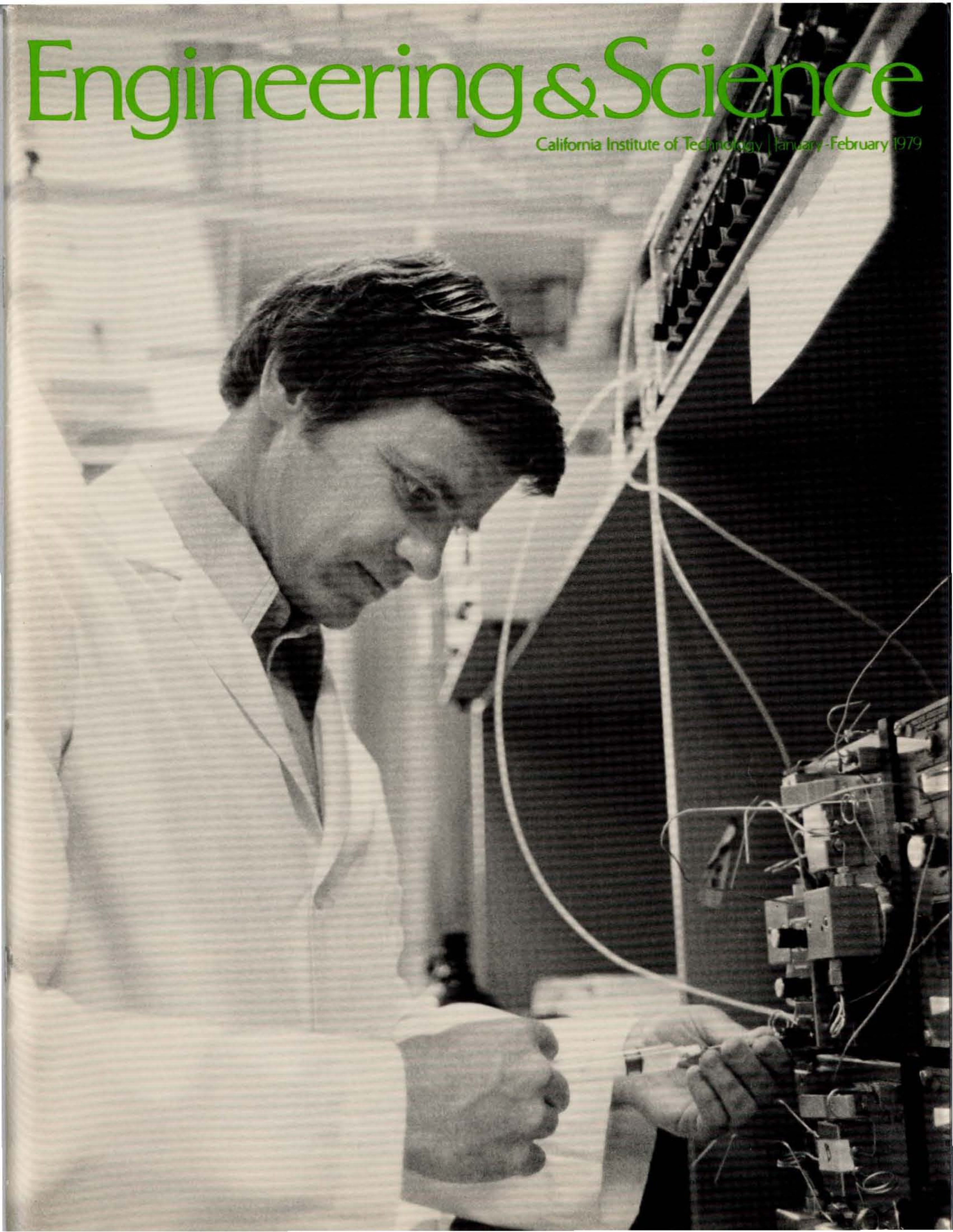
Engineering & Science

California Institute of Technology | January-February 1979



Don Hartman found a "model" way to troubleshoot the network.

The nationwide telecommunications network carries over 515 million phone calls on an average business day. Only a small number of them run into trouble, such as failing to go through the network, getting noise on the line, or being disconnected prematurely. Craftspeople in Bell telephone companies fix most of these problems quickly. But the causes of some can be difficult to find among one-billion-plus miles of circuits and thousands of switching offices.

