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1951-1952

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1951-1952

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

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*Resigned July 14, 1952 †Resigned January 5, 1953
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Part I

THE REPORT OF THE PRESIDENT

To the Board of Trustees:

I have the honor to submit the following report of the California Institute of Technology for the year ending June 30, 1952.*

Introduction

The California Institute of Technology completed its 61st year of operation in an exceptionally strong position. We have never had a finer student body or a finer faculty. Our finances were adequate for current operations, though inadequate to cover certain desired new programs. The plant is in excellent condition, though seriously overcrowded in every department. Recognition of the achievements of faculty and alumni reached new heights. The Institute continued to render outstanding service to the community and to the nation.

The past year was a more "normal" one than either of the previous two. Student life was not so disrupted by uncertainties of military service as in 1950; the faculty returned to normal activities after completion of the Vista Project on January 1, 1952. Yet the shadows of the defense program remained on the campus. The new Air Force ROTC unit, which won laurels in its first year, brought a military air to the campus each Friday and on other special occasions. The Jet Propulsion Laboratory, far removed from the campus, was continually expandings its efforts. But for this period of international tension this was a "normal" year.

The Role of Higher Education

There are plenty of reasons why those concerned with higher education should now be thinking deeply about the place of our colleges and universities in this kind of world. There were times last spring, as students on various campuses gave vent in curious ways to their spring fever (as students have done from time immemorial), when many Americans wondered if college life was preparing our youth adequately for the serious business of living. Very few thought to ask whether, on the contrary, the colleges were too serious, and the safety valve just had to let loose.

*This report covers, officially, the fiscal year ending June 30, 1952. Since the annual meeting of the Board of Trustees was not held until several months later, a few items and events of the intervening period have been included.

In any case serious thinking about higher education—always appropriate—was now especially necessary. It has been the privilege of your president to be a member of a Commission which has been giving extensive thought to this question for the past three years. The task of this Commission, established by the Association of American Universities, was to study the problems of financing higher education. But as this group of 12 educators and laymen faced this problem they found it necessary to ask: what *is* higher education in America and *why* should it be financed? Our answers are contained in a report which will be off the press before this report is published. I hope many thoughtful friends of Caltech will find an opportunity to read it. Not that it pretends to say anything new; it only recalls to mind ideas that have been too often forgotten. For as we looked at American higher education we were impressed again with what a magnificent achievement it is. There are in this country over 1100 four-year colleges and universities, large and small, public and private, sectarian and non-sectarian, rich and poor, good and mediocre. They are bringing higher education in some form to a far larger fraction of our youth than any other nation has ever achieved. They are typical products of a free enterprise system, exhibiting diversity and freedom, uncontrolled by any central power. Yet they all seek a common goal—the preservation of the heritage of Western culture, the broadening of man's intellectual horizons, the maintenance of the dignity and the freedom of the individual. They seek, in other words, to preserve the values which made America great.

There was never a time when these values were in greater need of being affirmed. Are the colleges succeeding in this task? Our conclusion was that, on the whole, they are. It is true some individual students or faculty have been irresponsible or foolish or negligent. Some colleges, too intent on "practical" or "popular" goals, have neglected their primary educational mission. Higher education as a whole, however, remains the stronghold of our vital traditions, the defender of our freedom, the leader in the quest for new knowledge, new vision, new wisdom.

Is the future of American high education in danger? The answer is "No". There are thorny paths ahead, as there always have been. Colleges are being expected to do more things than they can afford. Inflation and fluctuating enrollments have posed grave financial problems. Yet we recall that pioneer America made the most unbelievable sacrifices to create and to maintain its colleges. Will rich, modern America neglect this heritage? Not if Americans understand the problems. It is therefore the duty of all alumni, faculty, students, trustees and friends of American colleges and universities to help

Americans understand the true values of higher education. To the extent they are understood, to that extent will higher education receive the support it needs and deserves.

Our Commission believes that this support should come from many sources. We do not believe it should come in handouts from the Federal Government. Private sources have not dried up. Individuals, foundations and corporations can furnish the necessary funds, provided only that in sufficiently large numbers they understand the need and respond to it.

The Institute and the Government

Caltech is a private institution. Its entire teaching program and a substantial part of its research program are financed by income from endowment and trust funds, tuition fees and gifts from individuals, corporations and foundations. However, our financial statements show also large sums of money "billed" to the Federal Government. The significance of these "billings" should be clearly understood.

The activity which accounts for the bulk of these charges to the government is the operation of the Jet Propulsion Laboratory, located about five miles from the campus at the northwest edge of Pasadena. This laboratory—land, buildings and equipment—is owned by the government, and is devoted exclusively to carrying out research and development in the field of rockets and guided missiles, principally under the auspices of the Ordnance Corps of the United States Army. The Ordnance Corps, rather than managing and operating this laboratory directly (for example, as a military station) has asked the California Institute to serve as operator, in the belief that under this plan the Laboratory will carry out its mission more effectively and more economically.

The Institute has been glad to render this service in the cause of national defense. In performing this service we expend, as agents of the government, large sums of money for salaries, materials and equipment as necessary in carrying out the program. The government then reimburses the Institute for these expenditures—auditing them item by item. No "management fee" is charged, but an allowance is made (also audited each year) to cover a reasonable share of the administrative or "overhead" expenses which the Institute incurs.

Thus, during the year just closed, the Institute billed the government for nearly $10,000,000 to cover expenses of the Jet Propulsion Laboratory.

Other "billings" to the government during the past year amounted to about $2,000,000. These covered reimbursements for the cost of research projects carried forward *on the campus*. These are projects

judged by the faculty to be desirable additions to the Institute's program of education and research. Each one, however, is also of current interest to some agency of the government. Because of this interest the government agency is willing to bear some portion of the costs of the project, just as an individual, a company or a foundation may bear the cost of a project in which it may be interested. The nation's scientific strength has been greatly enhanced in recent years—and its welfare and security correspondingly advanced—by this type of cooperation between universities and the government.

But all of these "billings" to the government in no way lessen Caltech's primary dependence on private funds. In fact they increase it; for we shall want to continue many of these special research projects even though some day the government's interest in them should cease. In addition there are many other projects of equal importance which can never command government interest, and we must never be forced to limit our interests to those of the government. In fact, except for a few large and expensive projects in fields such as nuclear physics and aeronautics, most of our educational and research work is still dependent on funds from private sources.

Financial

As shown in the report of the Comptroller the total net assets of the Institute passed the fifty-millon dollar mark this year, continuing the slow, steady climb which has added twelve million dollars in the past six years. The chief capital increment during this past year resulted from gains from the sale of securities.

The expenditures for the campus programs of instruction and research were $5,203,102, which was $131,329 less than the income available for these programs. Again this year budget economies and better-than-expected income enabled us to end the year with a modest surplus instead of an anticipated deficit.

The above figures do not include the money expended for others in managing off-campus research and development programs. The Cooperative Wind Tunnel, the Jet Propulsion Laboratory and the (temporary) Vista Project accounted for $11,479,309 in expenses which were reimbursed.

A most important section of the financial report is the one reporting gifts for current operations. These amounted to the impressive total of $1,200,419. (The entire budget of the Institute was less than this amount in 1939.) The many large grants by industrial corporations, some for research in certain fields, others for general support, are especially noteworthy and encouraging. While the argument goes forward as to whether or how business should help the colleges, many

forward-looking companies are quietly doing it, and have been for many years.

The Student Body

Violently fluctuating enrollments have been a cause of serious difficulty in many colleges during the past 20 years. Depression, the war, the post-war veterans' program, and now the abnormally low college-age population (reflecting the low birthrate of the depression years) have alternately boosted and depressed college attendance to an extent which has in many institutions played havoc with finances, with plant utilization and with staff.

Caltech has been freer from these large fluctuations than most other colleges. For example, as a result of the policy of keeping the entering class fixed at 180 students, the undergraduate student body, even at the peak of the veteran load, reached only about 800 compared with the present or "normal" of about 650—the level at which we expect to maintain undergraduate enrollment. The number of applicants for freshman admission for the fall of 1952 showed a sharp increase, which followed a more modest increase in 1951 over the low point of 1950. Choosing 180 freshmen from several hundred applicants offers the opportunity of securing a high quality class, but presents difficult problems of selection. The Admissions Office is being greatly assisted in this task by the statistical studies on methods of predicting academic success being made by Dr. John Weir, Associate in Psychology. Scores on the College Entrance Examination Board tests are found to be the most valid single criterion of success at the Institute. But in each individual case these scores must be supplemented by information on success in school, intellectual interest and motivation, and those personal qualties associated with character. Our aim is to select students of outstanding promise of future success—and to reduce academic failure to zero. But prediction of human achievement can never attain perfection, and in many cases failure results principally from unavoidable personal, family or financial difficulties or for reasons of health. These too we aim to keep at a minimum through student health and counselling services, student-aid programs, etc. Only 9 per cent of the 1951-52 freshman class withdrew for scholastic reasons. The Caltech sophomores ranked, as a class, in number one position among 128 colleges throughout the country in a National College Sophomore Testing program involving 14,000 students. They ranked first even in such subjects as English, General Culture and Current Affairs.

The number of students needing financial assistance continues to grow. Part-time jobs (the favorite: baby sitting) were of help in many cases. Indeed, more jobs were available than could be filled.

But the time available for outside work is, for a Caltech student, severely limited. Scholarships were awarded to 102 undergraduate students in the amount of $47,950. In the upper three classes only those in the top quarter of the class were considered for awards. Funds are needed to assist worthy students who, often for reasons beyond their control, do not quite attain the necessary B-average.

We note with satisfaction the growing number of industrial companies which are establishing undergraduate scholarship programs. If wisely administered, these can go far toward assuring educational opportunities to all talented and ambitious young people, regardless of family economic status. Such private funds will make unnecessary the Federal scholarship aid program being advocated in some quarters.

A large fraction of the graduate students must depend upon some form of financial assistance. For the most part this is earned through part-time services in teaching or research. There are also increasing numbers of industrial graduate fellowships and now the new fellowships of the National Science Foundation. Graduate students received in grants or stipends over $400,000 during the year, distributed among 280 out of the slightly over 400 such students.

There were 344 degrees awarded at the Commencement exercises on June 6, 1952, including 126 Bachelor of Science, 133 Master of Science, 20 Engineer's degrees (M.E., C.E., Ae.E., etc.) and 65 Doctor of Philosophy.

The geographic distribution of the student body continues to broaden. Of the freshman class entering in 1952, 35 per cent came from outside of California, representing 25 states and 1 foreign country. Of the 1952 Ph.D. recipients, 80 per cent received undergraduate degrees from institutions other than Caltech; 60 per cent of these undergraduate degrees were from institutions east of the Mississippi, and 13 per cent from abroad.

Curriculum

The goal of Caltech is not to educate more scientists and engineers but better ones. It is in the upper ranks of talent that the shortage is most acute. But how is this goal to be achieved?

One clue to the answer to this question comes from the fact that in the face of a severe national shortage of scientists and engineers (the demand for new graduates is more than double the supply), many who have been out of college for 10 to 20 years have been unsuccessful in finding better or more rewarding positions. Many have therefore left the engineering profession. There is no single simple reason for this paradox. Salary scales for white-collar workers are notoriously slow to respond to inflation; personnel directors seek freshly-trained

young people in preference to the "middle-aged"; many of the latter were not trained in the newer fields of science and engineering, where demands are the greatest.

It is clearly time for industry and government to outgrow the idea that $10,000 to $15,000 is an adequate top salary for senior engineers and scientists. But it is also desirable that young scientists and engineers be broadly enough educated so that they are both prepared and stimulated to keep pace with new developments in their fields. Such men will remain in the forefront of the profession. Caltech seeks to select and to educate such creative minds.

How well do we succeed? In proportion to their numbers Caltech alumni stand at the top in the frequency with which they receive unusual honors or recognition (e.g., the Institute has now graduated two Nobel prize winners: C. D. Anderson and E. M. McMillan). A more comprehensive survey of alumni is now under way to see how they have fared and to learn what aspects of the educational program have been of greatest value.

In the meantime the present curriculum is under continuous examination by the faculty. Substantial alterations have been made in the Humanities, Physics, Geology and Engineering Divisions, in the past year. For example, a new option has been created for Ph.D. candidates—to be called "Engineering Science". This is to give greater and more flexible opportunities for the unusual student whose interests extend beyond the bounds of one or more of the current civil, electrical, mechanical or aeronautical engineering fields. The boundaries between the fundamental concepts of these various traditional fields are already diffuse; for many students they should be ignored. This emphasis on basic concepts rather than specialized skills is behind all these recent curricular changes.

Alumni

The alumni of an educational institution constitute its "product". Their success is a measure of the success of the institution; hence, in their achievement the institution takes special pride.

Alumni achievements can not be measured in numbers or statistics, because the qualities of good citizenship are not measurable. At the same time statistical studies are frequently made and are often of interest. Thus a recent study published in *School and Society* lists the number of graduates of various institutions who have attained sufficient distinction to be listed in the volume *Who's Who in the West*. If one divides these figures by the number of living alumni of each institution, one obtains a figure representing "the percentage of distin-

guished alumni". The figure for Caltech, 26 per thousand, is higher by 60 per cent than that for the next highest institution.

Another study of the sources of American physicists shows that Caltech has produced in proportion to its enrollment more physicists (listed in *American Men of Science*) than any other institution in the country, leading by a margin of 50 per cent the institution in second place.

As has been mentioned in previous reports, the alumni have in recent years been showing an increasingly active and most welcome interest in the Institute. The alumni magazine, *Engineering and Science*, has been developed into an outstanding journal; the annual alumni seminars on the campus attract great interest; the alumni fund is growing at an ever-increasing rate. If steel allocations arrive as promised it should be possible to announce in next year's annual report the completion of the alumni swimming pool made possible by gifts to the Alumni Fund, which have now passed $130,000.

Placement

The current critical shortage of scientists and engineers has been a matter of national concern for the past two years. College enrollments generally showed a substantial decline after the peak veteran enrollments of 1949, but engineering enrollments fell even faster. And this occurred just at a period of rapid rise in demand for scientists and engineers—a demand partly attributable to the post-Korean defense program, partly to growing needs in industry and education.

No one questions the existence of this shortage. But there are widely differing estimates as to its magnitude and extent, many conflicting opinions as to its long-range significance and the nature of the remedies that might be invoked.

It is my own feeling that this is a deeply disturbing phenomenon. At a moment when our scientific and industrial progress toward a higher degree of national welfare and security should be unimpeded, it is being forcibly levelled off by lack of manpower. We are, as a nation, not adequately discovering and encouraging the talents of our young people, talents on which the nation's future welfare is critically dependent. Fortunately there is evidence now of a slight upturn in college enrollments in these areas, but these new freshmen will not enter the manpower pool for another four years. In the meantime the demand will continue to outrun the supply.

The Caltech Alumni Placement Office, directed by Professor Donald Clark, receives first-hand information on the manpower shortage. During the past year representatives of 132 companies or government agencies arranged for interviews with students through this office, in

addition to those who approached students directly and informally. This was a 38 per cent increase over the previous year. Two hundred students were interviewed, some by as many as 26 representatives. Some received as many as 8 definite offers of employment. Nearly 80 per cent received at least one offer resulting from an interview. We know of no single case of a man receiving a degree in 1952 who is still looking for a job. (At last report a few were still undecided among the various offers.)

As of July 30, 1952, 43.6 per cent of those who received B.S. degrees were planning to enter graduate work (of whom 3 out of 4 will remain here), 51.6 per cent were definitely employed, 1.6 per cent were undecided and the other 3.2 per cent were either in military service, were foreign students returning home or had not reported.

Of the seniors employed, 78.5 per cent went into industry, 13.8 per cent to government, 7.7 per cent to research positions in universities or institutes. Of those who received the Ph.D. degree and who were placed through our Placement Office, 56.8 per cent went into laboratories, 23.3 per cent into industry, 16.6 per cent into teaching and 3.3 per cent to government.

Nearly 62 per cent of all those accepting employment are remaining in California, 23 per cent went to the East or Mid-west, 5.3 per cent went abroad.

Salary offers to graduates showed a substantial increase over a year ago. The median for B.S. degree men was $340 per month ($310 last year), but the maximum was over $520 per month. Initial offers to Ph.D.s ran to as high as $750 per month—averaging, however, just under $500. (Many accepted low-stipend fellowships to gain further research experience.)

The Placement Office also makes a special effort to assist alumni who are unemployed or are seeking better positions. The number seeking better positions was about the same (160) as in previous years. Of these 14 per cent were placed through the Office. The number reporting themselves as unemployed was only 45 (compared to nearly 200 in 1949-50). On the average each of these was provided with 8 referrals.

Finally the Placement Office had no trouble providing part-time or summer jobs for most of the students seeking them.

Thus the Caltech students and alumni are doing well in this period of shortage. The chief complaint—and a serious one—is that those who graduated 10 or more years ago have frequently not kept up, salary-wise, with the inflationary spiral. Inflation has the unfortunate (sometimes disastrous) habit of leaving professional and other salaried men behind. Upward revision of salary scales for engineers and scientists, in industry and in government, is long overdue.

Library

The heart of any institution of education and research is its library. Therein lies the storehouse of knowledge and inspiration to which the classroom and the laboratory are but introductions.

An adequate library of science and technology need not contain as many volumes as are required for a research library in literature or history. But the volumes are individually all the more precious. A large fraction of them will be bound periodicals, the lifeblood of science.

The Caltech library now contains 86,500 volumes, including 32,000 bound periodicals. It is growing at a rate of 5,000 volumes per year, and these volumes cost on the average nearly $8.00 apiece. Scientific books and periodicals are thus both expensive and indispensable.

Our library has now considerably outgrown the space available for it. The small central library and all departmental libraries are filled to overflowing and each year additional rooms, basement corridors and other scarce and unsatisfactory space must be found for new shelving. A new library building in the campus space that has long been reserved for it now ranks as one of the Institute's most desperate needs. It is earnestly hoped that funds for it can be found in the near future.

The Caltech library is becoming more and more a community asset. During the year there were 2686 loans to other libraries in this area, more than double the previous high of last year. Every community with such a thriving industry and technology as is found in Southern California needs a first-class library of science and technology. We should take pride in the opportunity of providing it.

The Faculty

As of June 30, 1952, the faculty of the Institute numbered 343 members (about one for every 3 students). There were 85 professors, 36 associate professors, 41 assistant professors and about 125 research fellows.

During the year there were two new appointments to the rank of professor: Dr. Harrison Brown (geochemistry) and Dr. Heinz A. Lowenstam (paleo-ecology). Four associate professors were promoted to professorships: Pol Duwez (mechanical engineering), Robert B. King (physics), Paco Lagerstrom (aeronautics) and Charles F. Richter (seismology). Ten distinguished scientists came to the Institute for periods of from two weeks to several months as visiting professors.

Many honors and awards came to members of the faculty during the year. Professors Richard M. Badger and Carl G. Niemann, both

of chemistry, were elected to the National Academy of Sciences. Linus Pauling was the first recipient of the Gilbert Newton Lewis Medal of the California Section of the American Chemical Society; Harrison Brown (geochemistry) received the American Chemical Society's $1000 award in pure chemistry; and William A. Fowler (physics) received the Lamme Medal from his alma mater, Ohio State University. Many other faculty members were appointed to various government committees or advisory boards; still others were elected to offices in national or international scientific organizations.

Three faculty members were lost by death during the year: Edward C. Barrett, Comptroller and Secretary, a beloved administrative officer of the Institute since 1911; Stuart S. Mackeown, Professor of Electrical Engineering, and Albert A. Merrill, Instructor in Aeronautics (retired).

Just after the close of the year the campus and the whole community were shocked by the passing of Franklin Thomas, a member of the faculty since 1913, Professor of Civil Engineering and Dean of Students. No member of the faculty has served the community more actively than Dean Thomas, the most recent of many recognitions of his services being his "Man of the Year" award by the Southern California Construction Industries "for having done the most to further the interests of the industry and of the entire community". His keen and kindly wisdom can not be replaced.

Research Highlights

The complete reports from the Division Chairmen found in Part IV of this report reveal advances on many fronts resulting from the Institute's extensive research program. Only a few of these can be mentioned here by way of illustration.

Virus Research. In the Division of Biology, Professor Renato Dulbecco has developed a new technique for studying those viruses which attack animal tissue (as compared to those which attack only plants or bacteria). Formerly such viruses could be studied only by the expensive and slow process of infecting monkeys or (at less cost) chicken embryos. Dulbecco's new technique is to grow a single layer of animal tissue cells in a nutrient medium in a small dish and then to introduce a weak suspension of virus particles. If a single virus attacks a tissue cell it will multiply and produce a small visible area of dead cells. Thus the number of virus particles in the original suspension can be counted and the progeny from any single virus can be "bred" for further study. This technique is analagous to the "plaque count" technique so widely and successfully used for study of viruses that

attack bacteria; it promises to accelerate enormously the study of animal viruses such as those which cause "polio" in human beings. Grants from the James G. Boswell Foundation made possible both the initiation and the continuation of this important work. Since the Institute does not yet have an adequately equipped laboratory to work with viruses that attack human beings, this work will be housed temporarily in the new Medical Research Laboratory of the Huntington Memorial Hospital in Pasadena.

High Energy Physics. A new landmark in the study of problems in high energy nuclear physics was reached when the new synchrotron which has been under construction for the past two years produced electrons with an energy of 525 million electron-volts. At the present writing this is the highest energy electron beam ever attained in a laboratory. The previous record was about 350 million. It has already been shown that this beam causes the creation of "pi" mesons, those mysterious short-lived particles first found in cosmic rays which appear to play an important but not-yet-understood role in the forces which hold atomic nuclei together. Experimental work with this unique electron beam and with the X-ray beam it produces will be in full swing during the coming year.

The high energy beam will give an approach to a tie-in with the much higher energy cosmic-ray phenomena which Dr. C. D. Anderson has been investigating so brilliantly for the last 20 years. This work too is moving into new areas with the completion of a new laboratory housing a large cloud chamber and magnet. Attention is now focused on a whole array of new nuclear particles discovered both here and elsewhere which have masses intermediate between the proton and the "pi" meson, and which are all unstable. How these particles fit into the structure of nuclear theory is still a puzzle; but first their properties and behavior must be learned.

Structural Chemistry. The structure of complex molecules is a problem requiring the continuous attention of chemists. Knowledge of structure not only casts light on the nature of the forces between atoms but also gives clues to reasons for chemical properties and to methods of synthesis. An important method of studying structure is through X-ray diffraction patterns—a complex array of spots on a photographic plate produced by the scattering of the X-rays from the electrons in the molecule. It has recently been found that there were inconsistencies in the X-ray data when molecules were studied which contained both heavy atoms (such as uranium) and light ones (such as fluorine). Dr. Verner Schomaker surmised that the theory of X-ray scattering from heavy complex atoms was incomplete, and

with the cooperation of Dr. Roy Glauber, Visiting Lecturer in Physics, and Dr. Robert Christy, Professor of Physics, worked out a better theory which has removed the discrepancies.

Last year Professors Pauling and Corey announced certain new ideas on the old and complex subject of the structure of protein molecules. These giant molecules are known to be made up of a multiplicity of sub-structures which are themselves complex molecules, known as amino acids. The problem has been to determine how these sub-structures were arranged to form the protein structure. In certain cases, Pauling and Corey showed, a helical or coiled-spring type of structure was indicated and they determined the diameter, the "tightness" and other properties of the "spring". Confirming investigations have now been reported from Cambridge University and the Royal Institution in England. It now appears that this spring-like structure is to be found in many proteins, including those found in hair, finger-nails, horns and skin.

Other proteins appear to be shaped like a plate or sheet, but one that is wrinkled or pleated in a particular pattern. These "inspired guesses" as to a particular structure can be verified from X-ray data, and much work is now in progress in many laboratories to test these new ideas. Knowledge of molecular structure is thus stimulated to rapid new advances.

Earthquake Studies. The recent Tehachapi earthquake stimulated renewed local interest in a subject which two Caltech groups have long been studying. In the Division of the Geological Sciences the Seismology Laboratory has been studying earthquake records for over 20 years. The recent shock and its many after-shocks were fully recorded on a dozen instruments in the Pasadena laboratory and in several field stations.

It was a quake of magnitude 7.5, on a scale in which an advance of 1 unit means a factor of 10 increase in amplitude of motion at a fixed distance from the source (100 kilometers). Thus a 7.5 quake is 10 times as "strong" as a 6.5 magnitude. The San Francisco quake of 1906 was of magnitude 8¼, thus was 5.6 times "stronger" than the Tehachapi quake. The Long Beach quake of 1932 was of magnitude 6¼ or 18 times less than Tehachapi.

