineral, but also brought together important structural and petrological information on a hitherto isolated and almost unknown area in the Mohave Desert.

With basic support from the U. S. Geological Survey, Dr. D. F. Hewett, Research Associate of the Division, continued vigorously to push many phases of the broad Mohave project which is aimed at increased knowledge of the vast unmapped areas of southeastern California. Detailed mapping, initiated a year and a half ago following the discoveries of bastnasite in the Mountain Pass area of San Bernardino County, and application of basic petro-chemical principles, have resulted in notable enlargement of the known reserves of cerium and other rare-earth elements in this area. At the same time Dr. Hewett has investigated all reported occurrences of radioactive minerals in the Mohave area and has made a start toward correlation of these occurrences with major rock distribution. Work was initiated during the year by Mr. W. R. Muehlberger, under the supervision of Dr. Hewett and Professor Jahns, on portions of the Garlock fault zone. This work will ultimately benefit the Tehachapi investigations of Professor Buwalda to the west and the studies in the Avawatz Mountains by Professor Engel and Jahns to the east.

Mr. L. C. Pray assisted in the bastnasite investigations. He also completed his monographic study of the Sacramento Mountains of New Mexico. This is an area of great stratigraphic importance, as well as one of considerable structural significance. It represents the easternmost and also one of the best exposed but hitherto least known of the "Block Fault Mountain Ranges" of the Basin and Range province.

Professor Jahns, in collaboration with Mr. William C. Miller of the Mount Wilson Observatory staff, completed a study of the Pinacate volcanic field in northern Sonora, Mexico. These investigations were directed primarily toward an understanding of the genesis of several large calderas, or deep but flat-floored depressions formed by sudden collapse, at the close of periods of intense volcanic action.

GEOMORPHOLOGY

Professor R. P. Sharp, assisted by several graduate students, carried on a wide ranging program in geomorphology. The glaciology program, initiated several years ago, was advanced by Mr. G. P. Rigsby's studies of crystallographic fabrics on Emmons Glacier, Mt. Rainier. Possibility of the existence of new slip planes was recognized in Mr. Rigsby's microscopic investigation. Supported by a grant from the

Southern California Edison Company, Mr. J. H. Birman initiated a program of detailed glacial mapping in and around Vermilion Valley in the central Sierra Nevada. He demonstrated a much more complex glacial sequence than was formerly suspected and obtained evidence of a possible third sub-stage of glacial activity within the Wisconsin, a heretofore unrecognized aspect of Sierran glaciation. Mr. R. L. Nelson began studies of the glacial geology of the Frying Pan drainage in central Colorado. His task is to reconcile the diverse glacial chronologies of the Rockies and the far western mountains.

Professor Sharp undertook a mapping program in the Trinity Alps of northern California. The objective here is to establish a Pleistocene glacial sequence which can be related to stream terraces and then carried down the Trinity and Klamath Rivers to the coast where it can be tied into the Pacific coastal terraces. If successful, this will be the first instance in which California Pleistocene coastal features have been related directly to the glacial succession.

Studies of the Kelso Dunes in the Mohave Desert are being conducted as a means of elucidating the dynamics and behavior of desert dunes. Also continued were Professor Sharp's studies on the Cima Dome. Geophysical studies aided by various members of the geophysical group have shown that this dome is of very different internal profile from that hypothecated by the late great geomorphologist William Morris Davis, and that the earlier ideas concerning the origin of desert domes are in need of drastic revision.

Professor J. P. Buwalda, incidental to other studies, has investigated the mode of transportation of the huge boulders, up to tens of feet in diameter, found on the surfaces of alluvial fans in the desert and occurring also in some of the older alluvial fan formations. It appears that in many cases, at least, they are not transported on the normal surface of the alluvian cones but in intrenched channels where water or mud of great depth or thickness could concentrate its horizontal force and buoyancy on the boulders.

GEOPHYSICS AND SEISMOLOGY

Instrument development under Professor Benioff has involved further modification of the capacity-transducer seismometer. In its present form the mechanical moving member is positioned between two fixed capacitor plates so that motion of the member produces capacity increments of opposite sign in the two condensers formed between the fixed and moving members. The recording equipment for use on the project sponsored by the Geophysics Research Division of the Cambridge Research Center, U. S. Air Force, has been placed in routine automatic operation with pendulum seismometers.

Results already obtained with a new vectorial seismograph indicate that it is an important tool for the study of seismic phenomena. A microbarograph with moving conductor electromagnetic transducer first developed by Professors Benioff and Gutenberg has been modified by Benioff and is now in continuous operation at the Seismological Laboratory.

Continuing the investigation of propagation of seismic waves in the core of the earth, Gutenberg has studied amplitudes and travel times of PKKP and P'P'. He has found that the energy spectrum for waves through the core differs from the corresponding spectrum for waves passing only through the mantle. The phenomena observed indicate a ratio of probably at least 1.7 for the densities inside and outside the outer core. In a further investigation on waves reflected at the core, Dr. Kazim Ergin found that the abnormal ratios of horizontal to vertical components reported previously result from the fact that the horizontal and vertical component maxima in PcP, ScP, PcS, and ScS are not simultaneous. A possible cause of the minor component is transformation between longitudinal and transverse waves at discontinuities in the crust.