For several years the Bell System used its computerized Network Operations Trouble Information System (NOTIS) to try to pinpoint those causes by analyzing trouble reports from all over the country. NOTIS was good. But Bell System managers wanted it to be better, more precise in identifying possible trouble spots. And they wanted the data in compact, easy-to-use form.

We assigned a new employee, Don Hartman, to improve NOTIS. Don came to us with a B.S. from the University of Texas and an M.S. and Ph.D. from Massachusetts Institute of Technology. He and his associates developed a second-generation system (NOTIS II) that does the job superbly.

For the new system, Don developed a mathematical model of the telecommunications network, including 28,000 local and long-distance switching offices and nearly a half-million circuit groups. Don also designed the system software and served as a consultant to the team of Bell System programmers assigned to the project.

Each day trouble reports from the entire country are sent to the NOTIS II center in Atlanta. Overnight, the system analyzes the reports, processes them through the network model, and discerns trouble "patterns" which help identify potentially faulty equipment. By 8 a.m. the next day, via data links, analysts at phone company service centers receive information on troubles traceable to circuits or switching equipment in their territories. Result: Better equipment maintenance. And better service.

With NOTIS II up and running, Don has moved on to other projects. Today he's a supervisor with broad responsibilities for planning the telecommunications network of the future.

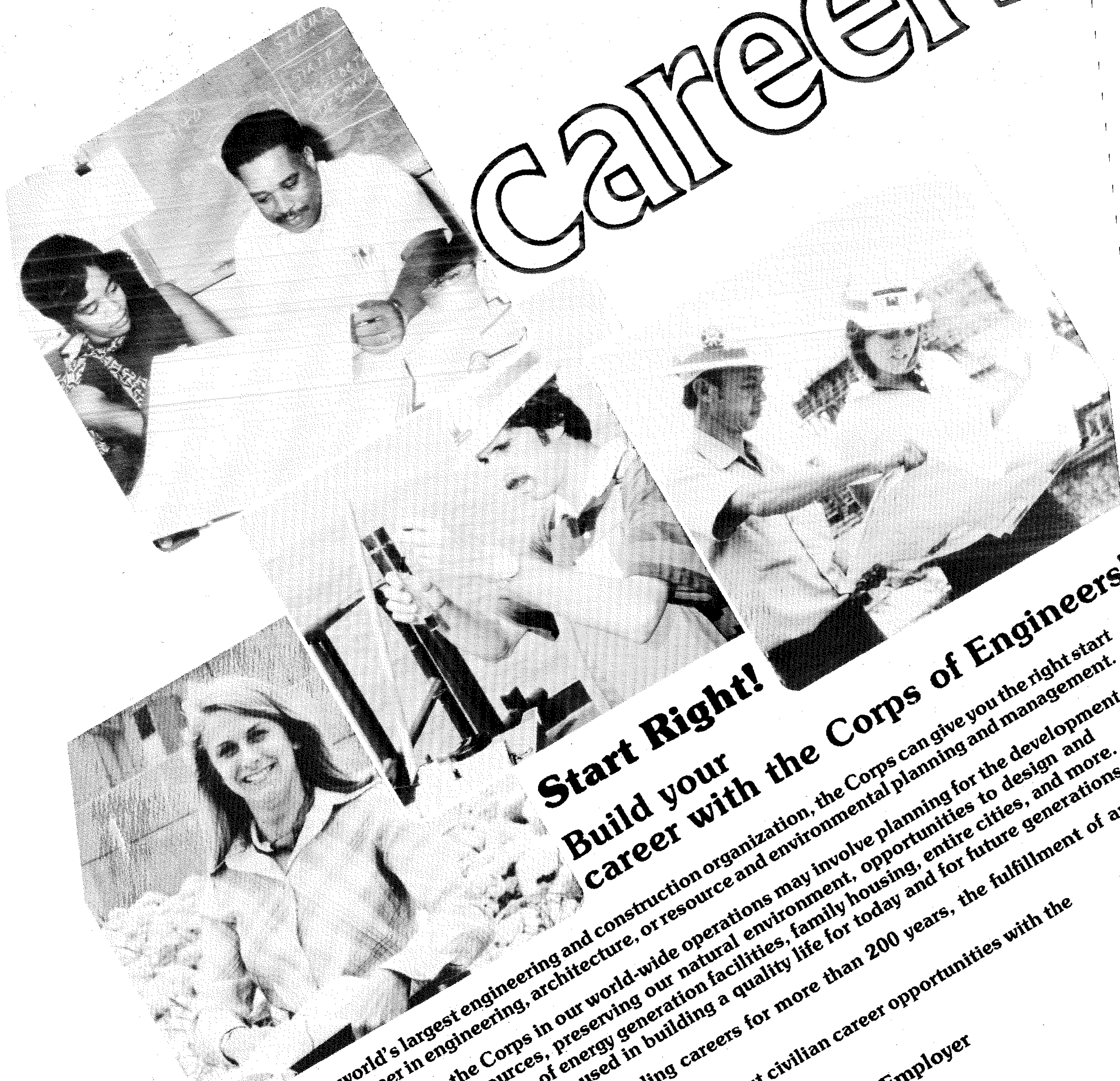
If you are interested in exploring equally challenging employment opportunities at Bell Labs, write to:

Director of Technical Employment
Center 831 EM
Bell Laboratories
Murray Hill, N.J. 07974

Bell Laboratories

From Science: Service

Careers



Start Right!

Build your career with the Corps of Engineers!

As the world's largest engineering and construction organization, the Corps can give you the right start toward a career in engineering, architecture, or resource and environmental planning and management.

Your career with the Corps in our world-wide operations may involve planning for the development of the nation's water resources, preserving our natural environment, opportunities to design and supervise the construction of energy generation facilities, family housing, entire cities, and more. Your talents and skills will be used in building a quality life for today and for future generations.

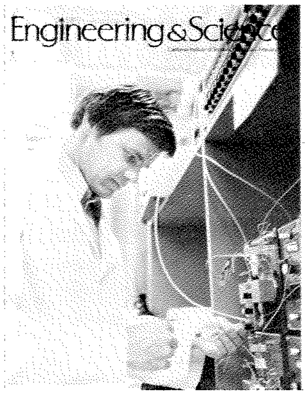
Because the Corps has been building careers for more than 200 years, the fulfillment of an exciting future awaits you.

Write us and we will tell you more about civilian career opportunities with the Corps of Engineers.

An Affirmative Action Equal Opportunity Employer

Corps of Engineers
Department of the Army
Washington, D.C.
20314

In This Issue

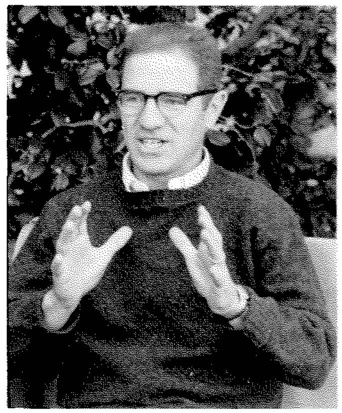


Cell Mate

On the cover — Leroy Hood is a young man with a long title and a big job at Caltech. He is Ethel Wilson Bowles and Robert Bowles Professor of Biology. He is also head of the Institute's cancer research program, which will increase considerably in size and scope with the completion in 1980 of the Braun Laboratories of Cell Biology and Chemistry. The staff housed in this new building — expected to total about 100 — will form the nucleus of Caltech's medical science program, the focus of which will be in immunology.

A native of Montana, Hood received a BS from Caltech in 1960. After earning his first doctoral degree — an MD — from The Johns Hopkins School of Medicine in 1964, he returned to Caltech, where he took his PhD in 1968. He served as a senior investigator at the National Cancer Institute in Bethesda, Maryland, from 1967 to 1970 and then joined the Caltech faculty.

On December 6, Hood gave the Watson Lecture at Beckman Auditorium. "Immunity, Disease, and Cancer" on page 6 is adapted from that talk.