The amount of ground motion at any particular location depends of course not only on the magnitude of the quake but the distance from the source. Thus the "Bakersfield quake" of August 22, 1952, was 1½ magnitudes weaker than the first Tehachapi shock of July 21. But because the source of the shock was very much closer to the city, Bakersfield was far more severely jolted on August 22.

Earthquakes, like the weather, are things one can talk about but which very few people do much about. One can not prevent quakes; one can not even predict them. But one can build buildings which will resist damage. Caltech engineers, led by Professor R. R. Martel and more recently by Professor G. W. Housner, have made great strides in this field. Their technique is to study the type of ground motion which accompanies quakes and then through model studies or by calculation (now made more accurate and easy by the analog computer in the Analysis Laboratory) they can predict the behavior of a given structure and can design new structures having maximum resistance. The question is often one of economics: how much expense is justified to protect against even the most violent quake? Fortunately, it is perfectly feasible economically—in fact it is an economic "must"—to build buildings which will withstand large shocks. Of course, no structural design will prevent electric light fixtures from falling, or bottles from tumbling off shelves. But the collapse of walls and roofs need not occur in properly designed buildings.

The Trustees

The Board of Trustees held its regular meetings the first Monday of each month (except one) during the year. The Finance Committee held five meetings and there were other meetings of regular or special committees. The Institute owes a great debt to the devoted services of the public spirited men on the Board who so effectively direct its complex operations.

During the year the Board lost through death the services of Edward C. Barrett, Comptroller and Secretary, whose long and intimate association with the Institute had given him a knowledge of Institute affairs which can not be replaced. His place will be taken by two men, George W. Green, Comptroller, and H. H. G. Nash, Secretary.

Mr. Ralph B. Lloyd, a member of the Board since 1939, resigned because of ill health.

Just as this report was in preparation came the news of the death on September 11 of James G. Boswell, a member of the Board since 1946. His devoted interest in the Institute will long be remembered, and we owe him a special debt for his generous financial support of the virus research program.

Respectfully submitted,

L. A. DuBridge, *President*

Part II

THE REPORTS OF THE SECRETARY AND THE COMPTROLLER

THE REPORT OF THE SECRETARY

To the Board of Trustees:

With the death on February 23, 1952 of Edward C. Barrett, who had been Secretary of the Institute continuously for forty-one years and both Secretary and Comptroller since 1934, the California Institute lost a highly capable and devotedly loyal administrative officer. His colleagues feel keenly the loss of a warm friend. He had been planning to retire on June 30, 1952 and we had been looking forward to a continuation of his valued friendship and wise counsel as he enjoyed his well-earned emeritus status. His successor as Secretary assumes the duties of this office with a feeling of gratitude for the many lessons learned as a result of long and close association with him, and with the humble hope that he may be given strength and wisdom to discharge these duties in a manner compatible with the high standards set by his predecessor.

During the fiscal year 1951-1952 the Board of Trustees held eleven meetings, the Finance Committee of the Board held five meetings and the Executive Committee one meeting.

Other Activities

In addition to the mechanics of Board and Committee meetings, and attending to the matters arising therefrom, the Secretary's office has continued certain administrative functions formerly performed by the office of the Assistant Secretary. The complex and ever-changing insurance structure of the Institute is given close and careful supervision, with the guidance of legal and insurance counsel. Properties and securities given to the Institute, and the recording of transactions in securities, are routed through this office, and, in collaboration with the other Institute administrative officers, suitably handled and recorded.

During the year, as a member of the Faculty Committee on Insurance and Annuities—and, again, with the collaboration of colleagues and the encouragement and support of the President and the Board of Trustees—considerable study has been made of various insurance and annuity plans for the staff of the Institute. This has resulted, so far,

in the improvement of such employee-benefit plans as the retirement annuity program and certain hospital, surgical and medical insurance coverages, as well as the adoption by the Board of a formal retirement policy for all members of the Institute group. A very favorable policy of student accident insurance was also negotiated. The Committee will continue its work, and I should like to express to my colleagues great appreciation for the many hours of "homework" they have contributed on the proposals which have been submitted.

Respectfully submitted,

HERBERT H. G. NASH, *Secretary*

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, 1952, 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, 1951 and 1952. It should be borne in mind that such table does not show either the segregation of assets and liabilities by funds or the inter-fund balances which are set forth on the accompanying balance sheet (Exhibit 2).

	1951	*1952*
Bonds, stocks and other investments	$27,819,180	$30,526,762
Plant and equipment	17,111,937	17,386,177
Cash	2,819,566	2,787,896
Receivable from U. S. Government	1,900,704	1,620,897
Prepayment of electrical energy charges		1,000,000
Other assets—books and supplies, student loans, miscellaneous receivables, etc.	758,301	977,818
	$50,409,688	$54,299,550
Deduct—		
Advances from:		
U. S. Government for expenditures under certain research contracts	$ 1,840,693	$ 1,773,771
Certain aircraft companies for prepayment of electrical energy charges for Southern California Cooperative Wind Tunnel		1,000,000
Current accounts payable and other liabilities	988,864	1,213,533
	$ 2,829,557	$ 3,987,304
Net assets	$47,580,131	$50,312,246

Representing capital of funds shown on following page:

	1951	*1952*
Current fund—		
Surplus:		
Unappropriated	$ 769,651	$ 776,583
Appropriated	458,758	537,737
Unexpended gifts and endowment income	1,428,220	1,850,654
	$ 2,656,629	$ 3,164,974
Loan funds	100,983	107,879
Endowment funds	23,888,572	25,644,210
Plant fund—		
Invested in plant	17,098,437	17,372,677
Unexpended	277,610	378,596
Trust funds	2,880,475	2,945,652
Agency funds	677,425	698,258
As above	$47,580,131	$50,312,246
Net increase during the year	$2,732,115	

Set forth below is a summary of the transactions for the year which resulted in net increase of $2,732,115 in Institute surplus and capital:

Current income (particulars on the following page)		$16,813,740
Profit on disposal of investments (net)		1,780,283
Gifts received, excluding gifts treated as current income		291,722
Allowance under research contracts for use of facilities		133,000
Repayment by trustee of advances to Eudora Hull Spalding trust		115,703
Unexpended investment income (not included above in current income)		108,418
Agency funds received, less disbursements		16,234
Other additions (net)		6,356
		$19,265,456
Current expenditures (particulars on following page)	$16,682,411	
Less—Expenditures for plant added to plant capital	187,204	
	$16,495,207	
Other expenditures charged to reserves, etc.	38,134	
		16,533,341
Net increase during the year		$ 2,732,115

CURRENT FUND

There follows a condensed summary of current income and expenditures for the year ended June 30, 1952:

	Instructional departments	*Organized research (see note)*	*Total*
Income:			
Tuition and fees	$ 588,873		$ 588,873
Endowment income	1,554,059		1,554,059
Gifts	951,715		951,715
Billings to United States Government under research contracts for:			
Direct expenditures	1,766,928	$ 9,622,901	11,389,829
Indirect expenditures (administration, plant operation, library, etc.)	248,453	473,730	722,183
Billings to others under research contracts for:			
Direct expenditures	108,342	1,322,994	1,431,336
Indirect expenditures	48,070	59,684	107,754
Auxiliary enterprises and activities (net)	13,208		13,208
Other	54,783		54,783
	$5,334,431	$11,479,309	$16,813,740
Expenditures:			
Administration and general	$ 224,279	$ 468,817	$ 693,096
Departmental instruction and research	2,319,782		2,319,782
Plant operation, maintenance, and improvements	443,820	44,704	488,524
Direct expenditures for:			
Research under contracts with United States Government	1,766,928	9,622,901	11,389,829
Research contracts with others	108,342	1,322,994	1,431,336
Retirement allowances, federal old age benefit taxes, etc.	141,379	19,893	161,272
Scholarships and fellowships	198,572		198,572
	$5,203,102	$11,479,309	$16,682,411
Excess of income	$ 131,329		$ 131,329

Note: Jet Propulsion Laboratory, Southern California Cooperative Wind Tunnel, and Project Vista.

Income from endowment investments used for current purposes totaled $1,554,059 during the year ended June 30, 1952 as compared with $1,547,939 in the year ended June 30, 1951 as summarized below:

	1951	*1952*
Income received from investments in:		
Marketable securities (see table below)	$ 1,272,352	$ 1,317,103
Real estate	229,385	230,746
Beneficial interest in—		
Eudora Hull Spalding trust	176,040	131,351
Other trusts and estates	5,711	6,191
Receivables and other investments	30,715	20,215
	$ 1,714,203	$ 1,705,606
Portion of income from certain investments applied in reduction of their carrying value in recognition of depreciation and depletion	(56,801)	(43,129)
Net investment income	$ 1,657,402	$ 1,662,477
Less—Income retained and added to unexpended income balances of endowment and other funds (net)	109,463	108,418
Remainder applied as current income	$ 1,547,939	$ 1,554,059

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, 1951 and 1952 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*	
	1951	*1952*	*1951*	*1952*
Bonds:				
United States Government	$ 92,334	$ 86,941	1.9	1.6
Municipals	4,920	4,813	3.7	3.7
Canadian and foreign	18,646	18,971	2.9	2.7
Utilities	25,921	31,528	3.1	3.7
Industrials	11,065	14,046	3.2	1.6
Rails	8,000	10,084	7.2	6.9
Others	6,700	6,700	10.3	10.3
	$ 167,586	$ 173,083	2.4	2.1
Preferred stocks:				
Utilities	$ 64,454	$ 62,891	4.6	4.3
Industrials	103,425	102,129	4.5	4.3
Rails	6,705	6,694	4.5	4.5
Banks and other financial	9,177	8,357	1.0	.9
	$ 183,761	$ 180,071	3.8	3.6
Common stocks:				
Utilities	$ 260,478	$ 335,020	6.5	6.6
Industrials	511,469	470,277	10.2	11.5
Rails	33,018	39,485	6.7	8.0
Insurance	14,164	14,299	4.5	4.5
Banks and other financial	101,876	104,868	4.7	4.7
	$ 921,005	$ 963,949	7.7	7.9
Total	$1,272,352	$1,317,103	5.3	5.2

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

Division	*Expenditures* 1951	1952
Engineering:		
Administration	$ 39,913	$ 29,439
Civil engineering	46,930	44,839
Mechanical engineering	149,616	134,696
Electrical engineering	97,443	92,485
Applied mechanics	27,477	24,105
Aeronautics	113,546	110,792
Jet propulsion	28,410	19,856
	$ 503,335	$ 456,212
Physical sciences:		
Physics	$ 184,145	$ 175,612
Astronomy	16,158	15,320
Mathematics	82,542	79,577
	$ 282,845	$ 270,509
Chemical sciences:		
Chemistry	$ 515,822	$ 440,368
Chemical engineering	93,680	89,553
	$ 609,502	$ 529,921
Geological sciences	$ 192,104	$ 202,790
Biological sciences	419,865	454,929
Humanities	171,517	185,707
Palomar Observatory	85,377	122,620
Physical education	58,292	54,704
Industrial relations	25,030	42,390
	$ 2,347,867	$ 2,319.782
The total expenditures in the two years were for:		
Salaries	$ 1,852,429	$ 1,797,230
Materials, supplies, etc.	337,302	369,162
Equipment added to plant capital	158,136	153,390
	$ 2,347,867	$ 2,319,782

Direct expenditures for research under contracts with the United States Government in the two years ended June 30, 1951 and June 30, 1952, are summarized below:

	1951	1952
Departments of the:		
Air Force	$ 428,841	$ 281,937
Army	4,614,333	9,371,814
Navy	1,020,381	1,131,434
Atomic Energy Commission	388,013	542,149
Others	39,658	62,495
	$ 6,491,226	$11,389,829

ENDOWMENT FUNDS

The following is a comparative classified summary of the Institute's investments (excluding investments of trust funds) at June 30, 1951 and 1952:

	Market value of securities		*Carried at*		*Per cent of total*	
	1951	*1952*	*1951*	*1952*	*1951*	*1952*
Marketable securities:						
Bonds—						
U. S. Govt.	$ 4,635,277	$ 5,954,852	$ 4,743,576	$ 6,043,983	19.2	22.1
Municipals	124,250	125,500	130,484	130,484	.5	.5
Canadian and foreign	581,480	826,950	597,020	796,770	2.4	2.9
Utilities	680,980	955,680	709,699	981,562	2.9	3.6
Industrials	288,161	1,417,740	298,540	1,405,649	1.2	5.1
Rails	160,500	232,200	111,588	181,587	.4	.7
Others	144,235	144,275	64,887	64,887	.3	.2
	$ 6,614,883	$ 9,657,197	$ 6,655,794	$ 9,604,922	26.9	35.1
Preferred stocks—						
Utilities	$ 1,349,121	$ 1,544,065	$ 1,401,799	$ 1,550,865	5.7	5.7
Industrials	2,050,517	2,503,927	2,130,397	2,575,121	8.6	9.4
Rails	126,080	130,800	147,539	147,539	.6	.5
Banks, etc.	974,250	974,049	970,650	970,650	3.9	3.5
	$ 4,499,968	$ 5,152,841	$ 4,650,385	$ 5,244,175	18.8	19.1
Common stocks—						
Utilities	$ 5,299,694	$ 6,479,420	$ 4,871,135	$ 5,236,643	19.7	19.1
Industrials	8,292,922	6,607,435	4,741,626	3,447,285	19.1	12.6
Rails	411,495	488,425	495,936	495,936	2.0	1.8
Insurance	378,688	449,672	314,241	316,540	1.3	1.2
Banks, etc.	2,028,767	2,326,326	2,187,305	2,248,621	8.8	8.2
	$16,411,566	$16,351,278	$12,610,243	$11,745,025	50.9	42.9
Total marketable securities	$27,526,417	$31,161,316	$23,916,422	$26,594,122	96.6	97.1
Stocks and bonds without market quotations			37,844	37,848	.1	.1
Notes and contracts receivable			4,574	2,864		
Real estate and leasehold			810,161	767,032	3.3	2.8
Beneficial interests in estates and trusts (carried at nominal amounts)			31	36		
Total investments			$24,769,032	$27,401,902	100.0	100.0
Comprising:						
Consolidated portfolio			$21,125,985	$23,393,196	85.3	85.4
Separate investments			3,643,047	4,008,706	14.7	14.6
			$24,769,032	$27,401,902	100.0	100.0

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

Charles G. Strater Fund	$10,000
Van Maanen Fund	14,470
Alumni Association	27,155
Others	4,666
	$56,291

PLANT FUNDS

There follows a summary of the changes during the year in the accounts for land, buildings and equipment:

	At June 30 1951	*Net additions*	*At June 30 1952*
Campus, buildings and equipment:			
Land	$ 706,000	$ (3,024)	$ 702.976
Land improvements	205,584	17,225	222,809
Buildings	6,385,977	61,618	6,447,595
Equipment	3,186,062	178,373	3,364,435
	$10,483,623	$ 254,192	$10,737,815
Construction costs of Palomar Observatory and related buildings and equipment:			
Building and equipment on Institute campus	$ 893,066		$ 893,066
Experimentation and manufacture of reflectors	1,334,787	$ 4,255	1,339,042
Design and mountings	3,106,750	11,775	3,118,525
Telescope site and improvements	847,265	(593)	846,672
Expense of committees	277,020		277,020
Auxiliary equipment	169,426	4,611	174,037
	$ 6,628,314	$ 20,048	$ 6,648,362
	$17,111,937	$ 274,240	$17,386,177

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

GRANTS, GIFTS AND INDUSTRIAL ASSOCIATE INCOME

Grants, gifts, and Industrial Associate income received during the year for restricted and general purposes amounted to $1,200,419 as compared to $1,024,612 in the prior year. Presented below is a list of payments, indicating the purpose for which each was contributed:

Educational and general purposes:

Restricted—

Rockefeller Foundation for:

Combined research in biology and chemistry $ 32,956

Aeronautics:

Sundry donors to A. A. Merrill Fund—Aerolab Development Co., I. L. Ashkenas, W. Bollay, E. L. Brown, W. Cerny, D. W. Douglas, Harold Fischer, R. E. Fisher, W. L. Koch, P. Kyropoulos, H. W. Liepmann, A. E. Lombard Jr., F. L. Malina, R. E. Marquardt, H. C. Martin, C. B. Millikan, J. K. Northrop, A. E. Raymond, E. E. Sechler, P. Serrell, and N. Svendsen 796

Biology:	
American Cancer Society	17,000
American Society of Heating & Ventilating Engineers	1,500
James G. Boswell Foundation	125,000
E. I. DuPont de Nemours & Company	10,900
Herman Frasch Foundation	11,833
General Electric Company	10,000
John Simon Guggenheim Memorial Foundation for Dr. Tyler	2,850
Ibec Research Institute	3,000
International Minerals and Chemical Corporation	14,505
County of Los Angeles, Air Pollution Control District	9,000
F. S. Markham	4,200
Merck & Company, Inc.	6,000
National Foundation for Infantile Paralysis	26,459
National Science Foundation	39,800
The Nutrition Foundation, Inc.	4,500
The Nutrition Foundation, Inc.-The McCallum Foundation, Inc.	2,500
Research Corporation (Williams-Waterman Fund)	5,250
Riker Laboratories, Inc.	6,000
Damon Runyon Memorial Fund	10,000
United States Public Health Service	37,257
University of California	10,319
Others—H. O. Eversole, M. McNaghten, I. M. Mountain, Planned Parenthood Federation of America, and donors to Cymbidium Society Fund (L. Sherman Adams Co., American Orchid Society, Armacost and Royston Inc., Beall Greenhouse Co., L. M. Boyle, Clarelen Orchids, Coolidge Rare Plant Gardens Inc., I. Haupt, E. W. Menninger, S. B. Mosher, Parmentier's Roses, Sherman Orchid Gardens)	3,283
Chemistry and Chemical Engineering:	
American Petroleum Institute	57,500
E. I. DuPont de Nemours & Company	10,000
Fluor Corporation, Ltd.	3,500
Lederle Laboratories Division—American Cyanamid Company	10,000
National Foundation for Infantile Paralysis	12,727
Shell Oil Company	5,000
United States Public Health Service	100,100
Others—American Cancer Society and National Research Council	521
Engineering:	
AiResearch Manufacturing Company	3,400
Consolidated Engineering Corporation	5,000
Continental Oil Company	10,000
Daniel and Florence Guggenheim Foundation	35,000
City of Los Angeles, Department of Power and Light	1,000
Cole Electric Company	4,000
Hughes Aircraft Company	6,500
International Business Machines Corporation	3,200
Kelman Electric and Manufacturing Company	8,112
A. O. Smith Corporation	10,000
State of California, Water Pollution Control Board	13,195
Union Carbide and Carbon Corporation	2,600
Other—F. A. Shaak, Jr.	50

Geology, Paleontology and Seismology:	
John Simon Guggenheim Memorial Foundation for Dr. Harrison Brown	7,000
Rockefeller Foundation	5,800
Others—Anonymous donor and C. Frick	1,200
Humanities:	
Carnegie Corporation	30,000
Industrial Relations:	
Consolidated Engineering Corporation	2,000
General Petroleum Corporation	2,500
Richfield Oil Corporation	2,500
Southern California Edison Company	1,500
Standard Oil Company of California	17,185
Others—70	13,393
Palomar Observatory:	
National Geographic Society	25,000
Physics:	
William E. Hale Fund	1,500
Hughes Aircraft Company	3,500
International Business Machines Corporation	3,200
Shell Oil Company	5,000
Other Restricted Purposes:	
Alumni Association—California Institute of Technology	1,586
Carnegie Foundation for Advancement of Teaching	1,800
Others—Coulter Dry Goods Company, F. F. Foss, and sundry donors for library	933
General or Undesignated purposes:	
Industrial Associates—	
California Research Corporation (subsidiary of Standard Oil Company of California)	10,000
Consolidated Engineering Corporation	10,000
Douglas Aircraft Company, Inc.	10,000
General Petroleum Corporation— Socony-Vacuum Oil Company, Inc.	10,000
Gulf Research & Development Company	10,000
Hughes Aircraft Company	10,000
Eli Lilly & Company	10,000
Lockheed Aircraft Corporation	10,000
Merck & Company, Inc.	10,000
North American Aviation, Inc.	10,000
Pacific Iron and Steel Company	10,000
Republic Aviation Company	20,000
Richfield Oil Corporation	20,000
Stanolind Oil and Gas Company	10,000
Union Carbide and Carbon Corporation	10,000
Union Oil Company of California	10,000
General—	
J. G. Boswell Company	1,000
C. F. Braun Company	1,000
California Institute Research Foundation	10,000
California Institute Associates	103,700
K. T. Norris	1,628
Class of 1927	1,305
John A. McCone	5,000
Others—Beckman Foundation, R. Crutcher, J. E. Fleming	625

Auxiliary enterprises and activities:	
Carnation Company	1,909
California Institute Associates	8,400
Emergency Hospitalization Fund	5,078
Service League	699
Non-educational purposes:	
Scholarships and fellowships—	
Allied Chemical and Dye Corporation	1,692
California Research Corporation	1,520
Douglas Aircraft Company	1,800
E. I. DuPont de Nemours & Company	5,900
Eastman Kodak Company	1,816
Ethyl Corporation	1,500
Forest Lawn Foundation	2,500
General Petroleum Corporation	2,750
John B. Keating	1,000
Amie S. Kennedy	1,000
McCallum Foundation, Inc.	4,600
George H. Mayr Educational Foundation	9,500
Radio Corporation of America	2,700
Shell Oil Company	4,232
Standard Oil Company of California	3,700
Stanolind Oil & Gas Company	1,850
United States Rubber Company	2,200
Westinghouse Educational Foundation	2,000
Others—Automotive Council, Inc., Gnome Club, W. Johnson, Management Club, S. G. Mudd, Phi Beta Kappa Alumni Association, sundry donors to Donald L. Shepard Memorial Fund, and sundry former students of Royal W. Sorensen	4,040
Other purposes—	
Sundry donors for Film Classic assemblies	1,865
	$1,200,419

Respectfully submitted:

G. W. GREEN, *Comptroller*

PRICE WATERHOUSE & CO.