Determinations of magnitudes and locations of epicenters of earthquakes supplementary to *Seismicity of the Earth* have been carried forward by Gutenberg and Professor C. F. Richter.

Our station at Crestline was destroyed by fire on August 31, 1950. The instruments formerly at Pomona College have been moved to a station at the Big Dalton Dam of the Los Angeles County Flood Control District. We are much indebted to the officials and personnel of the District for providing adequate housing and maintenance. The station at China Lake has been placed on a permanent basis with excellent cooperation from officers and personnel of the Naval Ordnance Test Station at Inyokern. A new seismometer vault and recording-room have been provided. A short-period Benioff vertical component seismograph with paper recorder is operating at its maximum available sensitivity. A film recorder has been modified by F. E. Lehner to accommodate a long-period galvanometer for use with the same vertical seismometer.

A book entitled *Seismic Exploration for Oil*, written by Professor C. H. Dix, is now in press and will be published shortly by Harper & Bros.

PALEONTOLOGY

In the field of vertebrate paleontology Professor Chester Stock had continued to push ahead with his studies of the Tertiary land mammal occurrences of Mexico and their relation to those of west-

ern North America. He was looking forward to the maintenance and expansion of the cordial relations built over a number of years with the Instituto Geológico de México. He was also actively pushing the development of the Hancock Park unit of the Los Angeles County Museum as an educational and research center. Unhappily his work was cut short. Nevertheless, although the vertebrate paleontology program at the Institute has had necessarily to suffer temporary curtailment, the field has not been permitted merely to lie fallow. Under general supervision from Professor C. W. Merriam and with help from Professor Buwalda, Mr. D. P. Willoughby has carried forward the teaching program, and field investigations have been continued by Mr. William Otto. Thus, the Division's important reference collections in this field have continued to grow and to attract scholars from many sources. Among such, particular mention should be made of Dr. G. Edward Lewis, Senior Paleontologist of the U. S. Geological Survey, who, largely through the efforts of Dr. Hewett, spent three months at the Institute in studies of vertebrate remains from key localities in the Mohave area. These studies have resulted not only in closer dating of certain key beds in the region, but they have also given a more graphic picture of the distribution and persistence of certain species of fossil horses. This information is proving of value, for example, in Professor Buwalda's Tehachapi studies.

In January Professor C. W. Merriam returned to his chair in invertebrate paleontology and has continued his researches on the invertebrate faunas and the stratigraphy of the Basin and Range province, particularly of the upper Paleozoic rocks. Not only have these studies already benefited our own groups working on related problems in this province, but the results have been eagerly awaited by the petroleum and mining fraternity generally, all of whom recognize the fundamental significance of Professor Merriam's investigations.

During the year the program of the Division has been furthered by support of many kinds from many individuals and organizations. All of this support, whether tangible or intangible, has been appreciated, although it is possible here to cite only a few examples, such as the long-continued and generous support of the research program in vertebrate paleontology by Childs Frick; the support given to research on glaciology by the Office of Naval Research; the support given to research on microseisms by the Geophysics Research Division of the Cambridge Research Center, U. S. Air Force; the cooperative support of the U. S. Geological Survey on several important field projects; the support given by the Southern California

Edison Company to Pleistocene studies in the Sierra Nevada; and the donation by Mrs. Fred B. Piehl of the notable collection of Goodsprings, Nevada, ores and minerals belonging to her late husband.

Most valuable has been the donation of several graduate fellowships: the research fellowship in geophysics of the Stanolind Oil and Gas Company; the research fellowship in geology of the Standard Oil Company of California; and the fellowship in geology of the Socony Vacuum-General Petroleum Company. Fellowships of this type not only afford the Division the opportunity of attracting top-notch graduate students to the Institute, but they also permit these men to carry out their graduate program under most favorable conditions. The Division is therefore greatly indebted to the companies that have made such fellowships available over a number of years.

Respectfully submitted,

IAN CAMPBELL, *Acting Chairman,*
Division of the Geological Sciences

THE DIVISION OF THE HUMANITIES

To the President:

During the past year a visitor from Oxford, making a study of American scientific and engineering institutions for the purpose of educational development in Australia, included in his report the comment that "the humanities courses at Cal. Tech. seemed to me to be the most effective I saw in America." He also remarked that "I felt at Cal. Tech., as I did not feel in other universities I visited, that the humanities were a social and intellectual force in the life of the undergraduates, not imposed from above but freely accepted as part of a liberal education." These two statements, if they do not describe accomplished reality, do at least describe the goals of the Division.