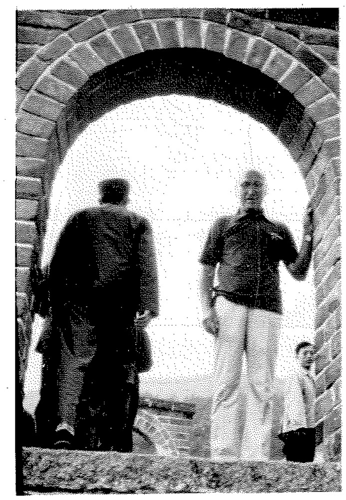


George Seielstad: A Broader View

The speaker for the Watson Lecture on November 8 was introduced by his colleague, Glenn Berge, a staff member of the Owens Valley Radio Observatory, who said in part: "George Seielstad came to Caltech almost 20 years ago as a graduate student, after finishing his undergraduate work at Dartmouth. He received his PhD in 1963 for work in radio astronomy, and after spending a year at the University of Alaska, he returned to Caltech. Now he is a research associate and lives with his family in Bishop, California, just a few miles from the Owens Valley Radio Observatory where he has his office.

"George has a number of interests outside radio astronomy — politics, for example. Four years ago he ran for the office of Representative from the 18th Congressional District, and he came close to upsetting the deeply entrenched incumbent. This talk represents another interest — that of examining some of the basic issues facing mankind from the perspective of an astronomer using the tools of scientific inquiry."

"From the Outside In" on page 21 is adapted from that talk.



Tourist Trade

For the group of Caltech trustees, administrators, and faculty who visited the People's Republic of China last fall, the very fact of receiving an invitation was somewhat surprising. After all, China has been essentially off-limits to American citizens for approximately 30 years. Now that may change. With the recent official recognition of China by the United States, not only diplomatic but social relations are likely to take a considerable upswing. In fact, the Caltech group may turn out to have been only in the vanguard of a wave of American tourists.

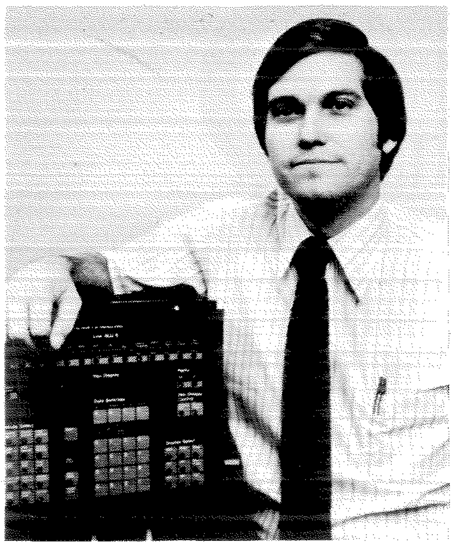
Whether or not other Americans start taking slow boats or fast airplanes to China, the ten men from Caltech had a fascinating experience there. In the November-December issue of *E&S*, Rodman Paul, Harkness Professor of History, reported on the first ten days of the trip. Part 2 of "Caltech Goes to China: Entries from a Diary" on page 13 completes the saga, which is illustrated by photographs taken by one of the travelers — Arnold O. Beckman, chairman emeritus of Caltech's board of trustees, whose picture above was taken at the Great Wall of China.

STAFF: *Editor and Business Manager* — Edward Hutchings Jr.
Managing Editor — Jacquelyn Bonner
Photographer — Richard Kee

PICTURE CREDITS: Cover, 28 — Richard Kee/13-20 — Arnold Beckman/21 — Hale Observatories/26-27 — Bell Labs.

Engineering & Science (ISSN 0013-7812) is published five times a year, September-October, November-December, January-February, March-April, and May-June, at the California Institute of Technology, 1201 East California Boulevard, Pasadena, California 91125. Annual subscription $5.00 domestic, $7.50 foreign, $15.00 foreign air mail, single copies $1.00. Second class postage paid at Pasadena, California, under the Act of August 24, 1912. Published by the California Institute of Technology and the Alumni Association.

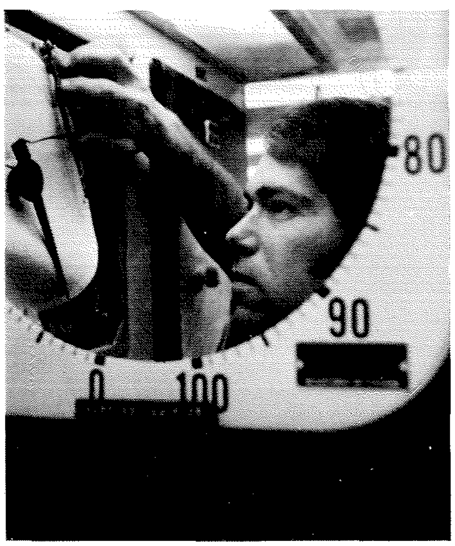
What's it like to be an engineer at IBM?