Exhibit 1

530 WEST SIXTH STREET
LOS ANGELES 14
September 12 1952

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 1952 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 1952 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		$ 746,170.63
Receivables:		
United States Government		1,620,897.43
Advances to trust fund		19,599.18
Tuition and fees, fully reserved	$ 15,242.40	
Other receivables		121,259.58
Supplies, food and books, at cost		172,936.05
Deferred charges		104,264.20
		$ 2,785,127.07
Restricted—		
Cash	$ 1,254,696.36	
Advances to current unrestricted fund	1,192,272.18	
Share in endowment fund assets	1,715,193.71	
		4,162,162.25
		$ 6,947,289.32
LOAN FUND ASSETS:		
Cash	$ 20,794.68	
Share in endowment fund assets	27,000.00	
Loans receivable	66,815.37	
		114,610.05
ENDOWMENT FUND ASSETS:		
Cash	$ 315,323.64	
Receivables	169.24	
Investments carried at	27,401,902.02	
		27,717,394.90
PLANT FUND ASSETS:		
Invested in plant—		
Campus buildings and equipment	$10,737,815.21	
Palomar observatory	6,648,361.78	
	$17,386,176.99	
Uninvested cash	94,321.80	
Share in endowment fund assets	284,273.94	
		17,764,772.73
TRUST FUND ASSETS:		
Cash	$ 32,228.41	
Investments carried at	3,124,859.83	
		3,157,088.24
AGENCY FUND ASSETS:		
Cash	$ 324,360.13	
Receivables	492,017.92	
Prepayment of electrical energy charges	1,000,000.00	
Prepaid insurance	20,355.95	
Share in endowment fund assets	46,717.08	
		1,883,451.08
		$57,584,606.32

—BALANCE SHEET—JUNE 30, 1952

Exhibit 2

CURRENT FUND LIABILITIES AND CAPITAL:		
Unrestricted—		
Accounts payable		$ 540,173.66
Accrued salaries and wages		245,993.44
Deposits and advanced collections		30,104.97
Payable to current restricted fund		1,192,272.18
		$ 2,008,544.25
Unappropriated surplus (Exhibit 3)		776,582.82
		$ 2,785,127.07
Restricted—		
Advances from United States Government for expenditures under certain research contracts	$ 1,773,771.34	
Appropriations of surplus for current purposes (Exhibit 3)	537,737.08	
Unexpended gifts for current purposes	1,145,061.66	
Unexpected endowment income	705,592.17	
		4,162,162.25
		$ 6,947,289.32
LOAN FUND LIABILITIES AND CAPITAL:		
Loan fund returnable to donor	$ 6,730.64	
Loan fund capital	107,879.41	
		114,610.05
ENDOWMENT FUND LIABILITIES AND CAPITAL:		
Share of other funds in endowment fund assets	$ 2,073,184.73	
Endowment capital	25,644,210.17	
		27,717,394.90
PLANT FUND LIABILITIES AND CAPITAL:		
Invested in plant—		
Deferred liability due in 1957	$ 13,500.00	
Plant capital	17,372,676.99	
	$17,386,176.99	
Unexpended plant funds	378,595.74	
		17,764,772.73
TRUST FUND LIABILITIES AND CAPITAL:		
Interest paid to creditors	$ 179,908.06	
Payable to current fund	19,599.18	
Undistributed income	11,928.45	
Trust capital	2,945,652.55	
		3,157,088.24
AGENCY FUND LIABILITIES:		
Accounts payable and accrued expenses	$ 185,193.47	
Advances from certain aircraft companies for prepayment of electrical energy charges	1,000,000.00	
Agency funds	698,257.61	
		1,883,451.08
		$57,584,606.32

	Total surplus	*Unappropriated*	*Appropriated*
Balance at June 30, 1951	$ 1,228,408.96	$ 769,651.26	$458,757.70
Current income and expenditures for year ended June 30, 1952:			
Income (Exhibit 4)	17,403,512.17	17,403,512.17	
Expenditures (Exhibit 5)	(17,272,184.78)	(17,272,184.78)	
Reversal of surplus appropriations made in prior years to cover expenditures included above		1,303.11	(1,303.11)
Appropriations for:			
Current purposes		(56,554.57)	56,554.57
Additions to plant	(69,144.37)	(69,144.37)	
Allocation of profit on disposal of investments of consolidated portfolio (Income of $22,278.55 allocable to appropriate balances invested in the consolidated portfolio was included in current fund income—see Exhibit 4)	23,727.92		23,727.92
Balance at June 30, 1952	$ 1,314,319.90	$ 776,582.82	$537,737.08
		(Exhibit 2)	(Exhibit 2)

YEAR ENDED JUNE 30, 1952

Exhibit 3

APPROPRIATED FOR				
Aeronautics research	*Income stabilization*	*Biology*	*Chemical engineering*	*Scholarships*
$223,012.43	$178,691.77	$52,372.89	$2,740.72	$1,939.89
				(1,303.11)
33,818.24	17,831.01			4,905.32
9,292.81	11,070.32	3,244.61		120.18
$266,123.48	$207,593.10	$55,617.50	$2,740.72	$5,662.28

Exhibit 4

CURRENT INCOME—YEAR ENDED JUNE 30, 1952

Educational and general:		
Tuition and fees		$ 588,872.55
Endowment income—		
For restricted purposes	$1,044,395.15	
For general purposes	442,029.07	
		1,486,424.22
Gifts—		
For restricted purposes	$ 609,098.48	
For general purposes	266,926.27	
		876,024.75
Billings to United States Government under research contracts		12,112,012.38
Billings for other special research—wind tunnel tests, etc.		1,539,090.18
Income from investments allocable to appropriations of current surplus		22,278.55
Sales and services of educational departments		15,744.28
		$16,640,446.91
Auxiliary enterprises and activities:		
Bookstore	$ 101,300.54	
Cafeteria	74,587.67	
Student houses—		
Campus	233,870.24	
Arcadia	18,690.56	
Athenaeum	125,224.34	
Dormitory	8,953.36	
Health center	33,578.54	
Student athletic fees	6,775.98	
		602,981.23
Other noneducational income:		
Endowment income—		
For annuities, scholarships, fellowships and prizes	$ 67,634.82	
Gifts—		
For scholarships, fellowships, etc.	75,690.34	
Rentals	5,423.46	
Miscellaneous	11,335.41	
		160,084.03
		$17,403,512.17

(Exhibit 3)

Exhibit 5

CURRENT EXPENDITURES—YEAR ENDED JUNE 30, 1952

	Salaries and wages	*Materials, supplies, etc.*	*Equipment added to plant capital*	*Total*
Educational and general:				
Administrative and general	$ 458,551.49	$ 228,172.04	$ 6,372.89	$ 693,096.42
Departmental instruction and research	1,797,229.71	369,162.30	153,390.02	2,319,782.03
Operation and maintenance of academic plant	347,228.31	126,681.32	9,123.95	483,033.58
Expenditures for campus land and improvements			5,490.08	5,490.08
Direct expenditures under contracts with United States Govt.	5,475,691.75	5,912,006.55	2,131.10	11,389,829.40
Expenditures for other special research	983,016.38	442,128.75	6,191.08	1,431,336.21
General library	30,219.98	3,082.61	865.44	34,168.03
Retirement allowances, federal old age benefit taxes and annuity premiums		121,547.29		121,547.29
	$9,091,937.62	$7,202,780.86	$183,564.56	$16,478,283.04
Auxiliary enterprises and activities:				
Bookstore	$ 11,820.15	$ 84,261.00	$ 426.64	$ 96,507.79
Cafeteria	28,320.10	45,410.89	2,082.40	75,813.39
Student houses—				
Campus	95,212.52	128,565.40	140.38	223,918.30
Arcadia	5,539.98	5,357.05	101.10	10,998.13
Athenaeum	61,289.33	72,379.86	190.77	133,859.96
Dormitory	4,307.21	3,010.11		7,317.32
Health center	29,397.69	11,262.02	698.62	41,358.33
	$ 235,886.98	$ 350,246.33	$ 3,639.91	$ 589,773.22
Other noneducational expenses:				
Scholarships and fellowships		$ 198,571.45		$ 198,571.45
Annuity payments		3,260.20		3,260.20
Other		2,296.87		2,296.87
	$9,327,824.60	$7,757,155.71	$187,204.47	$17,272,184.78

(Exhibit 3)

NOTE—Approximately $1,000,000 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 faculty of the California Institute has during the past year continued to increase in numbers as well as in experience and prestige. It now numbers 343. Of these, 85 are professors, 36 are associate professors, and 41 are assistant professors. The remainder are professors emeriti, visiting professors, research associates, lecturers, research fellows, etc.

As usual, a distinguished group of visiting professors and research associates spent the whole or part of the year lecturing or carrying on research at the Institute. These included, among others, such men as Kenneth T. Bainbridge, Professor of Physics, Harvard University; Hans Bethe, Professor of Theoretical Physics, Cornell University; Hans G. Borei of the Wenner-Gren Institute, University of Stockholm, Sweden; Edward G. Bowen, Director, Radiophysics Laboratory, Sydney, Australia; S. Chandrasekhar, Distinguished Service Professor of Astronomy, Yerkes Observatory, University of Chicago; E. Havinga, Laboratory of Organic Chemistry, University of Leiden, Holland; John von Neumann, Institute for Advanced Study, Princeton; Jan H. Oort, Director of the Observatory, University of Leiden, Holland; and Hans Wanner, Director, Institute of General Botany, University of Zurich, Switzerland.

An important new program in geochemistry was initiated during the year and the work in the earth sciences was greatly strengthened by the addition of Professors Harrison S. Brown (geochemistry) and Heinz A. Lowenstam (paleo-ecology), both from the University of Chicago. Other important additions to the permanent staff include William H. Corcoran, Associate Professor of Chemical Engineering; James N. Thurston, Associate Professor of Electrical Engineering; John R. Weir, Associate in Psychology; Guido Münch, Assistant Professor of Astronomy; and Henry D. Piper, Assistant Professor of English.

Faculty, as well as students, profited greatly by the initiation of the American Universities Field Staff plan during the year. Under this

plan a group of American colleges and universities send qualified young men out as their representatives in foreign areas. In addition to mailing back regular reports to the sponsoring colleges and universities, each of these men returns home every two years to visit the campus of each of the sponsoring institutions to report in person on current conditions, problems, and personalities in the area he is studying. During the past year four of these men spent several weeks at the Institute: Edwin S. Munger, a specialist on East Africa; John B. George, a specialist on West Africa; Albert Ravenholt, a specialist on the Far East; and Phillips Talbot, a specialist on Pakistan and India. Existing courses of instruction were expanded and enriched by these direct reports on conditions in these various sections of the world and the international outlook of both faculty and students was considerably broadened.

It is a rare year, indeed, in which some losses through death, resignation or retirement are not experienced along with the gains, and the past year was no exception. Through the deaths of Edward C. Barrett, Comptroller and Secretary of the Institute; Stewart S. Mackeown, Professor of Electrical Engineering, and Albert A. Merrill, Instructor in Aeronautics, the faculty lost valued friends and comrades who, in one sense, can never be replaced. Resignations were few in number, however, and included only Charles W. Merriam, Associate Professor of Paleontology, and Richard B. Beaman, Lecturer in Art. Arthur H. Young also resigned as Lecturer on Industrial Relations, but will still be associated with us as Lecturer Emeritus. Royal W. Sorensen, Professor of Electrical Engineering, Luther E. Wear, Associate Professor of Mathematics, and William N. Birchby, Assistant Professor of Mathematics, all reached retiring age during the year, after many years of outstanding service to the Institute.

Many honors and awards came to members of the Institute staff during the year as well as new responsibilities. President Truman named President Lee A. DuBridge as Chairman of the Science Advisory Committee of the Office of Defense Mobilization, and five Institute representatives have been appointed to the technical subcommittees of the National Advisory Committee for Aeronautics for 1952 —namely, Clark B. Millikan, Hans W. Liepmann, Ernest E. Sechler, Frank E. Marble and W. Duncan Rannie. Also, Milton E. Plesset and W. Duncan Rannie have been named by General Vandenberg, U. S. Air Force Chief of Staff, to serve as members of his Scientific Advisory Staff, and George W. Beadle was appointed to the National Science Foundation Divisional Committee for the Biological Sciences.

Election to the National Academy of Sciences came during the year to Richard M. Badger and Carl G. Niemann, thus bringing the present Institute staff membership in the Academy to 25.

Linus Pauling was the first recipient of the Gilbert Newton Lewis Medal of the California Section of the American Chemical Society; Harrison S. Brown received the American Chemical Society's $1000 award in pure chemistry—one of the highest honors in American chemistry; Guy Camus received the first award of the Louis Rapkine Foundation of Paris for distinguished work in biology; and William A. Fowler was awarded the Lamme Medal of the Ohio State University.

John P. Buwalda was reelected for a second term to the presidency of the Seismological Society of America, and Ian Campbell was elected chairman of the Industrial Minerals Division of the American Institute of Mining Engineering. Beno Gutenberg, at the meetings of the International Geophysical Union in Brussels, was elected President of the Association of Seismology and Physics of the Interior of the Earth. At the invitation of UNESCO he also spent some time in Turkey, advising government authorities on the installation of a Turkish Seismological Institute and several seismological stations.

Franklin Thomas was named "Man of the Year" by more than 100 representatives of the Southern California construction industry at their 17th annual banquet in Los Angeles and was presented with the Construction Industries Achievement Award "for having done the most to further the interests of industry and of the entire community."

Four Institute faculty members were awarded Research Fellowships by the John Simon Guggenheim Memorial Foundation. Harrison Brown received a three-year fellowship and Jerry Donohue, Kenneth W. Hedberg, and Marguerite M. P. Vogt one-year fellowships. Sterling Emerson also received a Guggenheim Fellowship together with a Fulbright award for a year's study at the University of Cambridge, University of Paris, and the Pasteur Institute, and George K. Tanham was awarded a Faculty Fellowship of the Fund for the Advancement of Education established by the Ford Foundation.

Robert T. Knapp was honored by being invited to deliver the annual James Clayton Lecture before the Institution of Mechanical Engineers in London, England, and I. S. Bowen was Halley Lecturer at Oxford University, England.

Changes in the Faculty

(a) Administrative Officers

1. H. F. Bohnenblust, Chairman of the Faculty, succeeding Ian Campbell.
   H. J. Lucas, Vice Chairman of the Faculty, succeeding H. F. Bohenblust.

2. Robert P. Sharp, Chairman of the Division of Geological Sciences, succeeding Ian Campbell, who served as Acting Chairman following the death of Chester Stock.

(b) PROMOTIONS

1. *To the rank of Professor, Emeritus:*

   Aladar Hollander (Mechanical Engineering)

2. *To the rank of Professor:*

   Pol Duwez (Mechanical Engineering)
   Robert B. King (Physics)
   Paco Lagerstrom (Aeronautics)
   Charles F. Richter (Seismology)

3. *To the rank of Associate Professor:*

   Norman Davidson (Chemistry)
   Renato Dulbecco (Biology)
   Arthur W. Galston (Biology)
   Peter Kyropoulos (Mechanical Engineering)
   Robert V. Langmuir (Electrical Engineering)
   Charles Wilts (Electrical Engineering)

4. *To the rank of Assistant Professor:*

   Matthew Sands (Physics)
   Ward Whaling (Physics)
   N. H. Wilcox (Engineering Drafting)

5. *To the rank of Senior Research Fellow:*

   Harvey A. Itano (Chemistry)
   Anton Lang (Biology)
   George C. Laties (Biology)
   Howard J. Teas (Biology)

6. *To the rank of Instructor:*

   Henry A. Dye (Physics)

(c) NEW APPOINTMENTS

1. *Professors:*

   Harrison S. Brown (Geochemistry)
   Heinz A. Lowenstam (Paleo-ecology)

2. *Visiting Professors:*

   Hans Bethe, Cornell University (Physics)
   David W. Bishop, Professor of Zoology, University of Massachusetts (Biology)
   Hans B. Borei, Wenner-Gren Institute, University of Stockholm (Biology)
   Edward G. Bowen, Director, Radiophysics Laboratory, Sydney, Australia (Physics)
   S. Chandrasekhar, Yerkes Observatory (Astronomy)
   E. Havinga, Laboratory of Organic Chemistry, Leiden University (Chemistry)
   Warren D. Kumler, Professor of Chemistry, University of California College of Pharmacy (Chemistry)
   John von Neumann, Institute for Advanced Study, Princeton University (Mathematics)
   Jan H. Oort, Director of the Observatory, Leiden University (Astronomy)
   Hans Wanner, Director, Institute of General Botany, University of Zurich (Biology)

3. *Associate Professors:*

William H. Corcorn (Chemical Engineering)
James N. Thurston (Electrical Engineering)

4. *Research Associates:*

Kenneth T. Bainbridge, Professor of Physics, Harvard University (Physics)
Stanley Benscoter, Consulting Aeronautical Engineer (Engineering)
Sidney Siegel, Director, Atomic Energy Research Group, North American Aviation (Physics)
Charles E. Weaver, Professor Emeritus, University of Washington (Paleontology)

5. *Associates:*

Frederick Tolles (History)
John R. Weir (Psychology)

6. *Senior Research Fellows:*

Ernst S. Selmer (Mathematics)
A. M. Binnie (Engineering)

7. *Assistant Professors:*

Demorest Davenport (Biology; Summer only)
Guido Münch (Astronomy)
Henry D. Piper (English)

8. *Lecturers:*

John H. Carr (Applied Mechanics)
Roy J. Glauber (Physics)
Edward J. Hutchings, Jr. (Journalism)
Charles H. Papas (Electrical Engineering)

9. *Visiting Lecturers:*

John B. George (International Affairs)
Edwin E. Munger (International Affairs)
Albert Ravenholt (International Affairs)
Phillips Talbot (International Affairs)

10. *Instructors:*

F. Brock Fuller (Mathematics)
Forrest Gilmore (Applied Mechanics)
Robert D. Wayne (German)
Richard S. Westfall (History)

11. *Research Fellows:*

Fay Ajzenberg (Physics)
Raymond Appleyard (Biology)
Gunnar Bergman (Chemistry)
Sidney A. Bernhard (Chemistry)
David Bertin (Mathematics)
Claude Bloch (Physics)
Jean Campbell (Biology)
George Cleland (Chemistry)
John Cushing (Chemistry)
Warren Danielson (Physics)
August H. Doerman (Biology)
Samuel Epstein (Geochemistry)
Jose Fernandez-Alonso (Chemistry)
George E. Florey (Biology)
Hugh S. Forrest (Biology)
Robert J. Foster (Chemistry)
A. P. French (Physics)
Akio Fujiwara (Biology)
P. G. Gane (Geology)
Justine Garvey (Chemistry)
Morris Goodman (Biology)
Francis Haskin (Biology)
Joseph T. Holden (Biology)
Paul V. C. Hough (Physics)
Harry C. Hoyt (Physics)
Walter L. Hughes, Jr. (Chemistry)

Herbert M. Hull (Biology)
Lewis Katz (Chemistry)
B. Kenneth Koe (Chemistry)
Peter Kriezis (Mathematics)
Otto B. Landman (Biology)
William Lijinsky (Chemistry)
Jan Links (Biology)
Raphael Littauer (Physics)
James L. Liverman (Biology)
Henk G. Loos (Jet Propulsion)
Ole Maaloe (Biology)
Pierre Marmier (Physics)
Ronald G. Mason (Geophysics)
Charles R. McKinney (Geochemistry)
Curt Mileikowsky (Physics)
Claire C. Patterson (Geochemistry)
Thad H. Pittenger (Biology)
Leonard Rack (Chemistry)
Wilfredo de Rafols (Biology)
Moshe Rim (Engineering)
Heinrich Rinderknecht (Chemistry)
Anatol Roshko (Aeronautics)
Findlay E. Russell (Biology)
Richard C. Schweet (Biology)
Yataro Sekido (Physics)
James N. Shoolery (Physics)
Massimo Simonetta (Chemistry)
Neville Symonds (Biophysics)
Alfred Tissieres (Biology)
Kay Verkerk (Biology)
Niccolo Visconti (Biology)
John L. T. Waugh (Chemistry)
R. L. Weintraub (Biology)
William A. Wenzel (Physics)
James R. Wilts (Physics)
Harry L. Yakel, Jr. (Chemistry)
Noboru Yamada (Biology)
Paul C. Zamecnik (Chemistry)

(d) RESIGNATIONS

Charles W. Merriam, Associate Professor of Paleontology.

Richard B. Beaman, Lecturer in Art.

Arthur H. Young, Lecturer in Industrial Relations (now Lecturer, Emeritus).

(e) DEATHS

E. C. Barrett, Comptroller and Secretary.

S. S. Mackeown, Professor of Electrical Engineering.

A. A. Merrill, Instructor in Aeronautics.

(f) RETIREMENTS

W. N. Birchby, Assistant Professor of Mathematics.

R. W. Sorensen, Professor of Electrical Engineering.

L. E. Wear, Associate Professor of Mathematics.

(g) LEAVES OF ABSENCE

Charles R. DePrima, Associate Professor of Applied Mechanics, was granted leave of absence for one year, effective August 1, 1951, to assume the position of Head of the Mathematics Branch of the Office of Naval Research, Washington, D. C.

Sterling Emerson, Professor of Genetics, was granted leave for one year, effective August 15, 1951, to accept a Guggenheim Fellowship for study at the University of Cambridge, University of Paris and the Pasteur Institute.

Richard P. Feynman, Professor of Physics, was granted one year's leave, effective July 1, 1951, to accept an appointment as Visiting Professor of Theoretical Physics at the University of Brazil.

Joseph B. Koepfli, Research Associate in Chemistry, continued on leave of absence, granted January 1, 1951, to serve as Science Adviser to the Secretary of State.

Hans W. Liepmann, Professor of Aeronautics, spent the first term of the 1951-52 academic year in research work in Switzerland, England and Germany.

William H. Pickering, Professor of Electrical Engineering, was granted two years' leave, effective July 1, 1951, to September 30, 1953, to devote full time to the activities of the Jet Propulsion Laboratory.

George K. Tanham, Assistant Professor of History and Master of the Student Houses, was granted one year's leave, effective July 1, 1952, for a year's study in England on a Faculty Fellowship of the Fund for the Advancement of Education, established by the Ford Foundation.

Respectfully submitted,

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

THE DEAN OF GRADUATE STUDIES

To the President:

The year 1951-52 came nearer to being classified as "normal" for the graduate student group than any other of the past five years. Enrollment was excessive in 1946-47, immediately following the war, but has declined gradually to a figure slightly above four hundred. This number appears to be nearly optimum in relation to existing staff and research facilities. Although a sharp decline in graduate enrollment was thought probable for 1951-52 because of increased demands for military service, it did not materialize, and student registrations changed little from those of the previous year. Despite this small change in total enrollment, there was some change in distribution within the graduate group, the number of students in engineering decreasing somewhat with a nearly corresponding increase in the number of science students. The ratio of graduate students to faculty members has remained nearly constant for the last three years at a very satisfactory value near two and a half to one. The spread of values of this ratio among the different divisions has narrowed, although that for engineering is still higher than for the science fields.

The approach to a normal condition continued in regard to the financial support of graduate students furnished by the Veteran's Administration. The number of veterans receiving benefits from this source dropped below half of that for the previous year, and the average amount received by individual veterans also decreased as a result of terminations of eligibility occurring during the year. The number of graduate students receiving benefits during 1951-52 was 68, which was only about one-third of the registered graduate student veterans and about one-sixth of all graduate students. Although governmental assistance to graduate students through veteran benefits will decline still further during the coming year, the advent of fellowship grants through the National Science Foundation will give financial aid of another sort, also supplied by the tax payer.

Academic appointment procedures for graduate assistants were modified during the year to provide for two groups, designated respectively as Graduate Teaching Assistants and Graduate Research Assistants. Although they are considered to be academic appointments of equal rank, the methods of administering them differ in accordance with the needs of the two classifications. Teaching assistantships are financed through the teaching budget of the Institute, whereas research assistantship stipends are provided from the various research funds and projects available to the individual divisions.

Tuition grants were made to 230 students through scholarships and fellowships. Direct financial assistance was received by 280 students, to a minor extent as fellowship grants but primarily in stipends for services rendered to the Institute as graduate assistants, technical assistants in connection with research projects, and otherwise. All of these grants and stipends aggregated to a value in excess of $400,000 for the year.

At the Commencement exercises in June, 133 students received the degree of Master of Science; 20, the degree of Engineer; and 65, the degree of Doctor of Philosophy. In the last group, three-fourths of the students majored in science subjects; one-fifth took undergraduate work at the Institute and one-sixth were from foreign countries. Of the doctoral candidates who came from other institutions in this country, 60 per cent were from colleges located east of the Mississippi River. Approximately one-third of the M.S. candidates, excluding those granted in meteorology, planned to continue study at the Institute for advanced degrees. Of those graduate students registered during 1951-52 who will continue their studies here during the next year, over 70 per cent registered for research activities during the summer period and many of these

are receiving financial assistance in return for additional services in connection with research projects. Thirty per cent of the graduating senior class elected to proceed with graduate study at the Institute during 1952-53, despite the great demand from industrial and governmental agencies for men trained in science and engineering, making job opportunities particularly attractive.

On the whole, matters relating to graduate study and research have gone well during the year, and prospects are equally bright for the year to come.

Respectfully submitted,

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

THE DEAN OF STUDENTS

To the President:

The national policy followed during the academic year 1951-52 in the application of the Selective Service Act to college students has created quite stable conditions in contrast to the uncertain and disturbed attitudes of students throughout the previous year. The recognition that the colleges are serving an indispensable function in turning out vitally needed trained personnel has impressed upon men so fortunate as to enjoy the privilege of higher education that their continued study is in the national interest. Upon completion of their training at the Institute a number of men are going into the Armed Forces. This, at present unavoidable necessity, intensifies the acute shortage of technically trained personnel for industry and other civilian needs. Consequently, many requests from prospective employers for Institute graduates have gone unsatisfied during the past year.

During the past year the veteran contingent of the undergraduate student body decreased further to only 14 per cent compared with 23 per cent the previous year. Among the freshmen, only six, or 3 per cent, were veterans. For most of these veterans the period for which they were entitled to G. I. educational benefits had expired, so there has been a considerable increase in use of student loans. The number of married students is sufficient to justify continued maintenance of the Institute's housing project for students with families. There were 52 married undergraduate students enrolled during the past year.

The Caltech Service League continued its numerous and diverse welfare activities during the year. Among the new accomplishments of particular significance were development of recreation

facilities for wives and children of married students at the Institute's housing project; rehabilitation of the pianos in the Student Houses; establishment of a clothing pool or "clothes closet" on the campus for students; and furnishing added equipment for the Health Center. Through the Service League an improved model electrocardiograph instrument was provided as a result of generous individual gifts by Mrs. Willard C. Jackson and Mrs. Anna Bissell McCay.

During the year Dr. W. S. Gevurtz resigned as Director of Student Health after several years of devoted service in that capacity. The Institute was fortunate in obtaining as Dr. Gevurtz's successor, and on a full-time basis, Dr. William R. V. Marriott, Major, Medical Corps, U. S. Air Force. Dr. Marriott had as a foundation for his later medical training and practice both bachelors' and master's degree in biology at the Institute. Much appreciation is due Dr. E. D. Kremers, Director of Student Health, Emeritus, for his generous assistance and counsel at various times during the year.