The generous grant of the Carnegie Corporation, announced in last year's report, has enabled us to work in two directions: toward the integration and strengthening of our undergraduate offerings, especially in the fields of history, economics and government; and toward the enrichment of the students' intellectual and artistic environment close to, but outside, the actual curriculum.

Modifications of the freshman and sophomore courses in history have been worked out by the staff in such a way as to focus more sharply upon the study of political philosophies from the time of Locke to the time of Hitler and Stalin and upon the practical effect

these ideas have had. In the sophomore course the three subjects selected for intensive study are the evolution of the American federal constitution and government, the attempts to cope with the economic and social problems caused by the industrialization of the United States during the past century, and the position of the United States in world affairs since 1900. In the required senior course in current public affairs much thought and effort have been devoted by members of the staff in economics and history toward making this course the liveliest part of a senior's educational experience. Taking as its subject the conflict between East and West, the course attempts a critical evaluation of the impact of this struggle on the American economy, on American institutions and on the American way of life.

The conversion of the Treasure Room in Dabney Hall to a Public Affairs Room was a major project of the year. Located on a main artery of student traffic, the room affords an opportunity to read the great national daily newspapers as soon after publication as they can be delivered by air. Supplementing the New York *Times* and *Herald Tribune* we have the *St. Louis Post-Dispatch*, the *San Francisco Chronicle*, *The Christian Science Monitor*, and two local newspapers. From abroad come the air mail editions of the weekly London *Times* and the Manchester *Guardian*. More than 35 foreign publications and 60 American periodicals are available, in addition to special pamphlets of the State Department, the Foreign Policy Association and many other information agencies all over the world. *The Congressional Record* is displayed and tabbed to call attention to important speeches on the floor of Congress.

On the walls of the room are exhibits of significant documents and commentary on issues of current interest. These exhibits, and the activities of the room generally, are co-ordinated with the required senior course in current public affairs. The custodian, Mrs. Doris Logan, co-operates with the faculty members in charge of this course and is available to help students and instructors find source material.

Use of the room has increased steadily since its opening in December, 1950. From an average of 60 visitors a day at the beginning, attendance had grown to 120 at the end of spring term. Almost none of this attendance is compulsory; student debaters make use of the material, and the lectures in the senior history course encourage attendance, but the principal values of the room seem to have impressed themselves upon the minds of our students. The Public Affairs Room attempts to develop a sense of public responsibility, to promote maturity of judgment in evaluating news reports, and to emphasize the intimate connection between political freedom and easy access to information.

In the field of the arts, the Carnegie grant has enabled us to stimulate and encourage the interest of many of our students in music and the visual arts. In the winter quarter we brought to the campus the distinguished composer Ross Lee Finney, of the University of Michigan, for a series of six lectures on "How the Composer Thinks." His lectures, illustrated with slides and musical examples, were:

January 18, "The Uniqueness of Musical Craft"
January 22, "Music Moves Only in Time"
January 25, "Melody—Flat and Round"
January 29, "The Musical Plot"
February 1, "True Confessions of a Composer"
February 8, "The Trained Intuition of the Composer"

Mr. Finney's lectures, prepared especially for delivery on our campus, are to be published in book form, and it is believed that they will be recognized as an important contribution to the understanding of music.

In addition to the Finney lectures, the Division has encouraged student interest in music by providing additional subsidy for the Caltech Musicale concerts in Dabney Lounge and by providing those students who play in the orchestra and band with a non-credit course in musical theory and harmony.

Co-operation from the Division of the Geological Sciences and from the trustees of the Stickney Fund has enabled us to open an art studio in the basement of Mudd Hall for practice and training in drawing, painting and other visual media. Professor Richard Beaman of the University of Redlands has been appointed Stickney Lecturer in Art. He conducts informal classes on Saturdays and has arranged a series of art exhibitions from various sources running continuously through the academic year in the Lounge of Dabney Hall. About a dozen students took advantage of the Saturday class, and many more were interested in the exhibitions.

Professor McCrery has continued to develop the interest and proficiency of our students in public speaking and debate. Caltech speakers won a number of important contests, both regional and national. During the year a Foreign Students Speakers Bureau was organized to present informational programs at colleges, schools, civic organizations and service clubs. Twenty-four Caltech students from 17 foreign countries are members.

Members of the Division continued to make contributions to knowledge in their special fields. Dr. Stern published additional results of his study of contemporary philosophies, and Professors Mead and Bures have both been engaged in writing textbooks in philosophy. Professor Paul continued his work on the history of California agri-

culture; Professor Elliot began an investigation of some British admiralty records. Professor Shutz published a biographical study of Thomas Pownall, colonial governor of Massachusetts. Professor Langston published a paper on Essex and the art of dying, a part of a larger study on Elizabethan attitudes toward death. Professor Hallett Smith contributed an essay on Shakespeare to the *Yale Review*, and Professor Lester McCrery published two articles on speech and speech training.