Bill Kleinhofer
BS/Electrical Engineering '72
University of California, Santa Barbara
MS/Electrical Engineering '77
University of California, Santa Barbara
"The technical vitality here at IBM is attractive for young engineers looking for a future."

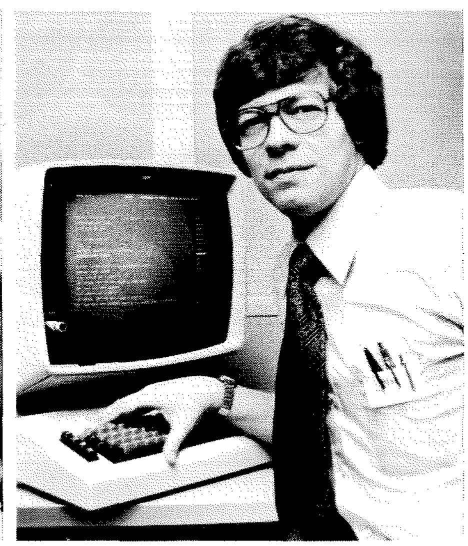
Evelyn Gratrix
BS/Electrical Engineering '74
University of Washington
"Growth and success in IBM are only limited by an individual's own ambitions and ability."

Doug Brooms
MS/Mechanical Engineering '72
Stanford
"The atmosphere is relaxed and informal, quite distinct from the dark suit and tie image of IBM. The people as a whole are congenial and cooperative."



Ric Davis
BS/Mechanical Engineering '68
University of California, Davis
MBA '76, University of Santa Clara
"IBM has provided me with all that I've desired in an engineering career."

Homer Dean
BS/Mechanical Engineering '72
San Diego State
"IBM has elevated my responsibilities as fast as I was willing and able to accept them."



Tony Spear
BS/Electrical Engineering '77
Purdue University
"IBM encourages me to challenge the accepted ways."

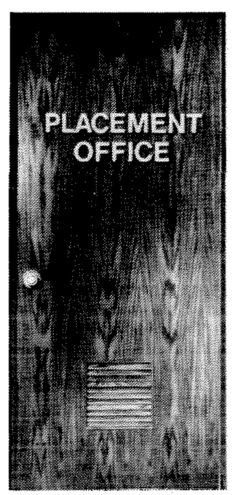
If you could talk with some of the engineers who have joined us recently, you'd hear some good reasons for working at IBM. Our people are given responsibility for projects as soon as they can handle it and they have the freedom to carry their projects through to completion. There's a lot of room for personal growth and outstanding opportunity for advancement because we make a practice of promoting from within. If you'd like to know more about a career in engineering, sign up for an interview at the Placement Office, or write: H.A. Thronson, Corporate College Relations Manager, IBM Corporation, 3424 Wilshire Boulevard, Los Angeles, CA 90010.

IBM®
An Equal Opportunity Employer

We will be interviewing at Caltech, Tuesday and Wednesday, February 27 & 28.

HOW TO LAND A JOB WITH BOEING:

Knock.



If you're a graduate in AE, CE, EE, ME or Computer Science, drop by your campus placement office. There's all kinds of information about The Boeing Company and opportunities in your specialized field. After all, opportunity only knocks once.

BOEING

An equal opportunity employer.

Engineering & Science

January-February 1979/Volume XLII/Number 3

Engineering&Science
JANUARY-FEBRUARY 1979

Immunity, Disease, and Cancer

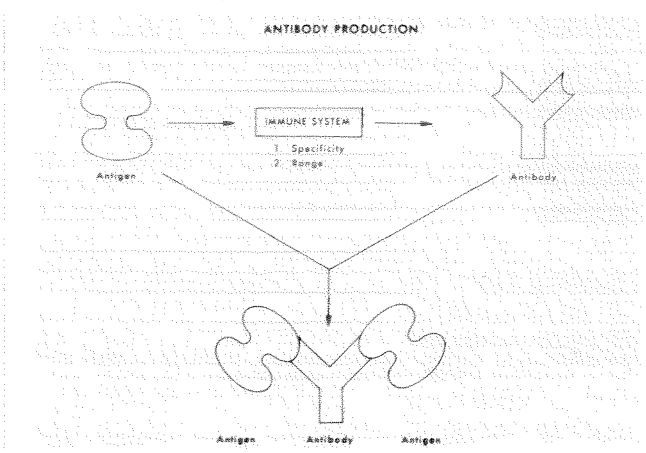
by Leroy E. Hood

The immune system plays a central role in protecting vertebrate organisms against disease. Indeed, immunology, the study of the immune sustem, has played a fundamental role in many striking advances of modern medicine. This discipline relates to a variety of disease states including infections, allergies, autoimmune conditions, organ transplantation, and cancer. Here I would like to discuss two aspects of immunity — how the immune system functions, and the interrelationship between immunity and two general categories of disease, infections and cancer.