The Deans' Office has been greatly aided by the work of Dr. John R. Weir, who was added to the staff this past year as Associate in Psychology. Although probably the major portion of his time was spent on student problems related to the Deans' Office, Dr. Weir's activities were spread over such a large portion of the campus that it seems pertinent to insert the following sub-report from him.

"The staff position of clinical psychologist was established for the first time in September, 1951. Primary attention was given to identifying and defining problem areas which would benefit most from the employment of the special skills and techniques of such a professionally trained person.

The functions and activities which have proved most effective to date can be divided into two categories: analytical and remedial.

A. In the analytical category, the following projects were undertaken:

1. A statistical study was made of the use of the College Entrance Examination Board tests for admission purposes. The tests were evaluated for their ability to predict subsequent success at Caltech, and a method was devised to permit a maximum use of their predictive efficiency. The evaluation indicated that we are using the best aptitude and achievement tests available, and are interpreting the scores on these tests in such a way as to select the best students from those who apply. This study will be repeated on the following class in order to verify the initial results.

2. An extensive analysis of admissions procedures was made for the Registrar. The high schools which contribute students to Caltech were studied as to the number and academic success of the students coming from them. The attrition rate among students at all levels was analyzed, and evaluated in terms of the worth of reinstating a student whose work had fallen below passing grade. Also, a definite and important relationship between the number applying for freshman admission and the number failing in the freshman year was found: as the number of applicants decreased, the number of failures increased, indicating that the Institute must have a large number of applicants from which to select in order to maintain or improve the academic quality of its student body.

3. The entire sophomore class was tested as a part of our participation in the 1952 National College Sophomore Testing Program. The same tests were given to over fourteen thousand college sophomores in 128 colleges throughout the country. The tests cut across subject-matter boundaries and measured general learning in the basic fields of English, General Culture, and Contemporary Affairs. Caltech stood at the top in the ranking of the colleges participating in the tests. In addition, the sophomore class was given the Strong Vocational Interest Test, and the significance of all his test scores was interpreted to each student. Several students who had been undecided about their options and future plans expressed their satisfaction with the results.

4. An analysis of transfer student admissions was made, together with an evaluation of the scholastic achievement of transfer students after they had been admitted to Caltech.

5. A basic aptitude and ability testing program was set up for the Non-Academic Personnel office for the purpose of screening and selecting clerical, stenographic, and semi-skilled employees.

6. With the cooperation of the Placement Office, a survey was made of causes of industrial job terminations of scientists and engineers.

7. An elaborate questionnaire survey of the entire Caltech alumni was instigated. Initial results will probably be available in the summer of 1953.

B. In the remedial category, the following activities were carried out:

1. All of the freshman class was tested for reading speed and comprehension. Although the class as a whole read better than 85 per cent of all college freshmen, based on national norms, a remedial reading class, using the Harvard reading films, was established for the bottom quarter of the class. The class was voluntary, and about forty students started. Less than half of this group finished, but the reading speed of those who did finish more than doubled. The course will be repeated this fall.

2. Approximately fifty students, mostly freshmen, were referred by the deans, and were interviewed for one or two hours of counseling and guidance for educational reasons.

3. A clear-cut referral procedure among the deans, the Director of Student Health, and the clinical psychologist was worked out for those cases needing long-term help of a psychological nature. Twenty-five such people were seen for two or three hours; five students were seen twice weekly for a period of several months.

4. Eleven people, referred for psychological help, were subsequently referred to psychological or psychiatric agencies outside the Institute."

That the past year on the Institute campus has been one characterized by wholesome relations and cooperative effort between administration, faculty, and student body is due largely to the competence of those officers who have most direct and intimate contact with the students on matters of policy and conduct. Appreciation is specifically expressed for the services of Professors Paul C. Eaton, Associate Dean for Upper Classmen, Foster Strong, Associate Dean for Freshmen, Harvey Eagleson, Chairman, Committee on Student Relations, and George K. Tanham, Master of the Student Houses.*

Respectfully submitted,

FRANKLIN THOMAS, *Dean of Students*

*This report was submitted on August 11, 1952. On August 27 Dean Thomas passed away.

THE ASSOCIATE DEAN FOR UPPER CLASSMEN

To the President:

The academic year just closed was one in which undergraduate unrest dramatically, if not always originally, manifested, made headlines in almost every section of the county. The Caltech campus, by contrast, provided no sensational reading. Credit for this healthy and stable situation is largely due, in the opinion of this office, both to the maturity and seriousness of purpose of the individual Caltech student and to the responsible leadership provided by the elected student body officers.

The general high level of this leadership was significantly indicated when the Hinrichs Award was this year divided, for the first time, between two of the several outstanding seniors: David L. Hanna, ASCIT President, and Richard Y. Karasawa, Athletic Manager.

There was, however, some evidence of the impact of the present disturbed times on our undergraduates, as the following tabulation may indicate. The graduating class, 1952, had two pre-Korea and two post-Korea, or Selective Service, years in college. The class entered in 1948 with 171 students selected from 515 applicants. Of these 171, only 96 were graduated on 6 June 1952, among the total, increased by transfers, of 129 receiving bachelor's dgrees. What happened to the other 44 per cent of the original class is shown below:

Reasons for Withdrawal

Academic failures	28
Financial	4
Military	6
Transfer to other college	9
Health	1
Disciplinary	4
Change of plans (non-academic)	5
Death	2
Failed to return, no explanation	16

Data from other colleges or other years are not readily available, but comparing these figures with what data do exist indicates (a) the losses are not greater, percentage-wise, than those in other similar colleges, but (b) rather higher than in other post-war Caltech classes.

These figures further point up another important fact; namely, that the Caltech upper classes are too small. Despite a well-advertised shortage of engineers and scientists, each of the upper classes started the past year below the authorized strength of 180 men per class. In September, 1951, 135 sophomores, 139 juniors, and 138 seniors were

registered. Stimulation of interest among junior college graduates and possible transfers from other colleges is, in my opinion, essential. Admission of more than 180 freshmen is another possibility.

Some progress has been made in providing for the superior undergraduate, the Sophomore Honor Section operating, apparently with success, for the second consecutive year. This group, for which the men from the top 20 of the freshman class are eligible on a voluntary basis, completes the required sophomore mathematics and physics year courses in two terms, the third term being devoted to individual projects of a research character under the supervision of the professional departments. One question in a questionnaire circulated among the 15 juniors who had been members of the section as sophomores was, "What is now your considered opinion of the experience?" Replies indicated: 9, pleased; 1.5, indifferent; 4.5, displeased. Twelve felt that the opportunity for special work in the third term, whatever the cost in lowered grades or faster competition, was of great value.

In the matter of counseling, this office has this year been greatly aided by the presence on the campus of Dr. John Weir, a clinical psychologist attached to the Division of the Humanities. Like Dr. W. R. V. Marriott, '40, new Director of Student Health, he has constantly provided both genuine interest in individual undergraduate problems and broad professional experience in helping to solve them. Col. Arthur Small, Professor of Air Science and Tactics, has been exceptionally cooperative in matters relating to the integration of the AFROTC unit into the Institute community, and as a consequence this activity seems firmly established.

It would be remiss, in this connection, not to mention again and with gratification the continuing support and cheerful cooperation which this office has received from the Faculty, Administration, and the non-academic members of the Institute group, without which its efforts would be of little value.

Respectfully submitted,

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

THE ASSOCIATE DEAN FOR FRESHMEN

To the President:

Altogether 200 freshmen attended the Institute in 1951-52. Of these, 194 were students new to the campus; six were former students returning on reinstatements to repeat freshman work. The large entering class of 194 students was not the result of a deliberate choice of the Admissions Committee to increase the class beyond the usual number of 180; it resulted from an unexpected decrease in the number of cancellations received during the summer.

All of these freshmen attended New Student Camp, held just before the opening of the fall term. Here, as in previous years, the new students met a number of the faculty and student leaders, and became informed about their life ahead of them at the Institute. This camp seems to continue to be successful in providing a momentum toward work and living at the Institute that could not be gained in any other way.

The Parents Program, inaugurated in 1950, was held again in 1951, at the end of the fourth week of the first term. The experience gained the year before enabled both the Deans' Office and the Service League, which cooperated on the program, to give the visiting parents this year a better view of the Institute and of its people. To this program parents came from as far away as the Northwest and the Middle West. Judging from comments and letters from both parents and students, the program was considered a success.

In 1951-52 an Air Force ROTC was inaugurated at the Institute. One hundred and seventy-five of the entering freshmen joined the unit; it is expected that most of these will continue with the ROTC program to graduation.

In previous years this report has noted the need for a course in remedial reading for many of our students, this course preferably to be given in the freshman year. This year, with the arrival of Dr. John Weir, this need was met. A standard reading test was administered by Dr. Weir to the entire freshman class. Although the class as a whole exhibited a reading speed and comprehension greater than the national norm for college freshmen, those at the bottom end of the test range showed definite need for improvement. Most of those in this bottom group voluntarily attended a class in remedial reading given by Dr. Weir. The results very definitely justify the continuance of this work in future years.

Dr. Weir has given valuable assistance to the freshmen in other ways. With his cooperation, the range and effectiveness of personal and vocational counseling of students has been increased considerably.

The Student Houses, through their officers and upper class committeemen, continue to strive to improve the academic effectiveness of the freshmen in the houses. Lines of communication between the Deans' Office and the Student Houses are continually being strengthened, to the end that no problem of any student will go unrecognized for too long. In this, the cooperation and interest of the Master of the Student Houses and of the Resident Associates has been invaluable. In the coming year, the officers of Throop Club, the house for off-campus students, have planned an expanded program of help to the freshmen.

The statistics of the freshman class of 1951-52 are as follows:

Formally failed scholastically	9
Withdrew to avoid formal failure	9
Total of those academically deficient	18
Reinstated to repeat freshman work next year	5
Withdrew for financial reasons	3
Wtihdrew to change vocation	4
Leave of absence to return later	1
Known to be very doubtful returness, but not yet formally withdrawn	3
Total loss before the sophomore year	34

This represents an attrition of 17 per cent, a definite improvement over the previous year. Two additional facts may be of interest. Last year eight freshmen were reinstated to repeat the freshman year; six of those actually returned to this year's freshman class; of these only two are eligible to go on as sophomores—four failed again, and finally.

Forty-four freshmen, on the basis of need and estimated academic potential, received scholarships; of these 21 made scholarship eligibility for next year. This respresents a definite improvement over last year in our prediction technique.

Respectfully submitted,

FOSTER STRONG, *Associate Dean for Freshmen*

THE DEAN OF ADMISSIONS AND REGISTRAR

To the President:

Enrollment figures for the 1952-53 academic year and for the two preceding years are given below. The figures for September, 1952, are final and were inserted after fall registration. It is necessary, however, to write this report prior to registration day and, therefore, without knowledge of what the enrollment will actually be in September. It is anticipated that there will be very little drop in numbers during the summer because of calls to military duty or for other reasons, and we should start the year with a total enrollment only slightly below that of September, 1951. The decrease in numbers of students over the past three years is accounted for largely because from 1947 to 1950 inclusive there was a steady decline in the number of acceptable students applying for admission. The decline commences with the tapering off of the big surge of veteran applications, and the trend was not reversed until 1951. In addition to the decline in applications there has been a steady increase in cancellations on

the part of those accepted for admission. The great majority of these cancellations come from those who had to be denied scholarship help and undoubtedly reflects the influence of the current inflation on the salaried classes from which our students are largely drawn. As a result, the present junior and senior classes are abnormally small. The fewer applications from 1947 to 1950 resulted largely because it was impossible during the war years to keep up our personal contacts with the high schools. Resumption of these contacts, made by members of the Admissions Committee during interview or school visiting trips in the spring and fall and locally by a selected group of undergraduates, naturally took time to bear fruit but has resulted in a decided increase in number of applications. The total of those who completed the examinations for admission in 1951 was 17 per cent above 1950, and the total in 1952 was 31 per cent above 1951.

Students' Day, under the able guidance of Professor Wilbur Varney, was mentioned in my report for last year. It brings to the campus a large number of high school students and their teachers from as far away as Bakersfield and San Diego and is a valuable adjunct to the admissions program. So far the military situation has not materially affected enrollment. No student in good standing was drafted during the 1951-52 academic year, and it appears that most draft boards will continue the policy of postponing induction, at least for undergraduates, as long as possible. This situation can, of course, change for the worse at any time; however, 155 undergraduates, mostly freshmen, were enrolled in the Air Force ROTC unit at the end of the 1951-52 academic year and are entitled to exemption from active duty until graduation as long as they remain in good standing. It is believed that a large proportion of the freshmen entering in September, 1952, will also join the unit.

Registration Figures

	September 1950	*September 1951*	*September 1952*
Undergraduates	645	611	608
Graduates	425	412	417
	1070	1023	1025

Figures on Veterans' Enrollment

	1950		*1951*		*1952*	
	No.	*Per cent of Total*	*No.*	*Per cent of Total*	*No.*	*Per cent of Total*
Undergraduate Veterans	147	23	86	14	55	9
Graduate Veterans	264	62	203	49	193	46
	411	38	289	28	248	24

In September, 1951, Dr. John Weir joined the staff of the Humanities Division as Associate in Psychology. In addition to his work in counseling students, which has been mentioned in the reports of the Deans, Dr. Weir has spent a great deal of time on admissions problems. The Admissions Office, long handicapped by the lack of personnel adequately trained in statistical techniques, is now able to correlate and evaluate entrance examination and other admissions data much more effectively. In addition, Dr. Weir's judgment and experience have been very valuable to the registration committees in handling the cases of those students who fail to meet scholastic requirements.

The Air Force ROTC unit, activated in September, 1951, has been well received by the students. At the end of the academic year 135 freshmen and 20 sophomores were enrolled in the unit. Sophomores were eligible to join only under certain conditions. Juniors and seniors were not eligible. In spite of the fact that the unit was made up almost entirely of freshmen with no previous military experience, it produced a precision drill team which won a competition held among southern California colleges most of which had older units which included upperclassmen, thus once more proving the point that California Institute students can have an interest and aptitude in other things besides studies. We have been very fortunate in the selection of officer and enlisted personnel assigned to the AFROTC unit here. Under the command of Colonel Small these men have done an excellent job of fitting the ROTC program smoothly into the Institute's already crowded program of activities.

In 1951-52 a total of $47,950 was awarded in undergraduate scholarships. The awards made to 102 individuals ranged from $100 to $1000. The average grant was $467. Need was the chief factor in determining awards, and in the three upper classes all recipients ranked in the top quarter of their respective classes. In terms of percentages, 16.7 per cent of all undergraduates, including 22 per cent of the freshman class alone, received scholarship aid. In spite of the high percentage of freshmen scholarships, twenty-five of those accepted for admission cancelled their applications for financial reasons. The majority of these were among the most desirable applicants and were awarded larger scholarships by other colleges. With increasing inflation and a decreasing number of veterans receiving government aid, the problem of obtaining additional scholarships becomes more and more urgent.

The geographical distribution of the homes of freshmen who will start here in September, 1952, gives representation to 25 states and one foreign country. Of the number who at the date of writing this

report have sent in their registration fees, 64.3 per cent are from California, 35.2 per cent from other states, and 0.5 per cent from abroad. The decrease in representation from foreign countries, which has continued for several years, is easily accounted for by present world conditions. The percentage from outside the state of California has, however, increased and shows the effect of the policy of the last few years of visiting schools in areas where we are not so well known in order not only to avoid becoming a "local" college but also to increase the number of good applicants. It would appear that this program of school visiting should be expanded and that more members of the Institute faculty should be encouraged to participate.

Respectfully submitted,

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

THE DIRECTOR OF STUDENT HEALTH

To the President:

The Health Center has continued its primary purpose to suuply a relatively complete medical service to the students of the Institute at a very low cost. So that the facilities available may be efficiently utilized to their full capacity, the policy of allowing the faculty, employees of the Institute and their immediate families as well as the immediate families of students to obtain inexpensive outpatient medical care has also remained in effect. There have been no major changes during the past year but continued progress has been made toward the improvement of the medical program.

In order to protect the Emergency Hospitalization Fund from excessive demands, yet provide even more financial aid for medical care in serious cases, an accident insurance policy was taken out with Lloyd's of London. This policy covers every student in case of accidents occurring on the campus or in authorized school activities. The insurance premium is paid out of the Emergency Hospitalization Fund. In valid cases the policy will cover medical care up to $500. The Emergency Hospitalization Fund continues to take care of acute illnesses, and in cases of magnitude a maximum of $125 may be made available to help defray medical expenses. The athletic department has a separate policy with Lloyd's of London which handles athletic injuries in a manner similar to the general insurance policy.

The medical staff at the Health Center has changed during the past year. There is now a full-time medical director, and he has another physician as a part-time assistant.

As an added service in preventive medicine, the Health Center has instituted a program of making available yearly physical check-ups for all members of the faculty over 40 years of age. This includes a thorough history, physical examination, blood and urine analysis, and electrocardiogram. Eligible members of the staff receive this service for the regular $2.00 fee for an office call. They may also take the results of this examination to their private physician.

The Service League has helped the operation of the Health Center in many ways. In the past year they have greatly augmented the diagnostic facilities by the gift of an electrocardiograph. They also continue to furnish gifts of funds for other equipment and to provide special foods and reading material for infirmary patients.

Respectfully submitted,

WILLIAM R. V. MARRIOTT, M.D., *Director of Student Health*

THE DIRECTOR OF LIBRARIES

To the President:

A summary of acquisitions for the fiscal year 1951-52, and of holdings at the end of the year, is as follows:

	Total 1950-51	*Added 1951-52*	*Total 1952*
Books	51,164	3,069	54,233
Periodicals	30,433	1,848	32,281
	81,597	4,917	86,514

The total spent for books throughout the year was $13,108.46; for periodical subscriptions, $12,239.57; for back issues of periodicals, $8,431.17; for binding, $5,478.50. Acquisitions of periodicals, in biology and mathematics particularly, will continue to be heavy for a number of years. It is difficult for a scientific library, in contrast with one in the liberal arts, to overemphasize the importance of the periodical literature. The apparently small number of books in the Institute libraries compared with the number of periodicals reflects this relative importance.

Acquisitions by gift, special purchase, and exchange are more extensive this year than formerly. Gratefully acknowledged are gifts as follows: from the late Mr. Feodor Foss of Santa Barbara, his library of approximately 1000 books and many pamphlets, maps, and periodicals; from the Republic of France—through M. Raoul Bertrand, Consulat de France, Los Angeles—approximately 60 recent scientific

books in French; from the Jet Propulsion Laboratory, approximately 60 unbound volumes of miscellaneous periodicals; from the Shell Development Company, 17 books from the library of the late Dr. Otto Beeck, Research Fellow at C.I.T., 1930-1933; from Professor G. W. Beadle, approximately 160 unbound volumes of periodicals, duplicates from his private collection; from Professor E. T. Bell, in addition to miscellaneous books and periodicals, the following rare volumes: Lobatschewsky, *Geometrische Untersuchungen zu Theorie die Parallellinien* (Berlin 1840); Gauss, *Disquisisiones Arithmeticae* (Lipsiae, 1801); and *Fundamenta Nova Theoriae Functionum Ellipticarum* (ed. 1829).

Gratefully acknowledged also are gifts of books and periodicals from the following: Dr. F. Bedell, General W. M. Rose, Mrs. M. M. Ramsay, and Professors Beno Gutenberg, W. G. Cady, Peter Kyropoulos, C. W. Merriam, and Alfred Stern.

The California Institute acquired by purchase, from the estate of the late Professor Chester Stock, his professional library, consisting of approximately 950 books and 6000 reprints, chiefly in the field of paleontology. This purchase was made possible by the Childs Frick Fund.

The Library is receiving, at present, twenty-five foreign mathematical journals in exchange for the *Pacific Journal of Mathematics*, for which the California Institute became a sponsor last year.

Members of the faculty borrowed on inter-library loan, 921 volumes, almost double the number last year. A notable part of the increase is explained by heavy borrowing for Professor J. E. McKee, as part of the *Literature Survey of Water Quality Criteria*, carried on under his direction.

The California Institute, on the other hand, loaned to other libraries 2686 volumes, more than double the record-breaking number last year. The increase reflects, in part the active program in government-sponsored research, in part the fact that the periodical collections are more extensive and in better order than ever before, and in the fact that, being listed in the Special Libraries Union List of Serials in southern California, the collections are becoming widely known locally.

Outstanding among the physical improvements in the libraries is a reading deck opening from the General Library on the roof of the new cosmic ray laboratory. The deck is a tiled area 18 by 40 feet, attractive furnished as a roof garden, where students are invited to read and study.

The Current Affairs Room in Dabney Hall increases constantly in usefulness and popularity.

In closing, emphasis must be placed once again upon the serious overcrowding in the libraries. How serious, is illustrated vividly by the fact that shelving in basement storage now exceeds the shelving in the Biology and the Chemistry Libraries combined (in basements 3609 running feet; in Biology and Chemistry combined, 3394 running feet). Moving and re-arrangement of book stock, with attendant changes in the records, make heavy demands upon the library staff, as do frequent and lengthy trips to the widely-scattered basements where the books are stored.

In the General and Humanities Libraries, work space necessarily encroaches upon reader space, with the result that students inevitably are distracted by librarians in the performance of their duties. Furniture in the General Library has been re-arranged, both in order to increase staff space and in order to function as a partition between students and staff; even so, the minimum noise level remains discouragingly high. A plan to open free class rooms as study halls hopefully will alleviate the situation; but it does nothing for those students who are working with numerous reference books which cannot be taken from the library.

The libraries can continue to improve for several years to come only by crowding out ever more readers and by digging ever deeper into basements—in short, by alienating, instead of inviting, ever more faculty members and students, the very people the library exists to serve.

Respectfully submitted,

ROGER STANTON, *Director of Libraries*

THE DIRECTOR OF ATHLETICS AND PHYSICAL EDUCATION

To the President:

The Athletic and Physical Education Department of the California Institute undertakes to provide the opportunity for some sort of physical activity for all undergraduates at least three times a week. This may be in the form of intercollegiate or intramural sports participation, or physical education classes. The only persons excused from such activities were those who are over 24 years of age or who, because of some physical impairment, are unable to pursue the required work. During 1951-52, only 10 per cent of the students were so excused, a decrease of 4 per cent from the preceding year.

This year, 61 per cent of the students entered into some phase of the sports program, a slight decrease from last year. The Senior class produced a remarkable record, as 54 per cent had played on inter-

collegiate teams during their undergraduate days and 34 per cent had won varsity letters.

With the introduction of the Air Force ROTC unit at the Institute this year, it became necessary to readjust the schedules to allow for the increased academic load. Therefore, Freshmen enrolled in ROTC were excused from the physical education requirement. This, together with the abandonment of Freshmen teams for the year by the Conference, naturally produced a reduction of the number of Freshmen participating in sports. However, 55 per cent of the class entered into some phase of the intercollegiate or intramural sports program.

The Institute is a member of the Southern Intercollegiate Athletic Conference together with Occidental, Pomona-Claremont, 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 conference program is carried on in football, basketball, baseball, track, swimming, tennis, golf and cross country. Several junior varsity games were also scheduled in these sports. The Institute also sponsors teams in soccer, water polo, skiing and sailing; and contests are scheduled with numerous non-conference schools. During the year, 104 Varsity and 27 Junior Varsity 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 part 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 won the soccer championship, placed second in water polo and tied for second in baseball, finished third in swimming and tied for third in tennis. Many individuals on our teams are recognized for their ability, and on the All-Conference teams selected by the conference coaches, three Institute men were selected in football, one in basketball, three in baseball and two in water polo.

Special recognition was given during Commencement week to the fourteen seniors who had won three or more letters in one varsity

sport. All were outstanding men, not only in athletics but also in student body and campus activities. Five men were team captains, seven had been selected on All-Conference teams, and three were members of Tau Beta Pi, honorary scholastic society.

The Wheaton Football Trophy, presented annually to the outstanding football player for achievement in scholarship, sportsmanship and moral influence, was awarded to Richard Y. Karasawa, senior from Chicago. In addition to his participation in football for three years, the recipient was a three-letter man in baseball, and was prominent in many student body activities. Captain Norman Gray, senior from San Diego, received the Vesper Basketball Trophy and the Alumni Baseball Trophy, both for the second time, and the Goldsworthy Track Trophy was awarded to Donald Tautz of Denver.

Fleming House, with 53 per cent of its members in intercollegiate sports, won the Varsity Rating Trophy for the tenth consecutive year. This trophy is presented each year to the Student House having the largest number of men participating in intercollegiate sports.