Respectfully submitted,

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

THE DIVISION OF PHYSICS, MATHEMATICS, AND ASTRONOMY

To the President:

At the end of the year the Division had 32 staff members in physics, 16 in mathematics, and 6 in astronomy. Of these, 20 in physics, 10 in mathematics, and 2 in astronomy are professorial members and 5 are visiting professors—2 in physics and 3 in astronomy. The remainder are research associates, senior research fellows, and research fellows largely engaged in project research financed by government funds. During the year the Division had 72 graduate students in physics, 17 in mathematics, and 8 in astronomy. About half of these graduate students held assistantships and were engaged either in teaching activities or in research work under one of the projects. In June 1951, Ph.D. degrees were awarded to 19 candidates in physics and 4 in mathematics.

Starting at the beginning of the third term, many of the senior members of the Division began to spend part or in some cases all of their time on Project VISTA. Professor Fowler became the Scientific Director of the project and was joined in this work by Professors R. F. Bacher, H. F. Bohnenblust, R. F. Christy, L. Davis, R. P. Dilworth, P. S. Epstein, J. L. Greenstein, C. C. Lauritsen, T. Lauritsen, W. R. Smythe, and E. C. Watson. In addition, Professor H. P. Robertson was granted leave to become Director of Research of the Weapons Systems Evaluation Group of the Department of Defense. A heavy burden was thrown on those staff members who did not join Project VISTA, and in many cases senior research fellows and research fellows carried major responsibilities during the absence of the professors with whom they had been working. In spite of the efforts of remaining staff, work with graduate students inevitably suffered.

Physics

In physics, very active work was continued on the study of the new unstable particles which appear in the cosmic rays. Professors C. D. Anderson, Eugene Cowan, and R. B. Leighton greatly improved methods of studying these particles and obtained valuable new information about the nature of their decay products. The decay products of the neutral V-particle have been shown to be a meson and a second particle of considerably greater mass. It seems most likely that the meson is a pi meson and the heavier particle is a proton, although this identification has not yet been established with complete certainty. A total of about 100 cases of cloud chamber photographs of V-particles has been obtained. It appears that the energy released in the disintegration of a neutral V-particle is roughly 100 Mev.

Plans were completed and funds were allocated by the trustees for the construction of a new addition to the Norman Bridge Laboratory, which is especially designed for cosmic ray studies. This Laboratory has a lightweight roof over the region where a large magnet and cloud chambers will be installed. Work on the new magnet and the equipment to go with it was started and is expected to be completed in 1952. The new laboratory makes use of the adjoining laboratories in the connecting wing between East and West Bridge.

Professor H. V. Neher developed a new lightweight ionization chamber and electroscope to be used in studying cosmic ray intensity at high altitude. He prepared a large number of these ionization chambers for a summer expedition, during the summer of 1951, to Thule, Greenland, which is located very near the North Magnetic Pole. Simultaneous flights were made from North Dakota and Thule to study variations in cosmic ray intensity.

Professors C. C. Lauritsen, W. A. Fowler and T. Lauritsen continued their studies of the properties of light nuclei in the Kellogg Radiation Laboratory. During the year the 600 Kev electrostatic generator was fully activated and has been completely equipped with auxiliary apparatus for particle analysis and detection. Many problems of nuclear disintegration and activation of light nuclei were studied in detail, and some further measurements were made on the carbon cycle, which is believed to play a role in stellar energy generation.

Construction work on the Caltech electron synchrotron was started. A foundation for the magnet was built and the shell for the power supply room was constructed. The magnet itself was assembled, the vacuum system installed, a radio-frequency accelerator system

developed and built, and an injector which provided electrons at just under 1 Mev was developed and installed. With an improvised power supply, the magnet was excited to low magnetic field so that electrons could be injected into the machine. Toward the end of June evidence was obtained that electrons had been captured in synchrotron orbits and accelerated for some 2,000 revolutions. As far as is known, this was the first time that electrons had been successfully injected and captured in a race-track type machine. Work at higher energy will await the installation of the new power supply, the main parts of which arrived just before the end of the year.

Precision measurements of gamma rays were continued by Professor J. W. M. DuMond and his associates with the investigation of gamma rays from a number of the radioactive isotopes of the heavier elements. As more measurements have been made, the precision has increased. A point-focusing X-ray monochromator has been developed and successfully used to form low-angle diffraction patterns. This instrument has some advantages over the electron microscope and seems to have promising possibilities. Construction work on the precision beta-ray spectrometer and its auxiliary equipment was completed and the equipment assembled for vacuum tests.

Investigations in spectroscopy were continued by Professor R. B. King with his studies of transition probabilities. These studies are particularly interesting in the interpretation of the observed intensities of stellar spectral lines. Plans were drawn up for the construction of a grating spectrograph for these particular studies, and construction will go ahead as soon as a suitable grating can be obtained. Funds for the grating for this work will be taken from the memorial fund set up by friends of the late Dr. Otto Beeck, former Associate Director of Research of the Shell Development Company. Additional funds for the construction of the spectrograph and its mounting were made available from a special fund for research in physics granted by the Shell Development Company.