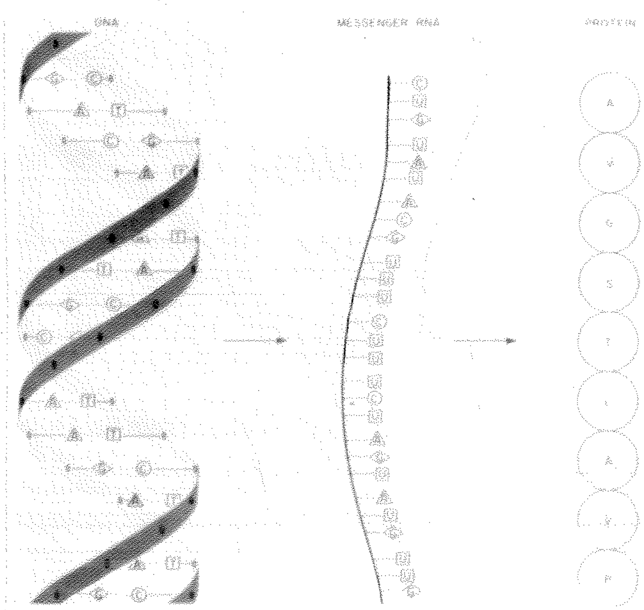
THE IMMUNE SYSTEM

Immunity and foreign patterns. The immune system has evolved to recognize foreign molecular patterns. These foreign molecular configurations may lie on viruses, bacteria, or even cancer cells. Accordingly, the function of the immune system is to recognize and destroy, or eliminate, any molecular patterns that are different from those contained within the organism itself.

How does the immune system function? Let us consider the vertebrate immune system as a black box (below). When a bacteria (antigen) invades the organism, its foreign



A black box model of the immune response. The immune system responds to foreign molecular patterns (antigen) with the production of specific antibodies.

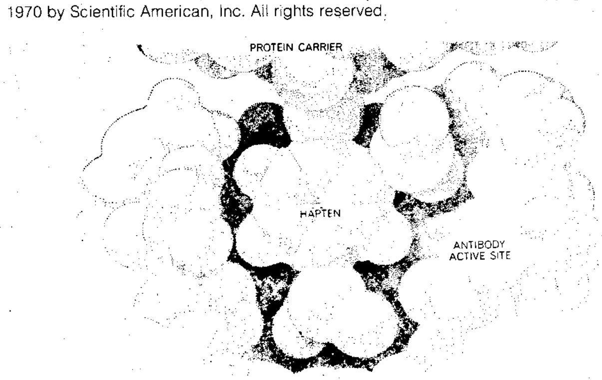


The synthesis of proteins. The linear information of a gene (DNA) is transcribed into messenger RNA which finally is translated into a linear protein.

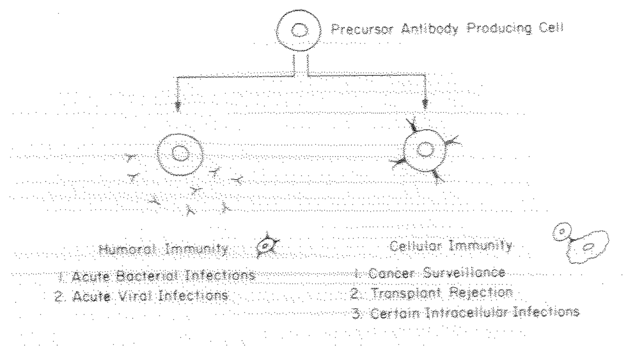
patterns stimulate the immune system to synthesize antibody molecules which are then released into the bloodstream. These antibody (protein) molecules have two special features. First, they can combine with the antigen that elicited their synthesis in a highly precise and specific manner. These precise molecular interactions ultimately lead to the destruction or elimination of the antigen. Second, the immune system can respond to millions of different antigens with the synthesis of specific antibodies for each. Thus the specificity and range of the immune response are virtually unlimited.