Supplementing the intercollegiate program is a strong intramural program which offers competition to all students not engaged in intercollegiate sports and provides an opportunity for the less skilled and experienced men to participate and develop physically. Teams representing the four Student Houses and Throop Club (the latter composed of students who do not reside on the campus) played 59 contests in which 45 per cent of the undergraduate enrollment participated. The Interhouse intramural program includes a round-robin schedule in baseball, basketball, softball, volleyball and touch football; a track meet, a swimming meet, cross country runs and a tennis tournament. Two tennis tournaments and an interclass track meet are held in addition to the Interhouse program. An annual presentation to the Student House accumulating the most points in the nine-sport program during the year is the Intramural Plaque. This trophy was regained by Fleming, which until 1950-51 had won it for 14 consecutive years.

The Institute has just replaced four of the asphalt tennis courts at the Athletic Field with concrete, thus increasing the number of concrete courts to seven. This most welcome improvement will provide greater opportunities for the instruction and practice for the large number of students who keep the courts constantly in use.

Constant progress is being made by the Alumni in their fund-raising program for the construction of a swimming pool. During the year, cash contributions amounting to $32,780 were received, bringing the total to nearly $130,000. Included in this is a $307 con-

tribution from the graduating class of 1952. It had been anticipated that the construction of the pool and the necessary dressing facilities could be undertaken during the summer of 1952, but governmental restriction in the use of steel may delay the project for a year.

Respectfully submitted,

HAROLD Z. MUSSELMAN, *Director of Athletics and Physical Education*

THE DIRECTOR OF PLACEMENTS

To the President:

The great demand for engineers and scientists has continued to be heavy. This activity is reflected in the very extensive recruiting programs of industrial and government organizations. During the year 1951-52, the number of organizations sending representatives to the campus increased 38 per cent over the previous year. In general, organizations continue to look for the best qualified men and are not willing to employ just anyone, even though the need is great and the supply is small. Approximately 80 per cent of all students who were interviewed received offers of employment, and 42 per cent of these men accepted.

About 44 per cent of those men who received the B.S. degree in June, 1952, expect to pursue graduate work, and about 29 per cent of those who received the M.S. degree expect to continue graduate work. Of the B.S. degree men who are not continuing their academic training, 78 per cent were employed by industrial organizations; 14 per cent, by government agencies; and 8 per cent, by research institutions. Only 1.6 per cent of the B.S. men entered military service upon graduation. A rather large proportion (15 per cent) of the men who received the M.S. degree were employed in teaching; the proportion taken by industry was 60 per cent; by government agencies, 16 per cent; and by research institutions, 9 per cent. As might be expected, the greatest proportion of the men who received the Ph.D. degree were employed by research institutions. The median of the salaries offered to men receiving the B.S. degree was thirty dollars higher than for the preceding year; similarly, the salaries accepted by these men were higher. The median salary accepted by B.S. degree men was $340 per month; by M.S. degree men, $405 per month; by Engineer degree men, $475 per month; and by Ph.D. degree men, $495 per month.

The demand for students to work part-time during the academic year was greater than the supply. Naturally, the type of work, loca-

tion, and time required were limitations to filling some of the requests for men. In spite of these difficulties, 83 students were placed in part-time work during the year. The part-time employment of students is an important phase of placement activities since many students must work to help pay their college expenses. The demand for men for summer work was good; and so far as could be determined, all men who were seeking work for the summer were placed. The majority of the 191 men who secured summer work were employed in technical positions. The experience derived by students through this summer work is of very great value and should be of value to the organizations giving the employment in the way of becoming acquainted with some of the students before they receive their degrees. It is because of the value of the summer training program that the Placement Office staff has exerted considerable effort in assisting students to secure summer work.

A further indication of the demand for men with engineering or scientific training is the large demand for men with experience. The requests for alumni were about the same as for the preceding year. The demand for men was most heavy in the fields of design and research. The total number of alumni who applied for placement assistance was the lowest within the past six years. This indicates that there is very little difficulty for men with some experience to secure employment in this period of great demand for men trained in engineering and science.

During the year 1951-52, the Placement Office handled the requests of about 900 men for placement assistance in all phases. The requests for the employment of about 4,000 men were also handled. These activities require the cooperation of the faculty of the Institute, and it is only through this cooperation that the placement problems of students and alumni can be handled effectively. Without the cooperation which the faculty gives the operation of the placement services of the Institute, it could not function to the best advantage of all applicants.

Respectfully submitted,

DONALD S. CLARK, *Director of Placements*

Part IV

REPORTS OF THE DIVISIONS

THE DIVISION OF BIOLOGY

To the President:

Many questions dealing with the fundamental why of living things have occupied the attention of the Institute's biologists during the past year.

RESEARCH HIGHLIGHTS

Much of the work reported here and in the separate report of the Division of Chemistry bears broadly on the cancer problem. To a large extent this work has been made possible by the very substantial Laurabelle Arms Robinson endowment fund, two specific grants from the American Cancer Society and one grant from the Damon Runyon Memorial Fund for Cancer Research, Inc. No separate report of cancer work as such has been made because so much of it, like the protein structure work of Pauling and Corey and the protein synthesis work of the Borsook group, is fundamental to all of biology as well as essential to any real understanding of the nature of the unregulated growth that is cancer.

Animal biochemistry has concerned itself for a number of years with the problem of protein synthesis. During the past year a large part of the work has been devoted to a study of the incorporation of labeled amino acid into immature red blood cells (reticulocytes) of the rabbit. The rate of incorporation is strongly influenced by four factors, namely, (1) certain amino acids, (2) carbohydrate metabolism factors, (3) a non-protein substance in plasma, and (4) a factor present in liver and spleen. There is an interesting possible application of this work in acclimatizing animals to upper atmospheres by increasing the hemoglobin content of their red blood cells. This possibility will be investigated by the group working in collaboration with Captain Ashton Graybiel of the Pensacola Naval School of Aviation Medicine.

The physiological and biochemical effects of the administration of betaine and glycocyamine to experimental animals have been investigated to provide background information for betaine-glycocyamine heart disease therapy.

In comparative physiology, with studies of the central nervous system, the crayfish has been found to possess many fewer nervous elements than, say, the vertebrates. Yet the simpler crayfish system is fully capable of making adequate responses to its environment. The main difference between the nervous system of the crayfish and that of the vertebrate lies in the greater amount of interaction of the nervous components of the crayfish. It has been found, for example, that a single giant fiber of the crayfish may make connections at six or more different synapses, and it can be demonstrated that a single impulse in this giant fiber will initiate a complex series of responses to an environmental situation. Nervous economy is also in evidence elsewhere. In maps of the nerves going to the muscles of the claws of the various crustacea, it has been shown that there are very few axons involved in their motor activity. All the leg muscles of a hermit crab, for instance, may be inhibited by a single axon.

The economy principle has been further demonstrated with respect to sensory innervation. Some interesting muscle receptor organs in the tail of the crayfish, which discharge in response to stretch when the abdomen is flexed, are being studied. A small number of these receptors are sufficient to signal all the necessary information concerning the position of the crayfish's tail.

The interest in vertebrate physiology has centered mainly around the nervous system, although some work has also been done on the blood circulation. Problems of nerve conduction have been studied. The potassium losses of peripheral nerve, incurred by asphyxiation, have been determined. The reflex activity of the spinal cord has been investigated, with use made to a considerable extent of asphyxiation as a tool. The cerebral cortex, in particular the so-called spreading depression, which is induced by electrical stimulation and may lead to convulsive activity not unlike that characteristic of epileptic seizures, has received a good deal of attention. The electroencephalogram has been studied, especially its reaction to weak stimuli which tend to suppress the cortical activity. The work on circulation apparatus has been concerned especially with pressures and flow in the vascular system.

In bio-organic chemistry, further important contributions have added to our understanding of the origin of Los Angeles smog from the emission of large quantities of hydrocarbons and nitrogen oxides into the air. This year it was shown that ozone is formed during the photochemical oxidation of hydrocarbons and their oxidation products, resulting in severe rubber cracking.

In the field of embryology, new insight has been obtained into the mechanism of fertilization in the eggs of animals. In the sea urchin,

the animal most thoroughly investigated in this respect, the egg produces a glycoprotein, fertilizin. It has been found that fertilizin causes a lateral displacement of the midpiece, a significant part structurally of the sperm. This change may be of importance in the fertilization process. A study of the fertilizin system in rabbits suggests that the same mechanism is also present in mammals. The short life of sea urchin sperm diluted in sea water is probably tied up with the presence of trace metals. Their removal by the addition of metal-binding agents greatly prolongs the life span.

In corn genetics and cytology, chromosomal rearrangements induced by X-rays and atomic bomb radiation are being studied cytologically and genetically. Cytological examinations have been completed on 400 translocations isolated from Crossroads (Bikini) tests and 250 accumulated from miscellaneous sources. In addition, several hundred semi-sterile lines have been isolated from Eniwetok, gamma ray and other radiation tests, but as yet only a few have been studied genetically or cytologically. Corn varieties grown by Southwest Indian tribes prove to be composites from three distinct sources: an ancient type, an "Eastern" complex, and a "Mexican" complex. Additional work has been done on "blue fluorescent" seedling mutants of corn.

Drosophila Genetics. Since its establishment 24 years ago, the Division of Biology has been noted for its genetic work on the fruit fly, Drosophila. During the year an investigation from a taxonomic standpoint has been made of a genus of small flies related to Drosophila.

In recent years there has been a growing amount of evidence indicating that genes with closely related functions often lie physically close together in a chromosome. Such genes are called pseudoalleles and their functions may be markedly disturbed if they are separated by chromosome rearrangements. Several such complexes of genes, in particular the bithorax complex, have been studied in Drosophila during the past year. In this group, five genes have been discovered, the largest number so far detected in any such cluster. By varying the special relations of normal and mutant forms of these pesudoalleles, important clues have been found concerning the way in which individual genes control the development of the thorax and the abdomen.

The year in Neurospora genetics was marked by the discovery of a cytoplasmically inherited trait in Neurospora which appears promising for study from a biochemical point of view. Up to the present, the main emphasis has been on studies of nuclear-controlled inheritance. The cytoplasmic trait concerned, known as "poky" because of its slow growth, appears to possess a cytochrome-destroying enzyme not detected in wild-type Neurospora and to be characterized by negli-

gible activities of the enzymes succinoxidase and cytochrome oxidase. These deficiencies are transmitted through the maternal parent by means of incipient fruiting bodies which are formed during the growth period of a single mating type. The asexual spores called conidia do not transmit the deficiencies.

In studies of mutants concerned with pyrimidine synthesis, apparent wild-type strains recovered from crosses of two mutants behave as mutants in further crosses to wild type. These "pseudo-wild" types may be forms which arise by non-disjunction of the chromosomes concerned and appear to be "disomic", i.e., to have one full set of chromosomes plus an extra one.

A number of gene-controlled enzyme systems in Neurospora have been studied during the year. Among such systems is the thermolabile tyrosinase found in a strain of Neurospora which differs in a single gene from strains producing thermostable tyrosinase. A "black" mutant has been studied in which a tyrosinase inhibitor seems to be reduced in amount. Other enzymatic work has dealt with a D-amino acid axidase in Neurospora; with lactase, an enzyme concerned with the utilization of the sugar lactose; and with tryptophane desmolase and an enzyme concerned with the cleavage of cystathionine.

Further studies have been made of the physical basis of genetic recombination in the colon bacillus, a problem made extremely difficult by the very low frequency with which such recombination takes place in a population of cells.

Several lines of work have been carried out in the field of immunology. Following similar work on the tyrosinase of Glomerella, a serological study of the tyrosinase enzyme found in the Schaeffer black mutant and the temperature melanin mutant of Horowitz has been made. There has been further work on the serological relation of tobacco mosaic virus to the normal proteins of the tobacco plant. Red cell antigens of rats, rabbits and the opossum have been investigated. In collaboration with Doctor Clyde Stormont of the University of California at Davis, guinea pig antibodies effective against cattle red cell antigens have been studied. With immune sera, antigenic differences in types of Drosophila and races of the protozoan Euglena have been studied. Immune sera directed against different human hemoglobins normal with respect to the sickle cell character have been prepared for a study of isoalleles postulated by Doctor Harvey Itano of the Division of Chemistry.

In marine zoology, Professor George MacGinitie has returned on a half-time basis to take charge of the work at the Kerckhoff Marine Laboratory at Corona del Mar. He has been chiefly occupied with completing a large report on the research begun while at Point Barrow, Alaska.

The Earhart Plant Research Laboratory has had an active year, and a variety of ecological and physiological problems has been studied. The physical plant underwent only minor changes, except for the construction of a fumigation hall, which will permit easier and safer handling of materials entering and leaving the building. The curtains between the light and dark rooms are gradually being replaced by sliding doors, which are a great improvement. The carbon filters installed last year have continued to protect the plants inside the laboratory against smog. An automatic air CO_2 analyzer has been put in operation. A closed-system air conditioning unit for growing plants in a radioactive CO_2 atmosphere has been constructed and put in use.

The work on sugar beets provides a good example of how the Earhart Laboratory can be useful in plant breeding. The plant breeder ordinarily measures the performance of varieties or strains in field trials carried on over a period of years, perhaps in several localities. If the investigator is fortunate in choosing a fair sample of years, climatically speaking, he may draw valid conclusions. But if he is less fortunate, he may draw quite misleading conclusions, for it is known that different varieties may differ widely in respect to adaptation to specific sets of climatic conditions. In working in a laboratory like Earhart, where conditions can be controlled experimentally, results are repeatable and tests can be made under the environmental conditions desired. In tests of eight sugar beet varieties under different conditions, their relative performances were not the same under all conditions. It has now been found feasible to determine the climatic factors responsible for optimum root and top growth and maximum sugar storage in the root.

It was through the use of sensitive indicator plants in the Earhart Laboratory that the plant-damaging components of Los Angeles smog were positively identified a year ago. This year, with the use of the oat coleoptile, there has been developed a smog test of higher sensitivity than any heretofeore available. It has also been observed that cotyledons of certain plants seem to be much more sensitive to hydrocarbon oxidants of smog than are true leaves.

A major activity of the plant physiology and plant biochemistry group has been a systematic study of plant respiration and phosphorylation. There is beginning to emerge a clear picture of how oxidative respiration takes place in higher plants, how pyruvate is oxidized via the Krebs cycle by a mitochondrial system, how respiration is related to growth, salt accumulation, water uptake and other energy-requiring processes, and how the latter activities depend upon a coupled phosphorylation process in which inorganic phosphate is

incorporated into the high energy phosphate linkages of ATP, which is then available for the various types of energy-requiring processes that go on in plants. The roles of many of the enzymes concerned have been determined. Through this work the Institute group has cleared the way for a new approach to many of the problems of plant growth and development.

Light effects on plants have been studied. The light control of flowering by photoperiod, the stimulation of leaf growth and the inhibition of stem growth, all involve pigments with strong absorptions in the red at 6600 A. In the case of stem growth inhibition, light appears to decrease the ability of the stem to take up the hormone indoleacetic acid (IAA) and also somehow increases the activity of IAA oxidase which catalyzes the destruction of this growth hormone.

It has been shown that day length exerts its influence on the flowering of plants through effects on the auxin balance of the leaves. Short days favor a low effective auxin level. The flowering of short-day plants is inhibited by applied auxin, whereas the flowering of long-day plants is promoted by the same treatment. Plants induced to flower by proper light treatment were grafted onto hosts not so induced. The result shows that flowering is induced by some substance that moves across a graft union. There is evidence that the flowering hormone is the same in long-day and short-day plants.

The presence of a virus-like component in crown gall tumors of plants was established. This component is characteristic of the disease rather than of the host plant.

In connection with soil erosion control in local watersheds, a study of native plants is under way in an attempt to find new plants that will make good ground covers. It has been found that the some existing plants can be made to provide better protection through the application of fertilizers, especially those rich in nitrogen.

In virology, unusual progress has been made at the Institute during the year in the study of bacterial and animal viruses. A hypothesis has been formulated which accounts for many of the quantitative aspects of genetic recombination in bacterial viruses. According to the theory, a mixed infection of a bacterium with different genetically marked types represents not a single genetic cross but an experiment in population genetics.

A question which may be asked by a person learning about virus research for the first time is: "Why work on bacterial viruses when an equivalent understanding of the viruses that produce diseases in man would be of so much more importance from a medical point of view?" The answer is that the techniques by which animal

viruses, including those which infect man, are studied are so difficult compared with those used in bacterial virology that knowledge of the latter can go forward enormously faster. It should be added that past experience in analogous situations leads us to believe that the basic principles of virology will be the same for all viruses, whether they inhabit a bacterial cell or man.

That the above reasoning is correct is well illustrated by recent work in the Kerckhoff Laboratory in which a successful transfer was made of the simple techniques of bacterial virology to two animal viruses. In bacterial virus studies, viruses are worked with quantitatively by mixing a few virus particles with a large number of sensitive host cells and plating the mixture on a standard bacterial culture plate of solid medium. The bacteria grow and opaque the plate, except where a virus particle lands. At such points there arises, owing to multiplication of the virus, a circle of dead bacterial cells which appears as a clear hole in the opaque background. This hole is called a plaque. By counting the plaques produced in a given mixture one knows accurately how many virus particles were initially present. Furthermore, one can easily recover the progeny of a single virus particle by transfering a single plaque to a suitable bacterial culture.

By developing a method in which the opaque bacterial layer in the bacterial virus technique is replaced by a single layer of susceptible animal cells grown in a tissue culture medium and in which subsequent infection is brought about with a suspension of virus particles, a way has been devised to produce visible plaques of dead cells comparable to the bacterial virus plaque technique. This method, named for its originator as the Dulbecco technique, works beautifully for two animal viruses, namely, the one that causes Western Equine Encephalomyelitis and the one that is responsible for Newcastle's disease in chickens.

Plans are under way to see if the newly developed Dulbecco technique can be used for the study of poliomyelitis virus and other viruses responsible for human diseases. If it can, progress will be greatly speeded up, for small tissue culture plates can be substituted for the scores of monkeys and the crates of eggs now required.

THE FUTURE

For the development of a sound future program of the Division, two urgent needs have arisen. The first is a further development of the Plant Research Center at the Dolk-Clark-Earhart site to take care of growing experimental plants free from smog damage. Much of the work of Bonner, Galston, Lang and their associates is con-

cerned with the chemical control of the growth and flowering of plants, and the smog damage frequently incurred at Orlando and at Dolk is a most serious obstacle. Experiments must often be discarded after months of work have gone into them. Greenhouse space next to the present Dolk laboratory, with a filter system that will free the intake air of smog for both Dolk and the new greenhouse, would solve this problem.

A second urgent need is additional space to take care of the virus work now being carried in in Kerckhoff. There are two reasons for this. First, because of the present crowded condition in Kerckhoff it is difficult to expand the animal virus program in the way justified by the gratifying progress made during the past year. Secondly, a segregated virus laboratory should be available, but cannot be provided in the present building in any economically sound way. Because of the crowding and lack of isolation, temporary arrangements have had to be made to do work on poliomyelitis at the new Huntington Memorial Hospital Medical Research Laboratory. This is not only inconvenient but will be impossible after the activities of this laboratory are under way to an extent requiring the use of all the available space. This problem could be solved by the construction of the contemplated new wing to the biological laboratories.

The need for space for the virus laboratory is closely related to a need for expanded facilities for those activities of the Chemistry Division bearing on medical and biological problems. It is hoped that a plan can be devised and the funds found to solve simultaneously both aspects of the space problem.

FINANCIAL SUPPORT

The total amount spent by the Division of Biology on instruction and research in the fiscal year 1951-1952 was in excess of $500,000. Approximately half of this was derived from Institute endowment income and half from special short-term grants or from government contracts. The funds used during the year came from the following sources:

Institute Endowment Funds	*Purpose*
William G. and Louise E. Kerckhoff Fund	General biology
Rockefeller Foundation Endowment	General biology
A. C. Balch Fund	General biology
Laurabelle Arms Robinson Fund	Biology and chemistry research, particularly as related to cancer
Frank P. Hixon Foundation Fund	Neurophysiology, physiological psychology and related fields

Institute Endowment Funds	*Purpose*
Gosney Research Fund	Gosney postdoctoral fellowships
Charles B. Holder Fund	General biology
Lucy Mason Clark Fund	Plant biology fellowships
Special Nonendowment Funds	
American Cancer Society	Chemical genetics
American Cancer Society	Plant tumors and plant tissue culture
American Cancer Society	Protein synthesis
American Society of Heating and Ventilating Engineers	Plant physiology fellowship
Beet Sugar Research Foundation (See University of California)	
James G. Boswell Foundation	Virus research
California Wine Advisory Board	Wine and grape constituents
Cymbidium Society Fund	Growth response
DuPont Company Fund	Predoctoral fellowship
Earhart Foundation	Earhart Plant Research Laboratory
Eversole Lecture Fund	Seminar speakers
Herman Frasch Foundation	Plant growth
General Electric Company	Light utilization by plants
Ibec Research Institute Fund	Plant physiology
International Minerals and Chemical Corporation	Creatine research
Lasker Foundation Fund	Fellowships, scholarships
Eli Lilly & Co. Fund	Amino acids, peptides
Loomis Institute for Scientific Research	Special biology expenditures
Los Angeles County Air Pollution Control District	Smog constituents and smog plant damage
F. S. Markham Fund	Electroencephalography
McCallum Foundation	Scholarships
Malcolm McNaghten Fund	Scholarships
Merck & Company Fund	Chemically induced mutation, new growth factors
Seeley G. Mudd Fund	Premedical scholarship
National Foundation for Infantile Paralysis	Virus research
National Science Foundation	Animal physiology
National Science Foundation	Plant physiology
National Science Foundation	Virus research
Nutrition Foundation	Biochemical genetics of Neurospora
Nutrition Foundation-McCallum Foundation	Predoctoral fellowships

Institute Endowment Funds	*Purpose*
Research Corporation - Williams-Waterman Fund for the Combat of Dietary Diseases	Tryptophane-nicotinic acid metabolism
Riker Laboratories	Veratrum growth and alkaloid formation
Edward G. Robinson Fund	Electronarcosis
Rockefeller Foundation Fund	Joint chemistry-biology program
Leonard G. Strater Fund	Plant physiology
Elbridge and Mary Stuart Foundation	Milk protein research
University of California - Beet Sugar Fund	Sugar beet research
Atomic Energy Commission (Administered by Office of Naval Research, U. S. Navy)	Radiation genetics
Atomic Energy Commission (Administered by Office of Naval Research, U. S. Navy)	Protein synthesis
United States Chemical Corps	Plant physiology
U. S. Department of Agriculture, Forest Service	Plant physiology
United States Navy, Office of Naval Research	Hemoglobin and red cells
U. S. Public Health Service	Mamalian physiology
U. S. Public Health Service	Protein synthesis
U. S. Public Health Service	Transmethylation
Williams-Waterman Fund for the Combat of Dietary Diseases (See Research Corporation)	

Respectfully submitted,

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

DIVISION OF CHEMISTRY AND CHEMICAL ENGINEERING

To the President:

CHEMISTRY

In the past year, several noteworthy contributions to the science of chemistry have been made by workers in the Gates and Crellin Laboratories. Some long-standing, difficult problems have been solved, and observations opening new fields for investigation have been made.

One of the principal fields of research in our laboratories since 1930 has been the determination of the molecular structure of gas

molecules by analysis of their electron-diffraction patterns. For some molecules containing both heavy and light atoms, such as uranium hexafluoride, the structures deduced by electron diffraction were different, in a striking and puzzling way, from the structures deduced by other methods. Professor Verner Schomaker surmised that the theory of the scattering of electrons by atoms that had been accepted for twenty-five years might be incorrect, and from the electron-diffraction photographs he formulated a correction, involving a change in phase of the electron waves scattered by heavy atoms. The theoretical problem was then attacked by Dr. Roy J. Glauber, Lecturer in Physics, who discovered that a simplifying assumption commonly used in electron scattering theory, the first Born approximation, does not adequately describe electron scattering by these molecules. The better approximation derived by him contains the suggested phase shift. As a result of this work the electron-diffraction method has been extended so as to be reliably applicable to the large class of molecules containing both light atoms and heavy atoms.

Professor Schomaker, Dr. K. Hedberg, and their collaborators have determined the structure of many interesting substances by the electron-diffraction method. Dr. Hedberg has also shown that the interatomic distance in the electron-deficient boron hydrides can be predicted rather accurately by use of the general relation between bond number and bond distance developed for the discussion of ordinary bonds and metallic bonds.

Professor Richard M. Badger, Dr. Roger Newman, and co-workers have continued to apply infrared spectroscopy to structural problems. By a combination of polarization studies on crystals and of studies on gases, solutions, and liquids, the important characteristic vibrations of the amide group have been positively identified in several cases. An especially interesting vibration is one concerned with the C-N link having partial double bond character; hydrogen bonding markedly increases the double-bond character.

Professor J. H. Sturdivant and his collaborators have carried on structural determinations by X-ray diffraction. One of the most interesting results is that the stereochemical configuration of 9,9′-dehydrocarotene around the central acetylenic group is *trans*.