In theoretical physics, Professor Richard P. Feyman, formerly of Cornell University, joined the Division as Professor of Theoretical Physics. He and Professor Christy continued their investigations of atomic nuclei and elementary particles. Professor Paul Epstein, who has been the senior professor of theoretical physics for many years and on whom the Division has leaned heavily in the graduate instruction in physics, went on half-time activity for the first of two years before his retirement.

Work continued in several other fields. Professor W. R. Smythe continued his work on the development of equipment for a precision determination of e/m for the electron. The second edition of his book, *Static and Dynamic Electricity*, was published by the McGraw-

Hill Book Company. Dr. S. J. Barnett continued his researches on the electro-inertia effect and the gyromagnetic effect by the method of electromagnetic induction. Dr. Walter G. Cady, formerly Professor of Physics at Wesleyan University, joined the staff during the year as research associate to continue his experiments on "Ultrasonics and Piezoelectricity." His plans include the study of these effects at ultra high frequencies. Professor Alexander Goetz carried out experiments with the molecular filters which he has produced and which are now used in a variety of biological and chemical studies.

During the year the staff in physics completed plans for a revision of the graduate curriculum in physics. This revision includes the introduction of several new basic graduate courses and the introduction of an oral examination for admission to candidacy for the Ph.D. degree. In addition, plans were drawn up to give placement examinations to all new graduate students in physics in order to determine somewhat better the graduate studies which they should undertake. Among the undergraduate students at the Institute, roughly one in five selects physics as his major, in spite of the admitted difficulty of the curriculum. Many of these students are among the top-ranking undergraduates and continue their studies in physics after graduation.

Lectures by visiting professors in physics attracted wide attention. Professor Enrico Fermi of the University of Chicago, Nobel Laureate, gave a series of lectures on "Properties of Elementary Particles." Professor H. A. Bethe of Cornell University gave a series of lectures on various topics in nuclear physics. Professor W. K. H. Panofsky of the University of California gave three lectures on properties of mesons.

Mathematics

The members of the mathematics staff and the students carried out research in the following fields: partially ordered sets, abstract analysis and applications, algebra of operators, number theory, differential equations and special functions.

Professor S. Karlin returned from a leave of absence and has resumed his duties at the Institute. Several mathematicians visited the Institute and lectured on various topics. Professor J. G. van der Corput of Amsterdam stayed for two weeks and delivered a more extended series of lectures on asymptotic series and number theory.

In the course of the year the department reviewed the undergraduate and graduate curricula in mathematics. Several changes were adopted. The undergraduate courses in the Mathematics Option were rearranged to combine the junior and senior classes. A

broader program and a wider choice of electives in mathematics will be offered without increasing the number of courses. The department continues to encourage those undergraduate students who intend to do graduate work in mathematics to take at least one graduate course in their senior year. The most important features of the new graduate program are a lighter course load during the first year and, for beginning graduate students, a seminar intended to provide a greater stimulus for independent work at an early stage.

For several years an urgent need existed for an additional periodical in mathematics to cope with the ever increasing number of papers. The Institute, together with the other leading educational institutions on the West Coast—the American Mathematical Society and the Institute for Numerical Analysis of the National Bureau of Standards—have agreed to sponsor a new periodical. The first two issues of the *Pacific Journal of Mathematics* have already appeared and have been well received.

The work on the Bateman Manuscript Project (which is sponsored by the Office of Naval Research) proceeded satisfactorily, and the major portion of the work was completed by the end of the academic year. At this time Professor F. Tricomi and Dr. F. Oberhettinger left the Institute, the former to return to his permanent position at the University of Turin, the latter for Washington, D. C., where he now holds a combined position in the American University and the National Bureau of Standards. The junior members of the team also left, Dr. Maria Weber joining the staff of the University of California at Los Angeles, and Dr. D. L. Thomsen the staff of the Jet Propulsion Laboratory. On the other hand, Mr. David Bertin, formerly of New York University, is joining the project staff to continue the work on the table of integrals and to assist in the production of the handbook of special functions. Professor A. Erdelyi continued to direct this project.

As in former years, the work on the project stimulated research activities and a number of papers were prepared for publication by several members of the staff.

Astronomy

Beside the graduate instruction by regular staff members in astronomy, the instructional program has been greatly aided by the participation of members of the Mount Wilson and Palomar Observatories staff. Dr. Baum, with the cooperation of Mr. William C. Miller, lectured on photoelectric and photographic photometry, and Dr. Olin C. Wilson lectured on planetary nebulae and Wolf-Rayet stars. Two well-known astronomers, Dr. T. G. Cowling of the University of Leeds, England, and Professor Polydor Swings of the

University of Liege, Belgium, gave lectures during the year. Professor Cowling lectured on "The Theory of the Interaction Between Magnetic Fields and Ionized Matter in the Stars," and Professor Swings gave a course on "Molecular Spectra in Astronomical Sources." Dr. Guido Munch of the Yerkes Observatory was appointed Assistant Professor of Astronomy and joined the staff in the summer of 1951.

Observational research by graduate students has begun to play a role in the activities of the Observatories. Besides such observational work, several theoretical and analytical investigations have also been carried out by them. Professor J. L. Greenstein has studied the abundance of certain elements in the sun which are subject to relatively rapid thermonuclear reactions. With Dr. R. S. Richardson he found that lithium is less abundant in the sun than on the earth; the isotope ratio, however, is probably normal. A deficiency of lithium is to be expected since protons would destroy lithium atoms in a few minutes at the temperatures found near the center of the sun. The suggestion by the physicists last year that the proton-proton reaction is the important source of energy in the sun led to the prediction that He^3 would be formed. Professor Greenstein searched with completely negative results for He^3 in the sun, but the paradox was resolved by the suggestion by Professor C. C. Lauritsen and W. A. Fowler that the He^3 disappeared in collision of two He^3 nuclei. Professor Fritz Zwicky has continued work on the theory of the clustering of galaxies. In this connection he has proposed an observational test based on his morphological method which may permit decision between the long and short time scales for the age of the universe.

Respectfully submitted,

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

INDUSTRIAL RELATIONS SECTION

To the President:

Two significant projects emphasized by the Industrial Relations Section during 1950-51 should have wide application in the future:

1. Practicing supervision—a new technique for the development of supervisors;
2. Improved methods of conducting wage and salary surveys.

It has long been recognized that training, in schools or on-the-job, should include some element of practice. For a variety of reasons, this element of practice, however, has not been included in most programs aimed at the development of supervisors and management. During the past year the Industrial Relations Section has taken the technique usually referred to as "role playing" and adapted it as practice sessions designed as part of a general program of managerial development. Experiments with this technique were made at meetings of the Management Club of Caltech and at other meetings arranged by the Los Angeles Chamber of Commerce, Los Angeles Times Foremen's Club, Merchants and Manufacturers Association, National Association of Foremen, Personnel and Industrial Relations Association, and the Training Association of Southern California. The procedure was also used in all of the summer conferences.

A series of special meetings, attended by a representative from each of 12 companies, provided the most intensive experimentation. During this program, 15 illustrative cases were developed, and everyone who participated gained sufficient experience to use this procedure in his own company. A number of companies, with the guidance of the Section, have already started to use this procedure.

The results have created such a favorable response that the Section will hold a similar series of meetings during the current year. Work is in progress on a bulletin which will describe the procedure in detail and provide a selected group of cases which can easily be adapted to a specific company. It is also hoped that the procedure can be used in the development of shop stewards and other representatives of unions.

The other technique developed by the Section, which can be used generally in business and industry, provides a new method of making a wage survey for shop, service, and clerical employees through the use of the conference method, rather than by questionnaires or interviews. The method has been developed with the cooperation of a group of employers in Pasadena and is being tested by employers in other small labor markets.

At the same time, the Section has been working on a method for making salary surveys of executive, administrative, and professional positions. Such surveys have not been generally conducted in the past because of the difficulty in comparing positions at these levels in various companies. With the cooperation of a small group of large employers, the Section has developed a workable method of outlining the duties and responsibilities for such positions. In addition, the

Section has prepared a set of key descriptions for a variety of engineering positions. These descriptions of key positions provide a convenient yardstick to facilitate comparison of salaries in engineering work among companies using different types of engineers.

In addition to these major developments, the Section has maintained and expanded all of its services to business and industry in the community. Its growing collection of books, periodicals, union contracts, and other materials in its specialized library have answered an increasing number of requests for information from companies, unions, and other organizations.

Four series of evening meetings on various aspects of personnel administration were held. Eight one-week, full-time conferences were conducted, four during July, 1950, and four during June, 1951. In January, 1951, a special one-day conference on overtime compensation was attended by 26 representatives from 23 organizations. Two dinner-discussion meetings were conducted and two bulletins were published.

The Section continued to provide instruction for regular students at the California Institute in the subjects of industrial relations and industrial management.

Continuing a special activity which was started in 1944, another survey of employee opinions in a specific company was conducted in the fall of 1950. A few tentative conclusions are now being drawn from these surveys. When several other surveys scheduled for 1951-52 are completed, it may be possible for the Section to draw some general conclusions which will be of value to executives and other employees.

The many activities of the Section were made possible by the integration of its resources developed during the past twelve years. These integrated resources include top-level guidance from the Trustees and faculty, an efficient, flexible staff of full-time employees, and a group of 41 experts from other divisions of the California Institute, from other schools and universities, from government, and from business and industrial organizations and associations. These experts cooperated on special projects. Another important resource of the Section is an extensive collection of specific and general materials on personnel administration.