Dr. Richard Marsh and Professor Linus Pauling have determined the structure of the unusual substance chlorine hydrate, $6Cl_2.46H_2O$. The water molecules are linked by a network of hydrogen bonds; this network defines cavities into which chlorine molecules or other small molecules, such as molecules of methane, krypton, or hydrogen sulfide, can fit.

Work on the problem of the structure of metals has been continued by Professor Pauling and his collaborators. The structures of two complicated alloys $Mg_{32}(Al,Zn)_{49}$ and $Mg_6Si_7Cu_{16}$, with 162 and 116 atoms respectively per unit cell, have been determined by Drs. Gunnar Bergman and John L. T. Waugh. In the determination of these complicated structures it has been found very profitable to apply the stochastic method; *i.e.*, to guess what the structure is and to test the guess by comparison of the predicted X-ray diffraction pattern with the experimental one, rather than to attempt to derive the structure from the X-ray data. The success of the method is largely due to the fact that only those structures are acceptable in which the atoms are packed with a minimum waste of space. Mr. M. Jones has shown that magnesium boride is MgB_2, rather than Mg_3B_2, as previously reported.

Work on the structures of proteins and of their building blocks, the amino acids and simple peptides, continues. In the year preceding this one Professors Pauling and Robert B. Corey discovered several possible protein structures—ways in which polypeptide chains can be arranged in coils or sheets, consistent with the principles of molecular structure and the known structures of simple peptides. This discovery has stimulated intensive work in laboratories throughout the world. It has become evident during the past year that one of the suggested structures, a helix with about 3.6 amino acid residues per turn, is present not only in some synthetic polypeptides but also in many important proteins, including hair, finger-nail, horn, skin, hemoglobin, and serum albumin. Confirmation of the discoveries made by Professors Pauling and Corey has been reported by English investigators, especially those working in the Cavendish Laboratory in Cambridge and the Royal Institution in London.

Professors Pauling and Corey have described two new pleated-sheet structures of polypeptide chains, and there is considerable evidence that they are present in natural protein fibers such as silk and stretched hair. Professor Corey and Drs. E. W. Hughes, J. Donohue, L. Katz, R. Pasternak, H. Yakel, R. Marsh, and J. Leonard have finished or soon will finish precise and complete determinations of the structures of the simple substances urea, histidine, glycyl-L-asparagine, and N,N′-diglycyl-L-cystine. The last of these contains a sulfur-sulfur bond, which also occurs in such fibrous proteins as hair, horn, and quills. X-ray studies of the macromolecules lysozyme chloride (in collaboration with our alumni Dr. K. J. Palmer of the Western Regional Research Laboratory and Dr. K. Trueblood of U.C.L.A.), poly-γ-methyl-L-glutamate, silk, collagen, and dried

muscle tissue have been made, and deductions have been drawn about the configuration of their polypeptide chains.

Dr. W. A. Schroeder, Dr. F. C. Green, and Mr. L. Honnen have continued their chemical studies of the sequence of amino acids in proteins by chromatographic analysis. Because of great interest in the structure of collagen, which is the protein in bone and tendon, the amino acid sequence in the related soluble protein, gelatin, has been studied and partly elucidated.

The extensive program of investigation in immunochemistry and the chemistry of blood has continued under the general guidance of Professors D. H. Campbell and Pauling. Dr. Harvey Itano, continuing his important work on the molecular basis of the hereditary hemolytic anemias, has discovered a wide variation in the ratio of concentrations of normal hemoglobin among individuals who have the sicklecell trait (that is, who are carriers of the disease sickle-cell anemia). These studies have led him to the hypothesis that different alleles controlling the production of normal hemoglobin at distinctive rates exist in the human population. Dr. Alexander Rich has confirmed the presence of fetal hemoglobin in individuals afflicted with Cooley's anemia and has encountered two adult patients with only fetal hemoglobin in their blood, a situation hitherto unknown. Dr. Morris Goodman and Professor Campbell are making immunochemical studies of normal, sickle-cell, and fetal hemoglobin.

The development of Oxypolygelatin as an emergency plasma substitute is being carried on by Drs. J. Vinograd and I. Bengelsdorf and their co-workers. Solutions of this material that do not gel at O°C have been produced.

Professor Campbell in collaboration with Dr. S. J. Singer (now at Yale University) has studied the properties of antigen-antibody complexes. The bivalence of antibody molecules has been firmly established, and the equilibrium constants for the formation of these complexes are being measured. New methods are being developed for isolation and purification of antibodies, based on the use of an insoluble antigen as a specific adsorbent.

Professor Campbell and Dr. Richard Lippman of the Cedars of Lebanon Research Institute are studying the pronounced effects of specific antibodies as toxic agents for tissues, with special reference to kidney disease. Drs. Justine Garvey and Norman Bulman are using radioactive labelling techniques to study the fate of injected antigens and antibodies in animals.

In the field of the organic chemistry of natural products, Professor L. Zechmeister and his collaborators have continued their

stereochemical studies of natural or related substances containing double bonds, using chromatography and iodine catalysis of spatial rearrangements. Dehydro-β-carotene has been shown to contain the *trans* isomer and several *cis* isomers. Dr. H. Pinckard is studying the isomers of the cyanine dyes. Dr. B. K. Koe has isolated carcinogenic hydrocarbons from barnacles that are used as food by some ethnic groups. A chromatographic method for the separation and detection of enzymes has been worked out by Dr. M. Rohdewald and Prof. Zechmeister. In collaboration with Professor H. J. Deuel and his group at the University of Southern California, the influence of structure on the provitamin-A potency of various carotenoids is being studied.

Professor Carl Niemann and his collaborators are carrying on studies of enzyme kinetics, of natural products, and of organic reactions. Dr. R. J. Foster's theoretical study of the possibility that several different functional groups in one substrate molecule can be attached to different sites on an enzyme molecule has led to a possible reinterpretation of the equilibrium and rate constants for some enzymatic reactions. With this new picture it is possible to explain quantitatively the effect of concentration of heteroauxin and 2,4-D, added separately or together, as growth promoters for oat shoots. Dr. M. Ikawa has continued his work on the agent from *E. coli* which causes hemorrhage and regression of experimental mouse tumors. The polysaccharide moiety of this complex material has been characterized; the phospholipid moiety contains an organic acid and an amine which have been identified, and which had not hitherto been discovered in nature. Dr. H. Rinderknecht has synthesized β-oxindolylalanine, a constituent of the toxic principle of the fungus *Amanita*, and is working on the resolution of some amino acids.

Professor H. J. Lucas and his collaborators have found that alkyl acetylenes coordinate silver ion about as well as do olefins and that a second silver ion can also coordinate to the acetylene. The complexing of silver by aromatic hydrocarbons has been studied. There is a rough correlation of complexing tendency with carcinogenic activity.

Dr. E. R. Buchman and co-workers have continued their investigations of cyclobutane derivatives.

Dr. Oliver Wulf, a member of the United States Weather Bureau working in the Division of Chemistry and Chemical Enigneering, has carried out investigations relating to the measurement of ozone in the upper atmosphere, to the thermodynamic efficiency of the driving of the large-scale atmospheric circulation by solar radiation,

and to the mechanism through which solar activity is connected with the transient variations of the earth's magnetic field.

Professor Norman Davidson and Dr. Tucker Carrington have developed a new method for measuring the rates of very fast reactions. By passing a shock wave through a gas in a tube, the gas can be heated up by a specified amount from 1° to 5000° in less than a millionth of a second. If there are any subsequent chemical reactions that are caused by the heating and that produce a change in the color or light absorption of the gas, their rates can be measured with a photoelectric cell and a cathode ray oscilloscope. The rate of dissociation of N_2O_4 into NO_2 has been studied as an example of the method. This reaction occurs in about ten millionths of a second. Professor Davidson and his students have carried on other investigations of the rates and mechanisms of chemical reactions.

In analytical chemistry, Professor Ernest H. Swift and his associates have continued to develop coulometric titration procedures. Methods for titration of tripositive antimony with chlorine and of thiosulfate with iodine have been established. The nature of the complex ions in acidic solutions of tripositive arsenic in water and ether are being studied.

Chemical Engineering

Experimental work in the Chemical Engineering Laboratory has been directed toward a fundamental understanding of problems of importance in several fields of engineering practice. The emphasis of the program is being gradually changed from the study of the equilibrium thermodynamic properties of fluids at elevated pressures to investigations of non-equilibrium phenomena, such as thermal and material transfer under quiescent and convective conditions. At present approximately two-thirds of the laboratory work is directed to the latter field.

Professor B. H. Sage, in collaboration with Dean W. N. Lacey and Mr. H. H. Reamer, has continued a study for the petroleum industry of the volumetric and phase behavior of hydrocarbons at elevated pressures. This series of investigations has now been in progress for twenty-five years under the sponsorship of the American Petroleum Institute. Utilization of the extensive background of experimental data thus produced in the application of equations of state to wide ranges of pressure and temperature for the purpose of predicting thermodynamic properties of such fluids in homogeneous and heterogeneous equilibrium has become an important part of this undertaking. Because of the particular interest of the Department of Defense, similar studies were made of the behavior

of nitric acid and the oxides of nitrogen at chemical and physical equilibrium. Dr. D. M. Mason studied optical absorption by mixtures of nitric acid and nitrogen dioxide, and the effect of metals upon the equilibrium behavior of nitric acid.

Investigations of the molecular diffusion of hydrocarbon components in liquid and gas phases at elevated pressures were also undertaken as a new part of the work for the petroleum industry. Methods were developed for the measurement of diffusion coefficients under steady transfer conditions in the gas phase at high pressures.

Dr. W. G. Schlinger, Professor Sage, and their collaborators continued with investigations of thermal transfer in uniform steady turbulent gas streams with particular emphasis upon the influence of turbulence in transfer processes. This work reached the point where reasonable predictions of behavior could be made for uniform flow under conditions of industrial interest. The temperature distribution in the wakes of heated cylinders and spheres when in turbulent gas streams and the thermal flux from them received attention. Data obtained in this way were directed toward the prediction of the distribution of temperature and thermal flux in the nonuniform steady turbulent flow of air. A detailed investigation of the mechanism of the evaporation of drops in a turbulent gas stream, with support from industry, has formed an additional part of the comprehensive program of investigation of phenomena related to turbulent fluids.

FINANCIAL SUPPORT

The work of the Division of Chemistry and Chemical Engineering has been supported in part by the income from California Institute endowment funds, in part by gifts, grants and research contracts from the following:

Abbott Laboratories
Allied Chemical and Dye Corp.
American Academy of Allergy
American Cancer Society
American Cyanamid Co.
American Petroleum Institute
Anonymous, for graduate fellowship
Atomic Energy Commission
California Research Corp.
Climax Molybdenum Co.
Dow Chemical Co.
E. I. du Pont de Nemours & Co.
Essick Manufacturing Co.
Ethyl Corporation
Fluor Corp.
General Petroleum Corp.
John Simon Guggenheim Memorial Foundation
Eli Lilly & Co.
Molybdenum Corp. of America
National Foundation for Infantile Paralysis
National Research Council
Office of Naval Research, U. S. Navy

Parke, Davis & Co.
Rockefeller Foundation
Shell Oil Co.
U. S. Army Medical Corps
U. S. Public Health Service
United States Rubber Co.

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

THE DIVISION OF CIVIL, ELECTRIC AND MECHANICAL ENGINEERING AND AERONAUTICS

Teaching is the major responsibility of the Division of Engineering. This past year has been marked by no significant changes in student enrollment nor in distribution of students among the several options for study, undergraduate and graduate. The heaviest graduate teaching load continues in aeronautics and inasmuch as it is directly pertinent to significant research progress during the past year, over two-thirds of the ninety aeronautics graduate students were candidates for professional or doctor's degrees, which require research activities and presentation of theses.

The Division has given much thought during the past year to critical examination of curricula and individual courses of study in order that the engineering training offered by the Institute can be as well adapted as possible to modern technology and trends and to shifting directions of emphasis in the basic sciences. From these studies, which are by no means finished, have emerged a number of courses changes and shifts of emphasis evolutionary in character, representing small but significant modifications of our present curricula. A new option for graduate study leading to the Ph.D. degree called "Engineering Science" was approved this year by the Faculty. This new option will permit greater flexibility for those students whose interests and abilities are not suitably represented by the other degree options of civil, electrical, mechanical engineering and aeronautics.

As a further improvement in the teaching program, certain laboratories, notably those for dynamics and servomechanisms, have been improved to insure that the methods, equipment and subject matter remain completely modern. The objective has been to maintain the instrumentation at a level somewhat in advance of current industrial practices. At the same time a general policy has been followed of having these laboratories useful for research purposes as well. Many of the laboratory experiments have assumed the form of small research projects which have produced significant results and in one instance has led to outside financing for continuation of the study.

In research most of the work of the Engineering Division has represented continuing or long-range programs in the following major fields of activity: in aeronautics, experimental and theoretical fluid mechanics, hypersonic flow, elasticity, and aeronautical structures; in civil engineering, soil mechanics, water quality investigations, and earthquake structures; in electrical engineering, arc phenomena and dielectric recovery, analog and digital computer studies, and electronics; in mechanical engineering, research in combustion and internal combustion engine problems, vehicle dynamics, axial flow compressor aerodynamics, physical metallurgy, and dynamic properties of metals; in hydrodynamics, wave and surge studies, dynamic force coefficients, cavitation, hydraulic machinery; in the Daniel and Florence Guggenheim Jet Propulsion Center, problems of propulsion and control of missiles, fundamentals of combustion and heat transfer, and physical chemistry of fuel systems.

From this sketchy and incomplete list of research studies in the Engineering Division attention is focused on a few particular studies primarily because they may be isolated from continuing projects or represent some specific result. No inference should be made of the significance of these particular studies relative to the many others which are not thus highlighted in this report.

For the past three years studies have been made of the possibilities of vibration compaction of soils. This work, which has been done on the campus with both experimental and theoretical attacks, permitted the prediction of the performance of a much larger compaction unit which we were able to design and test under the sponsorship of the U. S. Navy Civil Engineering Research Evaluation Laboratory at Port Hueneme, California. Under the direction of Professor F. J. Converse this mechanical vibrator, which is capable of exerting a dynamic force of 16,000 pounds against the surface of the soil over an area of about 20 square feet, has been tested on beaches. It was found that the sand was compacted to 95 per cent of the density which it is theoretically possible to achieve. This compaction unit is readily towed behind a vehicle and compaction is obtained for traffic lanes or substantial areas in a relatively short time. The significance of this development for quick achievement of traffic lanes over sandy stretches is apparent. The Institute's interest in this development has been primarily that of extrapolating to a large-size unit the theory and test results which were obtained on the campus with equipment of much smaller dimensions.

The studies of Professor G. W. Housner and his group on strong motion earthquakes and their effects on structures have led to statistical determination of probable upper-limit for the intensity of ground

motion to be expected from California earthquakes and the frequency with which cities in California can expect to experience such ground motion. It was found that a city in California can expect to experience ground motion of intensity equal to or greater than that experienced at Long Beach during the earthquake of March 10, 1933, at an average rate of once in seventy years. An earthquake of magnitude equal to or greater than the San Francisco shock of 1906 can be expected in California at an average rate of once in two hundred years.

As a part of this program, measurements were made of ground motion and building vibrations during an artificial earthquake produced by a quarry detonation of 370,000 pounds of explosive. This pre-planned earthquake permitted a precise determination to be made of the motion of the building and the stresses produced by the earth shock. These earthquake structures studies have been sponsored by the Office of Naval Research.

One of the most significant developments in the application of the Institute's Electric Analog Computer resulted from work sponsored by the NACA. By means of new electric circuit analogies, a rapid and general method has been developed for the static stress analysis of complex structures. In this specific project the method was applied to the determination of the stress distribution in short broad wing structures typical of new high speed aircraft wings or missile fin structures, which consist of a multitude of ribs and spars enclosed by metallic sheets. This was a general study of a wide variety of configurations providing important data for the proper design of such structures.

In the High Voltage Laboratory a new research program on the basic insulation characteristics of rotating machine insulation has been started during the year. This is sponsored jointly by the American Institute of Electrical Engineers, the principal electrical manufacturers of such equipment, and the Southern California Edison Company. This study is being undertaken for the purpose of establishing more accurately the 60 cycle and impulse breakdown characteristics of various types of such insulation. Such knowledge will lead to both a better design and application of such machines.

The work of Professors D. S. Clark and D. S. Wood in the dynamic properties of metals has been advanced significantly last year by application of modern theory of dislocations to the mechanism of yielding. A new rapid loading machine has been built which is designed to load a specimen in a short time, less than 5 milliseconds, hold this load for a pre-determined time, and unload the specimen in a very short time interval. The machine permits very accurate measurements of strain in the specimen. This machine permits an important

extension of the work which has been under way for some time here in the mechanism of yielding. The work is sponsored by the Office of Naval Research.

The Daniel and Florence Guggenheim Jet Propulsion Center, under the guidance of Professors Tsien, Marble and Penner, has made substantial contributions in the mechanism of flame stabilization in the combustion chambers of jet engines and in the application of spectroscopic data to the calculation of gas emissivities. Of particular significance, however, is the fact that due to the success of the fellowship program of the Center, additional funds have now been made available by the Daniel and Florence Guggenheim Foundation, allowing a considerable increase in the number of Jet Propulsion Fellowships for the coming years.

The Hydrodynamics Laboratory, under sponsorship of the Navy Bureau of Yards and Docks, Bureau of Ordnance, and the Office of Naval Research, has made a number of contributions during the past year to continuing and completing studies as outlined in the following brief and quite inadequate fashion. Professors Hollander, Knapp, Plesset, and Vanoni guided these extensive operations.

Studies have continued at the Azusa Laboratory on wave disturbances in harbors. Analytical methods have been developed for combining the effects of diffraction and reflection of surface water waves to determine the net wave disturbance at particular points in a harbor. Experimental measurements in the harbor model basin have given substantial verification of the analytical procedure. These studies, together with previously completed work on wave diffraction, constitute the basis for a manual on *Wave Protection Aspects of Harbor Design*, which has been completed.

In the High Speed Water Tunnel of the Hydrodynamics Laboratory an experimental study has been made of the effect of model size, or scale, on incipient cavitation. This study has great practical significance, since it is necessary for extrapolation from model data in water tunnels to full-scale situations. It had been assumed by other workers in this field that the effect of scale in incipient cavitation would be determined by the cavitation number alone. These experiments demonstrate that this is not the case. A theoretical investigation has also been made of the problem, which supports the experimental findings and relates the observations to the physical properties of gas nuclei in water.

A new technique has been developed for use in the High Speed Water Tunnel which makes possible the determination of the dynamic force coefficients of submerged bodies. Such measurements lead to direct conclusions, regarding the controllability and stability of such bodies in free flight.

In the Hydraulic Machinery Laboratory an experimental and theoretical investigation of two-dimensional centrifugal pump impellers has been completed. It was found that pressure distribution and overall performance were predicted reasonably well by the theory for some operating conditions, and large discrepancies occurred under other conditions. A study of the sources of these discrepancies is now being made.

Theoretical studies in the field of cavitation and vapor flow have continued. The effects of compressibility in the collapse of a cavity in a liquid have now been analyzed, and the problem of the heat flow in an expanding or contracting vapor cavity has been solved.

Mr. Albert Ellis developed a high-speed camera for photographing the growth and collapse of cavitation bubbles. Over small intervals of time pictures may be taken at the rate of 200,000 per second. The camera uses a Kerr-type electro-optical shutter and a rotating mirror which sweeps the successive images of the cavitation bubble over the surface of a stationary strip of photographic film.

The activities of the Guggenheim Aeronautical Laboratory in research are extensive and difficult to highlight because of the continuing nature of most of the investigations. Professor Clark Millikan has summarized the Laboratory activities very concisely as follows:

(1) *Experimental Fluid Mechanics:* Dr. Hans Liepmann's group made further advances in the two long-range programs: turbulence and compressible fluid flow. In the former the vortex street studies started over a year ago continued to yield significant results, as did the statistical analysis techniques developed earlier. The effects of turbulence and irregular loads on wings and complete aircraft were studied experimentally and theoretically, using modern statistical concepts. These studies are arousing widespread interest and promise to be of great practical importance. In connection with supersonic flow, the effects of viscosity and shock waves were futher investigated and important data on skin friction and heat transfer were obtained. A supersonic wind tunnel, based on a new principle of thermodynamic rather than mechanical drive, was designed and placed in operation and demonstrated useful new principles. These programs continued to receive support from the National Advisory Committee for Aeronautics.

Under Dr. H. J. Stewart's direction, hot-wire laboratory techniques were successfully applied to a study of atmospheric turbulence from the ground up to heights of some 500 feet. In addition to meteorological data, this program, sponsored by the U. S. Weather Bureau, furnished significant new information in connection with fundamental turbulence theory.

(2) *Theoretical Fluid Mechanics:* The mathematical investigation of the fundamental equations of compressible, viscous fluid motions, sponsored by the Office of Naval Research, continued under Dr. Paco Lagerstrom's direction and additional insight was obtained into some of the basic problems involved. This very interesting long-range program is expected to yield results of importance to practicing engineers only after a number of years. Dr. J. D. Cole and his students made important advances in the theory of heat transfer in supersonic flow and in the difficult problem of flow at speeds close to that of sound. It appears that these results may have fairly immediate practical applications.

(3) *Hypersonic Flow:* Dr. H. Nagamatsu's group is continuing its development of hypersonic wind tunnel designs and techniques under Army Ordnance and Air Force sponsorship. In addition, the existing hypersonic facilities have been actively used during the past year to produce new experimental and theoretical results on aerodynamic phenomena at the extremely high speeds at which guided missiles and rockets are now beginning to operate.

(4) *Elasticity and Aeronautical Structures:* The program in this field, under Dr. E. E. Sechler's direction, has been very intensively pursued during the past year. A final report on the design of thin, swept wings is in preparation for the Air Force, and another project on optimum wing design has been started under Air Force sponsorship. The program on buckling of low arch beams, which is sponsored by the National Advisory Committee for Aeronautics, has been expanded to include the buckling of curved plates, with application to wings for supersonic aircraft. Additional laboratory facilities have been installed in connection with the program on fatigue of aircraft structural materials and valuable results have been obtained. In the field of aeroelasticity attention has been focused on a statistical approach to the problem of dynamic loads on elastic structures. This activity is being closely coordinated with the statistical investigations mentioned above in connection with the turbulence problem.

The Cooperative Wind Tunnel was again fully occupied with important defense projects sponsored by government agencies and the aircraft industry. The $6,500,000 modification program to permit supersonic operation is being actively pursued concurrently with the normal research and testing program.

Respectfully submitted,

F. C. LINDVALL, *Chairman, Division of Civil, Electrical and Mechanical Engineering and Aeronautics*

THE DIVISION OF THE GEOLOGICAL SCIENCES

To the President:

In no other year, since its establishment in 1926, has the Division of the Geological Sciences enjoyed such rapid growth as in this year just passed. A new Division chairman was appointed, two professors, a research associate, three research fellows, and three research assistants were added to the staff; and an extensive program of new construction and installations was initiated in the Mudd and Arms laboratories. But notwithstanding the many problems that inevitably attend such rapid growth and expansion, the various research programs of the Division have been vigorously carried forward, and at the conclusion of the year it may fairly be stated that never have prospects been so bright for significant contributions to the field of the earth sciences, as they now are for the coming years at the California Institute.

In considerable part, therefore, the year 1951-52 may be looked upon as one of "spade work"—necessary preparation for the harvest that future years will see mature. This is particularly true of the major new development of the past year, viz., the development of a program in geochemistry. Of this there was no more than an adumbration in last year's report. This year, Dr. Harrison Brown, formerly of the Institute for Nuclear Studies at the University of Chicago, has joined our staff as Professor of Geochemistry and has had charge of getting an extensive program under way. This has involved some very large changes, especially in the Mudd Laboratory, where the entire basement floor is being converted to the needs of geochemistry. Among the important equipment that has been or is about to be installed, are three mass spectrometers of special design, an emission spectrograph, a radioactive counting laboratory, and several chemical laboratories. The research program is being directed, first, to a study of the fundamental geochemistry of uranium and of the uranium minerals. Soon, the geochemistry of other elements that have particular promise in the solution of earth-science problems will be brought under investigation. Along with this, studies in the important field of geochronology will be initiated. Geochronology is concerned with the most precise possible dating of geological events. Geologists, for too long, have had to be content with dating to "within a few millions—or tens of millions—of years, more or less". Methods involving the use of stable-isotopes hold the greatest promise of improving such dating, and thus the new laboratories are well suited to developing a geochronology laboratory for the solution of the time problem in earth history. Already one notable contribution to the

geochronology laboratory has been received, in the form of Mr. Harold Gladwin's extensive collection of well-authenticated specimens and detailed records of tree-ring chronology.

At the Seismological Laboratory, there have been a number of interesting and significant developments, some in instrument design, some in theory and interpretation. Under the supervision of Professor Hugo Benioff, development of a magnetic tape recorder for seismic waves has been very nearly completed. A laboratory model has been operating routinely throughout the year. Development of a new form of seismograph employing a capacity transducer is nearly completed. A linear strain seismograph with a recording galvanometer of three minutes' period has been placed in operation for recording the very long period earthquake waves not observable with other instruments.

The Geological Society of America has made a Penrose grant of $10,200 to Professor Hugo Benioff for construction of a fused quartz earth strain meter. This instrument will be installed in an abandoned tunnel of the Los Angeles County Flood Control District situated in Big Dalton Canyon north of Glendora. The temperature variations within the tunnel are quite small so that with the quartz indicator tube, thermal expansion effects should be negligible. The remote site insures freedom from man-made disturbances other than loading effects of the water back of the dam. The new instrument may be expected to provide the following contributions to the earth sciences: (1) Measurements of secular strain variations in the earth's crust for determining the character of tectonic movements now in progress and to delineate regional earthquake-generating strain patterns. (2) Direct measurments of tidal strains in the crust which in the past have been derived indirectly from measurements of tilt. (3) Exploration of the seismic spectrum in the long period region beyond the limit of existing instruments. This portion of the seismic spectrum should offer information as to the structure of the crust. If the free vibrations of the earth as a whole can be detected, additional information as to the structure of the earth can be obtained. (4) An improved linear strain seismograph having superior stability and hence higher magnification than can now be used with existing instruments of this type.

Professor Benioff has continued his investigations of earthquake sequences. The sequence of shallow earthquakes which began in 1925 in the Indian Ocean exhibited an elastic strain-rebound characteristic which up to October 23, 1933, was accurately represented by an equation of logarithmic form. Following the shock of that date the fault was locked strongly, so that no further earthquakes were produced for some sixteen years. During this quiescent interval, if

strain were accumulating in accordance with the above mentioned equation, it was possible, for any given date, to predict the magnitude of the earthquake required to reduce the accumulated elastic strain of the fault to zero. Thus in 1949 the accumulated strain was sufficient to generate a 7.5 magnitude earthquake. On October 7, 1949, the sequence became active again with the production of a magnitude 6.75 shock. This shock relieved only a small fraction of the strain. However, on December 8, 1951, a magnitude 7.5 shock occurred which relieved all of the accumulated strain to within 0.1 magnitude of the value predicted by the equation. The equation represents an elastic (or recoverable) creep which may be either an elastic afterworking following an earlier creep strain accumulation, or a forward creep in response to an external force. If the former case is the correct one, this sequence will die out. If the latter obtains, then large elastic and creep strains are stored in the fault blocks outside of the sequence earthquake-generating zone. If these blocks should fracture, a great earthquake of magnitude 8 or larger could be generated.

Professor Benioff has also continued his study of seismic sequences in relation to orogeny. The original investigations involved the Tonga-Kermadec and South American regions only. During the year the list of regions has been extended to include Mexico and Central America, the Aleutians, the Kurile-Kamchatka Arc, the Marianas, the Philippines, the Sunda Arc and the New Hebrides Islands. Evidence from these studies indicates that the principal orogenic structure responsible for each of the great linear and curvilinear mountain ranges and oceanic trenches is a fault. The faults occur either wholly within the oceanic realm or else are marginal to the continents.

Professor Beno Gutenberg carried out a comparison of microseisms recorded in November and December, 1951, at Pacific Coast stations from Victoria, B. C., to Mexico City with reports of waves recorded or observed at three points off the southern California coast. These showed a strong correlation, but it is not yet certain whether the waves produce movements of the ocean bottom large enough to be transmitted to the continent or whether the microseisms result from surf action at the coast.

Problems of ground motion in surface waves of earthquakes were investigated by Professors Benioff and Gutenberg with the aid of pendulum and Benioff strain seismographs at Pasadena, and the motion in transverse waves was similarly studied by Gutenberg.

Many other investigations of the Division staff deserve mention, but only a few more can be included in this report. Professor J. P. Buwalda summarized some of the results of field examinations in

many parts of the western United States in a paper presented at the Tucson meeting of the Cordilleran Section of the Geological Society of America. He set forth the generalization that very different types of tectonic movements affected neighboring areas simultaneously—during the Quaternary. For this concept, the term "heterosynorogeny" was coined. Professor Buwalda has also continued with the geologic mapping of the Tehachapi Quadrangle. This is not merely a descriptive study, but the work is throwing light on the relation of the three structures which project into that mountain mass: the Transverse Ranges from the west; the middle Coast Ranges, from the northwest; and the tilted Sierran block from the northeast. The Tertiary formations in the Tehachapis and their contained vertebrate fossils help to decipher this complex structural history.

Professor R. H. Jahns has completed the first of a series of studies on the genesis of pegmatite—a unique rock which has been the source of much scientific controversy, as well as the source of some of our most "critical" minerals (beryl, mica, spodumene, etc.). He has also completed a field investigation of the calderas, or "collapsed volcanoes" of the Pinacate region, in northwestern Sonora. These calderas are remarkably well-preserved examples of collapse following ultravesiculation in the throats of basaltic volcanoes. Hence these studies throw new light on the age-old problems of volcanism and of the sources of magma.

A geophysical survey, carried out by Robert D. Forester, under the supervision of Professors R. H. Jahns and G. Potapenko, of iron deposits of the Silver Lake District, San Bernardino County, has been successfully completed. The results of this survey suggest the presence of several million tons of iron ore in the form of large bodies buried beneath an irregular cover of alluvium, a reserve not previously anticipated on the basis of earlier purely geologic investigations of the deposits. The results also promise to shed more light on the origin of the deposits, a question that bears significantly on problems of further exploration and estimation of reserves.

On the Malaspina Glacier, Alaska, Professor R. P. Sharp, aided by a number of graduate students, has carried on a series of investigations designed to yield fundamental data for glaciology. These studies involved: (1) Seismic sounding to determine the thickness of the ice and the depth and configuration of the bedrock floor beneath the glacier. (2) Gravity surveys to investigate adaptations of this method to glacier work and to get finer details on topographic configuration than given by the seismic profile. (3) Structural studies of the ice both as to foliation, folding, fractures and other mega-structures, and as to fabric (orientation of ice crystals) in the glacier. The relation

of all these structures to one another and to the mode and nature of flowage occurring in the glacier is of considerable interest. (4) Movement studies in a vertical profile, actually the velocity of flow across a vertical section. This was attacked by sinking an aluminum pipe 1000 feet vertically into the glacier and measuring its orientation with an inclinometer. Repetitions of measurements in 1952 and subsequent years should show the deformation undergone by the pipe which is in essence a measure of the flowage. These data are absolutely necessary for establishing or rejecting the existence of extrusion flow in glaciers. All these studies tie together and support one another in what might be termed a study of the structure and mode of flowage in Malaspina Glacier, a piedmont ice sheet.

With assistance from Professor C. H. Dix and a few graduate students, Professor Sharp has continued his geological and geophysical investigations of Cima Dome. This is a continuing study designed to unravel the true origin of this type-specimen of a Desert Dome, a geomorphic form long the subject of considerable controversy.

Professor Dix has been making progress on a form of the gravity interpretation problem. Research is under way on the development of seismic sources and receivers of scale intermediate between the full-scale seismic prospecting instruments used in oil exploration and seismic scale model equipment. The purpose is to make the seismic method useful in a much greater range of geological problems.

Additions to the staff have been many and notable: Dr. Harrison Brown, as Professor of Geochemistry; Dr. Charles E. Weaver, as Research Associate in Paleontology; Dr. Samuel Epstein, Mr. Charles McKinney and Dr. Claire Patterson, as Research Fellows in Geochemistry; Mr. Wilbur Blake, Mr. Walter Nichiporuk, and Mr. Aiji Uchiyama as Research Assistants in Geochemistry. Arrangements have been completed for Dr. Heinz Lowenstam of the University of Chicago to occupy a new chair of paleoecology in the Fall of 1952. Arrangements have also been consummated whereby Dr. Thane McCulloh, of the U. S. Geological Survey and currently the recipient of a National Science Foundation post-doctoral research fellowship, will join our staff in September, 1953, as Assistant Professor of Geology. Dr. Ronald Mason, of the University of London, has been with us for the year, as Visiting Research Fellow in Geophysics. Dr. C. Hewitt Dix, formerly a part-time member of the staff, became Associate Professor of Geophysics, on a full-time basis, in January. Seldom is it possible to enjoy gains without suffering some losses. Thus it was with sincere regret that the resignation of Dr. C. W. Merriam, Associate Professor of Paleontology, was accepted on January 1. Dr. Merriam returns full time to the U. S. Geological Survey in order

to complete some important research projects which a continuation of his teaching duties would have unduly delayed.

Various honors, awards, and important responsibilities have continued to come to members of the Division staff. Among these the following might be mentioned. Professor Hugo Benioff received a Penrose Grant from the Geological Society of America to further his research in seismology. Professor Harrison Brown, at the October, 1951, meeting of the American Chemical Society, was given the Society's award in pure chemistry. Professor Brown is also the recipient of a three-year fellowship from the John Simon Guggenheim Memorial Foundation, and of a research grant from the Rockefeller Foundation. Professor J. P. Buwalda was reelected for a second term to the presidency of the Seismological Society of America. Professor Ian Campbell was elected chairman of the Industrial Minerals Division of the AIME. Professor Beno Gutenberg, at the meetings of the International Geophysical Union in Brussels, was elected President of the Association of Seismology and Physics of the Interior of the Earth. Professor Gutenberg at the invitation of UNESCO spent some time in Turkey advising government authorities on the installation of a Turkish Seismological Institute and several seismological stations. Also under UNESCO auspices, he visited Israel in order to study the most favorable locations for stations and to confer with Council members on seismological and meteorological problems. Professor R. H. Jahns was elected to a one-year term on the Executive Committee of the Industrial Minerals Division, AIME.

The interest, cooperation, and generosity of various individuals and organizations has significantly furthered the program of the Division, in this as in former years. It is impossible here adequately to acknowledge all of the help we have enjoyed. But as examples of such might be mentioned: the Standard Oil Company of California, the Stanolind Oil and Gas Company, and the General Petroleum Company, each of which provided research fellowships at the graduate level. In few other ways is it possible better to aid deserving young men and, at the same time, to further scientific investigation. The Kennecott Copper Corporation has announced the award to the Division for the coming year of a research fellowship in economic geology—the first fellowship of its kind to be received by the California Institute and one of the very few of its kind in American universities. Dr. Childs Frick, through the Frick Foundation, has continued his generous support of research in vertebrate paleontology and made possible the purchase of the library of the late Professor Chester Stock. The Atomic Energy Commission is supporting in large measure the program in geochemistry. The Office of Naval Research has continued to provide support

for glaciological studies, and the Air Force Cambridge Research Center has continued its support of seismological research, with the development of a seismological station on Palomar Mountain. Mr. Harold S. Gladwin has donated one of the country's outstanding collections of tree-ring materials, for geochronological research. To these, and to the many others who have aided the program of the Division of the Geological Sciences, the staff expresses its sincere appreciation.

As a stimulating climax to an already eventful year, came the announcement, at Commencement time, of the appointment of Professor Robert P. Sharp to the Division chairmanship—vacant since the death of the late Professor Chester Stock in December, 1950. This appointment, widely acclaimed both within and without the Division and the Institute, ensures that the gains made in the past by this, one of the youngest of the Institute's divisions, will not only be consolidated but will multiply.

Respectfully submitted,

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

ADDENDUM TO THE REPORT OF THE DIVISION OF THE GEOLOGICAL SCIENCES

Although it happend after the close of the fiscal year, nevertheless it seems pertinent at this writing to append a brief statement on one of the most interesting seismic and geologic events that have occurred in California in nearly 50 years, and all the more so in that the event is currently uppermost in the minds and activities of many of our staff, viz., the Arvin-Tehachapi earthquake.

This shock, registered by all of the Institute's network of stations at 4:52 A.M. on July 21, 1952, was immediately recognized as a major earthquake. Professors Buwalda and Richter, together with graduate students and Seismological Laboratory staff, were on the scene of the quake within a few hours, Professor Buwalda undertaking the mapping of the geological features; the seismological group, with portable equipment, undertaking the recording of after-shocks. Professor Buwalda has continued actively to map the many surface features displayed, and the seismological staff, under the direction of Professor Gutenberg, is carrying out the extensive calculations required to give precise information on this quake. All present statements* represent,

*As definitive a statement as possible has been prepared by Professors Buwalda, Benioff, Richter and Gutenberg at the invitation of Dr. O. P. Jenkins, State Mineralogist, for early distribution by the California State Division of Mines.

therefore, no more than preliminary judgments, and are subject to later revision.

The epicenter of the quake lies near Wheeler Ridge, west of U. S. Highway 99, near the junction with Highway 166. This location, together with epicenters of some of the after-shocks, indicates that the movement took place, at depth, on a fault mapped many years ago by the U. S. Geological Survey, and known as the White Wolf fault. The trace of this fault can be followed from the vicinity of the quake's epicenter, northeastward along the northwest-facing scarp of Bear Mountain (whence it has been called by some, the "Bear Mountain fault") to beyond the town of Caliente, a distance of some 20 miles. After-shocks, some of which have had magnitudes comparable to that of the Long Beach earthquake, are widely scattered geographically; some may be on the Kern Canyon fault; others are more directly in line with the White Wolf fault. Still others, like those of July 29 and August 22, 1952, responsible for the damage at Bakersfield, are associated with faults lying more to the west and nearer to that city.

In magnitude ($M = 7\frac{1}{2}$) the Arvin-Tehachapi earthquake ranks as a major shock, and it is indeed the greatest shock recorded from California since the San Francisco quake ($M = 8\frac{1}{4}$) of 1906. Because, fortunately, the epicenter was located in a sparsely settled area, property destruction and loss of life in the Arvin quake have been much less than for some quakes of lesser magnitude, such as Santa Barbara ($M = 6\frac{1}{4}$), 1925, and Long Beach ($M = 6\frac{1}{4}$), 1933. In several other respects this appears to have been an "unusual" quake. It occurred on a fault which had not hitherto given evidence of being a locus of major seismic activity. The surface expressions of the earthquake—offsets, scarplets, furrows, etc.—differ in important respects from similar phenomena associated with other notable California quakes. It appears doubtful indeed that any of these features actually reflects the motion on the fault at depth. Hence, no measures can yet be given of actual fault displacements.

The event has once again focussed attention on the necessity of proper building design for seismically active regions—a subject of continuing fruitful investigation by our colleagues, Professors George Housner and R. R. Martel, in the Division of Engineering; and on the need for more extensive and more intensive studies of earthquakes, such as have been pioneered by the staff of our Seismological Laboratory, toward the determination of the actual magnitudes and mechanisms involved in major quakes, and toward the resolution and recognition of all details in the broad and very complex spectrum that is popularly known as an "earthquake wave". The day when destructive quakes can be predicted is still far off. But important steps

in this direction have been taken by Professor Benioff, whose analysis of after-shock sequences has proved of much value in advising the public and officials of the probable future course of events.

THE DIVISION OF THE HUMANITIES

To the President:

The Division of the Humanities continued during the year to emphasize the liberal arts and the social sciences as a vital part of the education of scientists and engineers. The widespread interest in the question of how scientific students, with their heavy load of laboratory courses, can be given also an effective curriculum in the humanistic studies has brought to our campus many visitors from this country and abroad to study the methods used here.

To some observers the most interesting development of the year was the appearance of a literary magazine, called *Pendulum*, written and edited by Institute undergraduates and published by the Division. Three numbers of the magazine appeared during the year. The quality of our student writing received favorable comment, and the success of the experiment should aid in correcting popular misconceptions about narrowness and over-specialization in our students.

The Division brought to the campus four visiting lecturers from the American Universities Field Staff, each of them an expert in the politics, economics and culture of a particular foreign area. The lecturers each stayed on the campus about two weeks, gave lectures in economics and history classes as well as formal public lectures and informal conferences with faculty and students. Professor David Elliot coordinated the program, and he has worked out an elective course for seniors and graduate students in which the visiting lecturers will appear next year. The AUFS staff members who appeared this year, with their fields of authority, are as follows:

Edwin S. Munger . . . . . East Africa
John B. George . . . . . West Africa
Albert Ravenholt . . . . . Philippines and Formosa
Phillips Talbot . . . . . India and Pakistan

In order to answer some questions for us about the aptitudes and abilities of Caltech students the Division brought to the campus a clinical psychologist, Dr. John R. Weir, whose activities are partly summarized in the report of Dean Thomas. Dr. Weir's tests of reading skills and aptitudes led to the formation of a class in speeded reading. A test of our sophomore class in comparison with 14,000 second-year students in 127 other colleges throughout the country showed

that our students ranked at the very top in such non-technical subjects as English, General Culture and Contemporary Affairs.

Such cultural activities of the Division as the Public Affairs Room, the Art Class and Exhibitions, and the chamber music concerts in Dabney Lounge, all described in last year's report, have been continued, and it is worth noting how much of the liberal education our students receive is fostered by these activities just outside the range of the curriculum. Less easy to include in a report is the constant improvement of the classroom work in the fundamental branches of the humanities.

Members of the Division faculty, though their principal function is teaching, have also made significant contributions to knowledge in their fields. Professor Hunter Mead published *An Introduction to Aesthetics* (Ronald Press) and Professor Hallett Smith's *Elizabethan Poetry: A Study in Conventions, Meaning and Expression* was scheduled for August publication (Harvard University Press). Professor Mead began a revision of his well-known *Types and Problems of Philosophy*, and Professor Charles Bures is completing the manuscript of a book on the philosophy of science. Professor Alfred Stern continued to publish contributions in several languages, and his first book in English, on existentialism, is now in the press. The researches of Professor Beach Langston on the *Ars Moriendi*, of Professor Paul Bowerman on Mrs. Trollope, of Professor Kent Clark on Swift and the Dutch, and of Professor John Schutz on the policies of Pitt also progressed during the year.

Respectfully submitted,

HALLETT SMITH, *Chairman,*
Division of the Humanities

THE DIVISION OF PHYSICS, MATHEMATICS, AND ASTRONOMY

To the President:

During the first half of the academic year members of the Division contributed heavily to Project Vista. Professor W. A. Fowler continued as Scientific Director of the project and Professors C. C. Lauritsen and R. F. Christy spent full time on the project during the first half of the year. Professors R. F. Bacher, H. F. Bohnenblust, L. Davis, R. P. Dilworth, P. S. Epstein, J. L. Greenstein, T. Lauritsen, W. R. Smythe, and E. C. Watson all were members of Project Vista and spent much of their time in this work during the summer and fall terms. Members of the Division not participating in Project Vista continued to bear a heavy load of instruction and in the direction of

graduate students. Professor H. P. Robertson continued on leave for a second year to carry on as Director of Research of the Weapons Systems Evaluation Group of the Department of Defense. Professor Richard P. Feynman was on leave as Visiting Professor of Theoretical Physics at the University of Brazil. In spite of the absence of many senior members of the staff, research activities in the major fields under investigation continued and many new results were obtained.

At the end of the year the division had 46 staff members in physics, 14 in mathematics, and 6 in astronomy. Of these, 22 in physics, 10 in mathematics, and 3 in astronomy are professorial members and 5 are visiting professors—2 in physics, 1 in mathematics, and 2 in astronomy. The remainder are research associates, senior research fellows, instructors, and research fellows largely engaged in project research financed by government funds. During the year the Division had 75 graduate students in physics, 16 in mathematics, and 7 in astronomy. About 55 per cent of these graduate students held assistantships and were engaged either in teaching activities or in research work under one of the projects. In June, Ph.D. degrees were awarded to 11 candidates in physics, 9 in mathematics, and 1 in astronomy. This was the first Ph.D. degree awarded in astronomy by the Institute.

The Division had several distinguished visiting professors during the year. Dr. E. G. Bowen of the Australian Commonwealth Scientific and Industrial Research Organization gave a series of lectures during the Fall on the subjects of radio astronomy and rain formation. Professor S. Chandrasekhar of the Yerkes Observatory gave a series of six lectures in March on various subjects in astrophysics. Professor John von Neumann of the Institute for Advanced Study gave a series of lectures during January on "Probabilistic Logics and the Synthesis of Reliable Organisms from Unreliable Components". Professor J. H. Oort, Director of the Observatory of the University of Leiden, Netherlands, lectured during the second term on "The Structure and Dynamics of the Galaxy". Professor H. A. Bethe of Cornell University gave several lectures in May on "Properties of Mesons". In addition, Professor K. T. Bainbridge of Harvard University paid an extended visit and spoke on "Experiments of the Effects of Chemical Combination and of Pressure on the Life Time of the Nucleus".

Physics

Research in physics was supported by the joint program of the Office of Naval Research and the Atomic Energy Commission as well as by the latter agency directly. A research grant from the Shell Fellowship Committee and fellowship grants from Standard Oil Company, Hughes Aircraft Company, Westinghouse Electric Corporation,

Dow Chemical Company, Eastman Kodak Company, and the General Petroleum Corporation helped to provide much needed support for able graduate students.

The new unstable subatomic particles which occur in the cosmic rays have been the subject of active study by Professors C. D. Anderson, Eugene Cowan, and R. B. Leighton. Results obtained during the past year have revealed a great complexity in these new phenomena. At least five different types of such particles in addition to the more familiar pi and mu mesons have now been identified. The work of Professor Anderson and his colleagues has been directed toward a better understanding of the neutral and charged V-particles. It has now been established that at least two different kinds of neutral V-particles exist, one of which apparently decays into a proton and a negatively charged pi meson, and the other into a positively charged meson and a second, as yet unidentified, negatively charged particle. The former type occurs in much greater abundance than the latter and the energy given to the charged particles in the decay is most often 35 Mev but in some cases as high as 75 Mev. The life-time of these particles has been found to be three ten-billionths of a second.

The new addition to the Norman Bridge Laboratory for cosmic ray work was completed during the year and occupied during December, 1951. A new large magnet-cloud chamber specifically designed for the study of V-particles is now nearing completion. Meanwhile two smaller magnet-cloud chambers have been in operation on the summit of Mt. Wilson and one magnet-cloud chamber has been in operation on the Institute campus. The increasing complexity of phenomena has placed heavy demands on the experimental precision.

Professor H. V. Neher supervised two expeditions during July and August, 1951, which made simultaneous ballon flights with ionization chambers at Bismarck, North Dakota and Thule, Greenland. During the year the copious results from these expeditions have been studied and a number of interesting conclusions have been reached. It has been found that the true geomagnetic effect between Bismarck and Thule was considerably less than the fluctuations that take place from day to day. The fluctuations that existed at the two locations (2500 miles apart) are simultaneous, and correlation with measurements made elsewhere indicates that the fluctuations are world wide. It appears that there are fluctuations both in the high energy particles and also in low energy particles and these fluctuations seem to be independent.

Professor Jesse DuMond and his colleagues made the first successful application of the new point focusing X-ray monochromator for the study of low angle X-ray diffraction during the Fall of 1951. This

is an entirely new piece of apparatus which seems to have a number of very interesting applications to structure problems. Successful operation of the new high precision axial focusing magnetic beta-ray spectrometer was also achieved during the year. The high precision expected of this instrument was realized, and it appears possible to measure the kinetic energies of homogeneous groups of beta-ray particles with a precision approaching 1 part in 10,000. Significant improvements were obtained in the sensitivity of the 2-meter curved crystal gamma-ray spectrometer. The accuracy of measurements has been increased and precision measurements have now been made on different nuclear gamma-ray lines from a number of elements and including the annihilation radiation from Cu^{64}. From this latter it can be concluded that there is no evidence for any difference in mass between positive and negative electrons, at least to an accuracy of 1 part in 10,000.

Professors C. C. Lauritsen, W. A. Fowler, and T. Lauritsen continued their studies of light nuclei with the electrostatic generators of the Kellogg Radiation Laboratory. These include the study of the reactions $Ne^{21}(d,\alpha)F^{19}$, $D(d,p)T$, $N^{15}(p,\alpha\,\gamma)C^{12}$, $C^{13}(p,\gamma)N^{14}$, $C^{12}(p,\gamma\,p')C^{12}$, as well as the elastic scattering of protons by Li^7 and C^{12}. The study of the Ne reaction has bridged a gap which allows the determination of the masses from the neutron to S^{33} from nuclear reaction energies, with an accuracy of one part in a million.