Respectfully submitted,

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

JET PROPULSION LABORATORY

To the President:

The program of basic research at the Jet Propulsion Laboratory is continuing at about the same magnitude as during the preceding year, but the applied research program has grown substantially relative to the basic program. Research at JPL is carried out entirely under contracts with the Army Ordnance Corps, the Air Force, and, in a lesser amount, the Navy. Personnel at JPL now number 785, of whom 192, or almost 25 per cent, are professionals. The professional group comprises 30 with the Ph.D. degree, 7 with the A.E. degree, 77 with the M.S. degree, and 78 with the B.S. degree.

The Laboratory continues to share in the academic life of the campus by supporting a considerable number of joint appointments, both of senior faculty and of graduate students. The Laboratory employs a substantial number of Institute graduates, who constitute possibly 30 to 40 per cent of the professional staff.

RESEARCH

The research program for 1950-51 has included the fields of rocket propellants, materials, combustion, heat transfer, fluid dynamics, and certain engineering developments. The topics to follow are illustrative rather than comprehensive:

1. *Propellants.* The investigation of the physical properties, propulsion performance, and reaction kinetics of both solid and liquid propellants continues as a major activity. New formulations of solid propellants have been tested with the intent of reducing smoke, controlling burning rate, and improving mechanical properties. Detailed study of the reactions of various oxides of nitrogen has been carried forward, as well as infrared spectroscopic measurements of the absorption of molecules typical of combustion products.

2. *Materials.* The preparation and measurement of properties of several high-melting point alloy systems of current interest are well under way. Among these are the systems chromium-molybdenum-vanadium, titanium-chromium-aluminum, titanium-vanadium, and others. Refractories such as the zirconia-yttria-ceria system have also been synthesized and studied.

Preliminary results have been obtained on the diffusion of zirconium into titanium using the radioactive tracer technique.

3. *Combustion.* Both the fluid dynamics and the thermodynamics of the combustion process are being investigated, since their strong

inter-dependence is recognized. The ultimate aim of the program is to secure information useful in ramjet and rocket design. Problems are being investigated along several fronts; for example, the structure of low pressure flames, the conditions in a turbulent Bunsen flame, and the turbulence of cold gases in the wake of simulated flame holders.

Another area currently receiving attention is the phenomenon of rapid high pressure combustion under conditions simulating gunfire.

A radio-frequency mass spectrometer is well along in development which will display on a cathode ray screen the molecular weights and relative abundance of various molecular species drawn from (say) a rocket motor through a probe. This will make it possible to resolve the details of the combustion process in a rocket motor.

4. *Heat Transfer.* Measurement of the parameters of boiling heat transfer has been extended to fluids which are of interest in jet propulsion other than water. The unstable conditions under which the solid heater wall melts ("burnout") have been measured and typical burnout parameters tabulated. The behavior of mixtures of fluids with different boiling point (corresponding to practical fuels) is currently under investigation.

5. *Fluid Dynamics.* The 20-inch supersonic wind tunnel has been calibrated over its complete range of Mach numbers and is in preliminary operation. A beginning has been made on the study of aerodynamic heating and boundary layer (drag) at high Mach numbers.

In the field of hydraulics, a technique has been perfected for measuring the spatial distribution and local mixture ratio of droplets produced by impinging liquid streams. Consistent results were obtained only after the flow conditions of the fluid entering the "injector" were closely controlled. A study of the effect of various helices used to produce "swirl" sprays has also been completed.

6. *Engineering Development.* Extensive work of a classified nature is being done on the CORPORAL ground-to-ground guided missile. A considerable expansion of electronic personnel in the guidance, control and telecommunications sections has been necessary. Work has also been undertaken on a ground-to-air solid propellant *unguided* missile. Progress on one missile has progressed to the point where a school to train the ultimate military users is now being set up.

Engineering research on rocket motors has emphasized injector design and testing, since this component remains the most nearly empirical in design and profoundly affects both thrust performance and heat transfer.

The new subject of "combustion vibration" (i.e., rough operation) has been investigated in a preliminary way. This is a matter of great importance in vehicles which must carry delicate electronic parts.

FACILITIES

The year 1950-1951 has seen an exceptionally active building program at JPL. The original 164,000 square feet of structures were increased by an additional 45,000 square feet with a value well over a million dollars. The new construction included two new wings on the main administration building, a new cafeteria, a large assembly building and seven other laboratory and office buildings. There is proposed for the coming year a large electronics laboratory, now in the planning stage.

The 20-inch wind tunnel was instrumented, calibrated, and placed in full operation during this period, and a considerable amount of sound-proofing and landscaping was completed.

PUBLICATIONS

During the year about 100 JPL reports, 25 to 30 pages each, were published. About 33 per cent of these were unclassified or presented in the open literature. Space does not permit listing the individual reports, for which those interested are referred to the JPL bibliography.