The first successful operation at high energy was achieved with the Caltech synchrotron. High energy electrons were first obtained in mid-June, and early in July electrons of approximately 525 Mev were obtained. These are the highest energy electrons available at present. The production of pi mesons has already been observed, and preparation of auxiliary equipment needed for a number of experiments is now under way. Professors R. F. Bacher, R. V. Langmuir, Matthew Sands, and R. L. Walker and their colleagues in the Synchrotron Laboratory hope soon to be engaged in research with high energy X-rays.

In theoretical physics, Professor R. F. Christy and his colleagues carried out investigations on the stationary states of light nuclei and on the coupling of angular momenta as well as studies on the role of isotopic spin in the reactions of light nuclei. Studies have also been carried out on the influence of thermal vibrations on electrical conductivity of crystal lattices, and a quantum description of collective motions of electrons in metals is being studied. In quantum electrodynamics the self-action corrections to energy levels in the He atom have been calculated. In electron diffraction the phase shifts for electron scattering by heavy elements, which are of significance in inter-

preting the structure of molecules containing heavy elements, have been approximately calculated.

Professor L. Davis carried out an investigation of the polarization of starlight and, in collaboration with Dr. Oliver Wulf, carried out a study on the circulation of the atmosphere.

In spectroscopy Professor R. B. King carried out measurements of the relative oscillator strengths of atomic spectral lines both in absorption spectra of atoms excited under conditions of thermal equilibrium and in emission spectra. There has been considerable progress in the design and construction of a new spectrograph which is being built with funds established as a memorial to the late Dr. Otto Beeck and is also being aided by the Shell Research Grant for physics. A new grating for this spectrograph has recently been ruled by Dr. H. W. Babcock of the Mount Wilson Observatory.

Professor W. R. Smythe made a number of refinements in the apparatus for measuring the specific charge on the electron. He anticipates that he will soon be collecting data for a new measurement of e/m. While the ultimate precision which can be attained is still unknown, it is expected to be more than ten times as accurate as the best previous direct experimental measurement.

Dr. S. J. Barnett carried out a number of new experiments on the electron-inertia effect in metals, on the Einstein-de Haas effect, and on the Barnett effect. Professor A. Goetz has been engaged in the evaluation of the large volume of data collected during the development of an experimentation with molecular filter membranes.

Dr. Walter G. Cady and his colleagues carried out investigations on the properties, production, and measurement of ultrasonic waves in liquids. An improved method has been found for measuring the radiation pressure and avoiding errors due to the hydrodynamic flow.

The graduate curriculum in physics was modified extensively with the aim of giving the students a more representative cross section of physics in the basic courses. Placement examinations given before the opening of the Fall term provided a better basis for advice to new students. The first examinations under a new system requiring an oral examination before admission to candidacy were given. A review of the undergraduate curriculum in physics was conducted and suggestions were made for a number of modifications in the upper class courses.

Mathematics

Professors W. N. Birchby and L. E. Wear retired at the end of the academic year. The faithful services which they have given to the Institute over a long period of years have always been deeply appreciated by their colleagues. The gap left by their retirement will be

filled partly by the appointments to instructorship of Dr. H. A. Dye and of Dr. F. B. Fuller. For the last two years Dr. Dye has been Bateman Research Fellow at the Institute. His research work centered around the representation of finite rings of operators. Dr. Fuller is a geometer and is particularly interested in deformation and fixed point theorems in combinatorial topology. He obtained recently his Ph.D. at Princeton University. His research work will strengthen an aspect of mathematics previously not represented actively at the Institute.

The Bateman Project, sponsored by the Office of Naval Research, under the direction of Dr. A. Erdélyi, is approaching completion. The first volume of the handbook of special functions is in the press and substantial parts of the other two volumes are ready for lithoprinting. The work on the table of integral transforms made good progress during the period under report and substantial portions of this work are also ready for lithoprinting. Mr. David Bertin, who did most of the work during the past year, left the Institute at the end of the academic year.

A new project, also sponsored by the Office of Naval Research, was recently authorized. The work on this project has just begun. It will be centered first on asymptotic series connected with linear differential equations and also on those related to analytic number theory. Later on, non-linear problems will be discussed. Professor H. F. Bohnenblust, director of the project, will be assisted by Professors A. Erdélyi and Tom M. Apostol of the staff as senior investigators. In the Fall of 1952 Dr. L. D. Berkovitz will join the project as a junior investigator. Dr. Berkovitz is an analyst who took his degree at the University of Chicago and who spent the present academic year at Stanford University as an AEC fellow.

Professor J. von Neuman of the Institute of Advanced Study gave an exceptionally successful series of six lectures on probabilistic logics, attended by Institute members in many different fields and by many outsiders as well. Several other visitors delivered lectures on more specialized topics in mathematics.

Professor A. Erdélyi was invited to give an extended series of lectures on differential equations at the University of Kansas.

During the Spring, it was hoped to find a partial solution to the pressing need for a centralized location for the department of mathematics. Unfortunately, plans to house a large part of the department in the former residence of Professor H. Bateman had to be abandoned following an unfavorable ruling on zoning restrictions. The need remains, and an early solution of this problem is highly desirable.

Astronomy

The regular graduate and undergraduate instruction in astronomy was supplemented by a course given by a visiting professor, J. H. Oort of the University of Leiden, on the "Structure and Dynamics of the Galaxy". In addition, courses were given on the "Observational Basis of Cosmology" by Dr. Edwin Hubble of the Mount Wilson and Palomar Observatories staff and on "Solar Physics" by Drs. Richardson and Pettit. Professor S. Chandrasekhar of the University of Chicago lectured on "Turbulence and Convection in the Presence of Magnetic Field" as well as on "Radiative Transfer Theory". In addition to their activities in instruction, Professors Jesse Greenstein, Fritz Zwicky, and Guido Münch carried out an active research program which is mentioned in the report of the Mount Wilson and Palomar Observatories. In addition they provided supervision of graduate study for seven graduate students, among whom two finished most of their work for the Ph.D. degree and one was granted the first Ph.D. degree in astronomy.

Respectfully submitted,

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

INDUSTRIAL RELATIONS SECTION

To the President:

The Industrial Relations Section completed its thirteenth year in 1951-52.* The varied activities which constitute its general program were continued and expanded during the year. In addition, an important new project was inaugurated.

This new project on "Communication between Management and Employees" was given an overall presentation at a dinner-discussion meeting. This was amplified by a series of six intensive workshops which were scheduled once a month, January through June, 1952. At each session an entire afternoon was devoted to brief discussions of the day's topic by three men experienced in the method or the subject, followed by questions and discussion from the flooor. The total registration at these meetings was 468.

The general subject of communications was divided into small segments in terms of methods of communication and subjects to be communicated. In spite of its success this year, the project is far from being completed, since only three methods of communications

*A more detailed report of the Section's activity has been printed separately. Copies are available upon request.

were discussed: Surveys of Employee Opinions, Meetings with Employees, and Employee Publications. The only subjects for communication between management and employees that were covered were Annual Reports, Benefit Plans, and Economic Education.

This new project was a logical outgrowth of, and is closely related to, other projects in the Section which expanded during the year: Surveys of Employee Opinions, and Supervisory and Executive Development.

The Section completed surveys of employee opinions in five companies, covering almost 19,000 employees. Additional surveys in three companies, with a total of about 8,000 employees, are scheduled for the first part of 1952-53. The most encouraging fact is that two of the surveys completed this year and one of those scheduled for next year are in companies which have conducted polls in previous years. If additional funds can be secured, the Section will soon be in a position to start some fundamental research on opinions and attitudes of employees.

As a result of the increased number of surveys and the intensive collaboration with representatives of several companies, especially Standard Oil Company of California, a number of techniques have been improved, the volume of comments from employees has been increased, and a method of analyzing and classifying these comments has been developed. The value of the surveys has been increased by concentrating attention on one or more of the following objectives: (1) to develop a program of communication between management and employees; (2) to audit or inventory a number of management policies and procedures; and (3) to aid in the planning and development of a program of supervisory training.

The scope of activities in the general project on "Supervisory and Executive Development" also increased. Nine series of evening meetings were held on the campus one night each week for ten weeks, with a total registration of 171 representatives from many companies in this area. Major emphasis was given to leading conferences and practicing supervision. The fifth annual summer conferences were held in June and were attended by 78 representatives from 33 companies in California, Oregon, Washington, Texas, Hawaii, and British Columbia. Because the size of each group had to be limited, a number of applications could not be accepted.

All of these activities will be continued next year. A new series of evening programs will be started to present in a systematic manner a comprehensive and concentrated program in personnel administration. This series, which has been developed in consultation

with a number of representatives of Subscribers, will assist any company in the development of competent personnel specialists and administrators from among its line and staff employees. A research project on "Executive Development" will also be started.

Making a wage or salary survey by use of the conference method was started several years ago with a group of employers in the Pasadena area. Further trials of this method were made during 1951-52 with two new groups, one consisting of representatives of a manufacturing industry and the other of representatives of several different non-manufacturing industries. This technique has been so successful that the Section is preparing a manual to guide other groups in making similar surveys.

The many activities of the Section were made possible by the integration of its resources which have been developed during the past 13 years. These resources include top-level guidance from the Trustees and Faculty; an efficient, flexible staff of full-time employees; and a group of 40 experts from other divisions of the California Institute, from other schools and universities, and from business and industrial organizations and associations. These experts cooperated on special projects. Another important resource of the Section is the Library, containing specific and general materials on personnel administration.

In all of its activities the Section has been guided by its basic purpose which was formulated in 1939:

> To increase and disseminate a widespread knowledge and understanding of the philosophies, policies, principles, and procedures affecting human relationships in industry.

Respectfully submitted,

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

JET PROPULSION LABORATORY

To the President:

During the past year, the Jet Propulsion Laboratory has continued with its program of research and development. Although the Laboratory has assumed a major responsibility in the development of guided missiles, it has carried out an active program of engineering research. In the sections to follow, a selected few of the JPL projects will be described under the headings of Propulsion and Materials, Fluid Dynamics and Combustion, Electronics, and Engineering Development. Principal financial support for the Jet Propulsion Lab-

oratory is supplied by the Department of the Army, Ordnance Corps, with two additional, smaller projects under sponsorship of the Navy Bureau of Ordnance and the Bureau of Aeronautics.

PROPULSION AND MATERIALS

Liquid Rockets: The liquid rocket group carries on general studies, the results of which are used by rocket designers who have specific problems. For example, the high frequency pressure fluctuations in a rocket chamber, known as combustion instability, have been measured with rapid-action pressure gauges, and the existence of acoustic waves in the chamber interior has been corroborated by visual observations through windows in the rocket wall. Progress in mapping the conditions inside the combustion chamber has also been made by taking temperature measurements with a special pneumatic probe. This same probe will be used to feed gas samples for composition analysis to a special radio frequency mass spectrometer which is now in an advanced stage of development.

Complete rocket motors built of transparent material have been operated which show the time and space variation of the reaction in the combustion chamber. Other work programs include combustion performance at high pressures, measurement of radiation from rocket interiors, and heat transfer from solid surfaces to liquids in the transition region between nucleate and film boiling.

Solid Rockets: Studies on new solid propellants which are smokeless, and cheaper by a large factor than existing propellants, were carried to an advanced stage of development. A still newer propellant which is in the early stages of development requires only about one-twentieth of the production time and equipment taken by presently available compositions.

Development work on a small ground-to-air rocket of simple and inexpensive design, but superior performance, has progressed so rapidly that it is ready for field evaluation within one and a half years after initiation of the program.

Chemistry: The reaction kinetics of the oxides of nitrogen, because of their importance in rocket fuels, have received detailed study. One outcome of this study has been a possible technique for the fixation of atmospheric nitrogen, which may be of value to industries other than jet propulsion. The technique of generation of high pressure, relatively inert gases from liquids has progressed beyond the initial stage. Such gases have a number of uses, i.e., turbine operation and tank pressurization.

The ignition process at the boundary of solid propellants has been the subject of basic study, as has the transfer of heat in a propellant charge during exothermic polymerization.

Materials:. Materials research at JPL continues to be of fundamental rather than applied character. Exploration of interesting alloys has included preparation of isothermal phase diagrams for the ternary systems Titanium-Chromium-Aluminum, and Titanium-Vanadium-Aluminum at 1400°F, and 1800°F using X-ray diffraction and metallograph techniques. Other basic work was done with the binary systems Iron-Chromium (Sigma phase) and the refractories Zirconia-neodymia and zirconia-lanthana.

An interesting development of the applied type has been the fabrication of porous metal structures from wound wires which have been pressed and sintered. This technique results in greater uniformity and control of porosity than the powder method.

FLUID DYNAMICS AND COMBUSTION

Research Analysis: This activity is centered on the solution of problems of ballistics and aerodynamic design. Questions requiring specialized mathematical techniques are referred to the research analysis group: for example, trajectory calculations, determination of drag coefficients from flight data, correlation of dispersion data, and analysis of aeroelastic effects. Considerable use of the REAC analog computer, as well as of the JPL and Co-op wind tunnels, has been made in pursuing the above program.

Wind Tunnels: During the past year the large 18 x 20-inch supersonic wind tunnel (to Mach No. 4.8) has been calibrated and brought into full operation. Much information on flexible plate nozzle design has been acquired which is useful for other similar tunnels now being built in this country.

Important new information on surface friction in supersonic flow has been acquired by Mr. J. D. Coles, using a floating flush-mounted plate technique recently devised by Professor Hans Liepmann. Also, the temperature recovery in a supersonic flow boundary layer is being examined. In the course of these experiments, the range and versatility of the 20-inch tunnel have been fully exploited.

Air Fuel Combustion: The two principal investigations of this group have been on the structure of low-pressure flames and flame stabilization near solid boundaries. The front of a flame at 2 mm is expanded to a depth of nearly 5 cm, and it has been found possible to make a traverse of the flame and spectroscopically identify mo-

lecular species, as well as determine rotational and translational temperatures and flame velocity.

The stabilization ("flame-holding") of flames by bluff bodies and in ducts, and the influence of turbulence on these flames, is under study, and it is anticipated that the results will contribute materially to the understanding of the detailed mechanism of flames.

The air-fuel combustion group has been particularly fortunate in its cooperation with campus activities; nearly half of the work performed is thesis research where the benefits of the JPL facilities are particularly valuable. During the last year, five students for advanced degrees have been carrying out their research in cooperation with the air-fuel combustion group, three at the Ph.D. level and two professional engineers.

Instrument Development:. The instrument group consists primarily of electronic specialists, who offer general assistance to the rest of the Laboratory in the design of electrical measuring devices (timers, potentiometers, gages, etc.), as well as operate a central data recording center, a standards laboratory, and a mobile recording truck. Two significant instrument projects have been the development of an electronic computer for processing rocket data as the tests occur, thus making the reduced data instantly available, and the systematic study of the response of electrical gages to rapidly varying pressures, which makes possible an estimate of their fidelity in recording transient pressures.

A major effort of the group is the development of an integrated system of "mechanized" (i.e., electronic) computation for JPL. They have already accumulated several years' experience in using a Reeves analog computer (REAC) and are now embarked on a program of digital computer development, including devices for translating data from analog to digital form and back.

ELECTRONICS

Telecommunication: This group is concerned primarily with the transmission of information to and from missiles, whether this be for the purpose of guiding the missile or reporting conditions on the missile for the later use of research and development engineers.

During the past year large quantities of data were gathered by radio telemetry during missile flights. Improved methods of telemetry data reduction embodying more accuracy and clarity of presentation at reduced cost were developed and are now being used. Work continued on radio and antenna systems. The field operation and maintenance of the radio guidance equipment was transferred

to the Field Operations and Test Section. Some missile environmental simulation equipment (shake tables, acceleration table, altitude chamber, etc.) has been obtained and considerable work done to evaluate and improve the reliability of missile components.

Guidance and Control: The main activities of the guidance group have been along the following three lines: (a) synthesis, analysis, and evaluation of a guidance system; (b) design, construction, and testing of missile autopilot equipment; and (c) design, construction, and test of specialized guidance computers—both analog and digital.

Under (a), a great deal of work has been done in the analysis and study of noise analysis, filter theory, trajectory and ballistic theory, aerodynamics, and in the combining of these fields into an over-all guidance system. It is felt that an advance in the general knowledge and application of noise analysis and filter theory has resulted from the program.

Under (b), an electropneumatic autopilot and associated equipment, completely developed at the Laboratory, has been carried through the design, development, and testing stages, and has now progressed into the production stage.

Under (c), a special purpose analog computer has been carried through the design, development, and testing stages into a production prototype. Several new analog computer techniques and components have been developed and used in this program. In addition, a special-purpose digital computer has been designed and is in the preliminary testing stage.

Field Test Operations:. The growth of field testing operations at White Sands Proving Ground, New Mexico, has required the establishment of a new group, Field Test Operations and Training Section, which has been performing and assuming its duties since August of 1951.

The mission of this section is to relieve Research and Development personnel of routine activities in connection with field testing and to provide training for and liaison with Army personnel who will be engaged in tests and tactical training.

As new equipment or changes are introduced, they are first operated by Research and Development personnel, but as early as possible they are transferred to the Field Operations group and the military.

ENGINEERING DEVELOPMENT

Design: The design group, which has broad responsibilities for the fabrication and testing of specific hardware items as well as for their design, has focussed its efforts upon the CORPORAL and the

small ground-to-air rocket previously mentioned. It has supervised numerous flight tests of both rockets, and conducted special studies on such problems as vibration of missile structure, more available materials of construction, scaling up rocket power-plants, improved pressurization methods, and the like. It has also assisted outside manufacturers by supplying technical "know-how" and experience to sub-contractors.

Propulsion: The principal function of the Propulsion Section is to perform development and acceptance tests on liquid rocket propulsion components, sub-systems, and complete propulsion systems.

Late in 1951 a new facility, the Gas Metering Laboratory, was completed for use in this work. This facility contains an accurately metered supply of high pressure (3000 psi) air and suitable protective barricades for the testing of rocket pneumatic components and sub-systems. Of interest also is the five-story concrete tower in which complete rocket vehicles are subjected to water flow tests prior to being sent out for flight testing. These water tests greatly improve the probabilities of achieving successful flight operation.

Activity at the Edwards Test Station (formerly Muroc) was markedly increased during the past year. This facility, located in the Mojave Desert 85 miles north of Pasadena, is used in conducting static firings of large scale rocket motors and complete propulsion systems. The purpose of these tests is evaluation of new propellants, environmental checking of components, study of starting and stopping transients, and the like.

Industrial Planning: The chief duty of this group is to transfer information to and from industrial contractors who make hardware for JPL and for the government, relaying the "know-how" of the research group to those responsible for production. This is a difficult function, since it is essential to commercial fabrication that information be "frozen" and specific, and it is equally essential to the research and development men that they feel free to make continuous changes. The industrial planning section effects a compromise between the two groups.

During the past year their three principal functions have been (a) to secure prototype gear for troop-training purposes, in particular to supervise the development of launching and handling equipment; (b) to prepare detail drawings and written specifications of the JPL missile, and to act as a consulting group and educational medium for contractors; and (c) to prepare the first edition of the handbooks and technical manuals which must accompany a mech-

anism as elaborate as a guided missile. To date 16 volumes, totaling about 2,000 pages, have been prepared of a series which will eventually include 50 volumes.

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:

The Palomar Observatory was made possible through a grant of $6,000,000 by the International Education Board in 1928. This was supplemented with additional grants totaling $550,000 by the Rockefeller Foundation to cover the increased costs of completion after World War II. These funds were completely expended by December, 1951, and fortunately were sufficient to finish the telescope and practically all of its auxiliaries in so far as any such research installation may ever be said to have reached completion. Thus, while the basic telescope that collects the light may be expected to operate without change for a long period of time, the instruments that use this light, photometers, spectrographs, field lenses, etc., will quite certainly require remodeling or even replacement from time to time as new advances in optics, electronics and related fields render the present equipment obsolete. Indeed, modifications of this type were started in some of the first instruments even before the original installation of other instruments was completed. Experience with many of the older telescopes has shown that by this continual renewal and modernization of auxiliary equipment, a major telescope may continue as an active and thoroughly effective instrument of research for periods of 50 or even 100 years.

All of the major instruments on Mount Wilson and Palomar Mountain have been in regularly scheduled operation throughout the year on the programs described below:

1. *Solar and Planetary Research.* The Observatories' program for obtaining a continuous record of changes in the solar atmosphere during all daylight hours when the weather permits was maintained throughout the year. For this purpose over 600 direct solar photographs and 70,000 spectroheliograms were taken by Dr. S. B. Nicholson, Dr. R. S. Richardson, Mr. J. O. Hickox, Mr. James Parker, and Mr. Thomas Cragg. Detailed studies of large scale motions in the

photosphere were made by Richardson and Dr. Martin Schwarzschild and of motions in the hydrogen chromosphere by Richardson and Dr. Guido Münch.

Nicholson discovered a twelfth satellite of Jupiter with the 100-inch telescope on September 28, 1951. Its motion is retrograde with a period of about 700 days and it has a diameter of approximately 14 miles.

2. *Stellar Investigation.* During the present year more than 1800 spectrograms have been obtained with the 60-inch and 100-inch telescopes on Mount Wilson. More than 270 spectrograms have been taken in the same period with the 200-inch Hale telescope in spite of the fact that this instrument has been used largely for long exposures of objects too faint to be observed at Mount Wilson. The great majority of the plates were obtained for studies of the chemical composition and of the physical conditions such as temperature, pressure, magnetic field strength, and internal motions in the stellar atmospheres.

In some of the more stable stars it is now possible to make quantitative determinations of these properties. Dr. Jesse Greenstein has made extensive measurements of this type for various abnormal G-type stars, for subdwarf O-, F- and G-stars, and for several high velocity stars. Similar quantitative studies of magnetic variables have been made by Dr. Armin Deutsch, of Wolf-Rayet stars by Dr. Vainu Bappu, and of N-type stars by Dr. William Buscombe. Dr. Horace W. Babcock has measured the general magnetic field in several stars. In one case a general field of 10500 gauss was recorded.

In the more unstable stars such as the variable stars or stars with extended atmospheres such as the shell stars these problems are so complicated that only qualitative interpretations of the spectra can be attempted at this time. Dr. Paul Merrill, Dr. Alfred Joy, and Buscombe have carried out extensive studies of the spectra of long-period variable stars. The great light-gathering power of the Hale telescope has made it possible for the first time to extend detailed studies to the fainter part of the cycle of these variables. Similar investigations of the spectra of cepheid variables have been made by Bappu and Mr. Helmut Abt. The motions of the gases in the extended atmospheres of several shell stars have been given detailed study by Merrill, Bappu, and Greenstein.

Münch has investigated the distribution of interstellar gases in the Galaxy through a study of the interstellar absorption lines.

3. *Galactic and Extragalactic Nebulae.* The broad program for the study of the distances, dimensions, structures, motions, and distribution in space of the extragalactic nebulae has continued to oc-

cupy most of the time of the nebular department during the year. The first step in this program is the establishment of precise magnitude standards in 9 selected areas for the calibration of the apparent magnitudes of the distance indicators used for the determination of the distances of nebulae. Over 90 per cent of the stars in this program in the magnitude range from 9 to 19 have been measured at least once by Dr. William Baum and a few preliminary measures have been extended to magnitude 21.8.

The second step is the redetermination of the distances of a few of the globular clusters to calibrate their brighter stars as distance indicators. Mr. H. C. Arp, Mr. Allan Sandage, and Dr. Malcolm Savedoff have investigated several globular clusters, M3, M5, M13, M14, and M92, for this purpose.

A more precise determination of the distance of the Andromeda nebula is the third step in this program. Dr. Walter Baade has completed the series of plates on three fields in this nebula and with the assistance of Miss Henrietta Swope has discovered on them over 900 variables and 9 novae for use as distance indicators.

Dr. Edwin P. Hubble in the fourth step has extended these procedures to several groups of more distant nebulae including M81, M101, the Ursa Major cloud, and the Virgo Cluster. Substantial numbers of variables and novae have been found in each object.

For the fifth step Dr. Edison Pettit has completed the precise photoelectric measurement of the total magnitude of 561 nebulae.

The values thus far obtained have been used by Hubble to reevaluate the law of the red shift with results which do not differ greatly from the original formula. Additional radial velocities of nebulae in the Coma and Corona Borealis Clusters have been obtained by Dr. Milton Humason. Dr. Fritz Zwicky has continued his investigation of the distribution of nebulae in space and of luminous material between nebulae.

The National Geographic-Palomar Observatory Sky Survey made rapid progress during the year. About 60 per cent of the sky has now been photographed, although a substantial fraction of these fields will have to be repeated because of plate defects or poor observing conditions when they were taken.

4. *Guest Investigators.* Some 20 guest investigators from 10 American and 3 European institutions have made use of the observing facilities and plate files of the Observatories during the present year.

Respectfully submitted,

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