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:

Throughout the present report year, regularly scheduled observations have been carried out with all major instruments at both Mount Wilson and Palomar Mountain. At the beginning of the year the only major uncompleted item of equipment at Palomar Observatory was the large coudé spectrograph of the Hale Telescope. The collimator, the grating, and the longest of the cameras (144-inch

focus) were installed and the first spectrograms obtained in July 1950. These were followed by the 36-inch camera in October 1950 and the 18-inch camera in April 1951. The 72-inch and 8-inch cameras are still to be completed. Tests of this intrument leave little doubt that the many new and drastic features, which it was necessary to introduce in order to make effective use of the light collected by the 200-inch mirror, will be successful. Regular observations have been made with this spectrograph on every available clear night since November 1950.

1. *Solar Research.* The systematic study of the changes occurring in the solar atmosphere has been continued throughout the year by Dr. S. B. Nicholson, Dr. R. S. Richardson, Mr. J. O. Hickox and Mr. James Parker. Over 600 direct photographs and about 79,000 spectroheliograms were taken at regular intervals through each clear day to obtain material for this program. Richardson has continued his study of flares and has set up a system for their classification. Dr. Edison Pettit has extended his investigation of the motions of prominences to several additional examples that erupted during the current year. The chemical composition of the sun has been investigated by Mr. Allan R. Sandage, who measured chromium, and by Dr. Jesse Greenstein and Richardson, who studied elements that may play an important role in the thermonuclear reactions in the solar core such as Li and He^3.

2. *Stellar Investigations.* Following the completion of the Observatories' radial velocity program reported last year, Dr. R. E. Wilson has prepared for publication a New General Catalogue of Radial Velocities containing positions, magnitudes, spectral types, and definitive radial velocities of all stars for which a velocity determination has been made at any observatory. A total of over 15,000 stars are included.

General magnetic fields in stars have been further investigated by Dr. Horace Babcock. Recent observations have revealed the strongest field thus far observed, that of 9000 gauss in HD 133027. For the first time a magnetic field has been detected in a late type star, HD 4174 of type M2ep. Extensive investigation of the differences in chemical composition of stars of types A, F and G, and N is being undertaken by Greenstein and by Dr. W. A. Buscombe. No striking difference in composition between high and low velocity stars has been found, although preliminary results suggest that high velocity stars may have a higher helium content. The behavior of the spectra of several cepheid variables was studied by Dr. R. F. Sanford and Mr. Helmut Abt. Other variable stars were investigated by Dr. A. H. Joy.

A final list of 519 stars showing Hα in emission has been published by Dr. Paul Merrill and Miss Cora Burwell. Detailed study of the spectra of other emission-type stars has been made by Merrill. A systematic search for novae in the Milky Way, made by Dr. F. Zwicky during the summer of 1950, yielded three of these objects. Dr. O. C. Wilson and Abt have observed Wolf-Rayet stars and have been able to make new mass determinations for one of these objects.

3. *Galactic and Extragalactic Nebulae.* Since the start of regularly scheduled observations with the 200-inch Hale Telescope in November 1949, over 1000 direct photographs have been taken. Most of these have been collected for use in a systematic attack on the problem of the dimensions, structures, and distribution in space of the extra-galactic nebulae. Dr. Walter Baade is investigating several types of variable stars in the Andromeda Nebula for the purpose of establishing them as precise distance indicators for use in fixing the distance of this and other nearby nebulae. Dr. Edwin Hubble has obtained a series of plates to extend these distance measurements to a group of nebulae beyond the range of the earlier studies with the 100-inch telescope. As part of this program Pettit has made additional photoelectric measurements of the magnitudes of nebulae. Dr. William Baum has progressed rapidly in the establishment of precise standards of magnitude in nine selected areas using recent photomultiplier techniques. These will be used as a basis for the magnitude intercomparisons which are fundamental to the distance measurements of the nebulae. Using the new prime focus spectrograph of the Hale Telescope, Dr. Milton Humason has obtained the spectra of nebulae well beyond the range that could be reached with the 100-inch. Displacements corresponding to 61000 km per sec, or over 20 per cent of the velocity of light, have been observed. Zwicky has investigated the distribution of nebulae and the luminosity function in the Como and Cancer clusters.

Studies of the structure of the planetary nebulae based on photographs obtained with both the 100-inch and the 200-inch Telescopes have been carried out by Dr. Rudolph Minkowski. The structure and mechanism of illumination of these nebulae have been investigated by Dr. O. C. Wilson with the collaboration of Dr. L. H. Aller of the University of Michigan and by Greenstein working with Dr. Thornton Page of the University of Chicago. Over 34 spectrograms of planetary nebulae, many of several nights exposure, have been taken by O. C. Wilson and I. S. Bowen using the coudé spectrograph of the Hale Telescope.

In spite of mechanical difficulties during the most favorable observing season, substantial progress was made with the National Geographic Society-Palomar Observatory Sky Survey. Ninety-one addi-

tional fields were photographed by Dr. A. G. Wilson and Mr. R. G. Harrington, bringing the coverage to about 28 per cent of the total area of the survey.

4. *Guest Investigators.* The policy of making available to qualified observers from other institutions such telescope time as is not required by the programs of our own staff was continued throughout the year. This has brought to the Observatories over twenty outside astronomers.

Respectfully submitted,

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