Antibodies and molecular complementarity. How is it possible for antibody molecules to recognize any one of millions of different antigens? The chromosomes are blueprint repositories containing all of the information necessary to construct an organism (above). Individual units of information on each chromosome are called genes. The vertebrate organism has many genes encoding antibody molecules. The information in a particular gene is converted into a specific protein by a complex cellular process called protein synthesis. A protein is a linear polymer comprised of 20 different subunits termed amino acids. The precise linear order of amino acids in a protein is dictated by the gene. Proteins are the building blocks from which living organisms are constructed. How then is the linear one-dimensional information of the gene and the protein translated into the three-dimensional information that allows proteins to carry out their various functions? The individual amino acid subunits have different sizes, electrical charges, and shapes. The particular order of amino acid residues causes a protein to fold into a precise three-dimensional shape. Accordingly, the specificity of an antibody molecule arises from the fact that it folds into a three-dimensional pattern that exhibits molecular complementarity for its corresponding foreign pattern, much as a key fits into a lock (below).

The fundamental unit of function in the immune system is the antibody molecule. The range of vertebrate immunity arises because each organism can synthesize a million or more different antibody molecules, each of which exhibits a unique three-dimensional configuration that permits it to recognize and bind a unique foreign antigenic pattern. Moreover, the antibody molecule is an extremely sophisticated molecular machine that carries out two interrelated types of functions. One portion is involved in pattern recognition, and the second triggers the elimination or destruction of the antigen. Let us now consider the cells that synthesize antibody molecules and the two distinct ways in which they are employed.



A hypothetical example of the molecular complementarity an antibody exhibits for its corresponding foreign pattern or hapten.

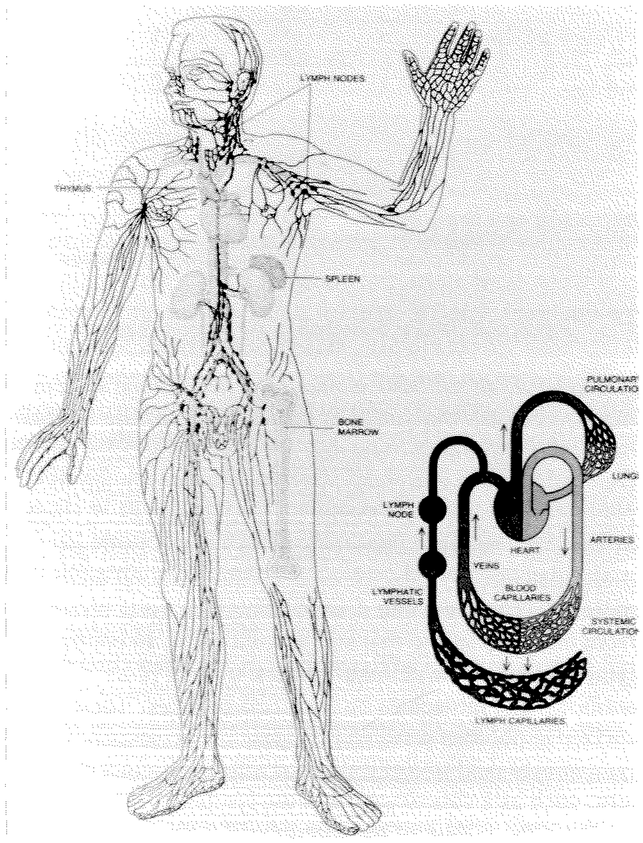


The humoral and cellular branches of the immune system

Humoral and cellular immunity. The immune system has two distinct functional branches which utilize antibody molecules differently (above). Antibody molecules are synthesized by cells designated lymphocytes which are morphologically indistinguishable for both branches. Lymphocytes of the humoral immune system secrete antibody molecules directly into the blood. Thus humoral antibody molecules can meet and destroy antigen at great distances from the lymphocyte that synthesized them. In contrast, lymphocytes of the cellular immune system place antibody-like molecules on their cell surfaces. These cell-surface antibodies serve to juxtapose the corresponding lymphocyte next to a cell that has a foreign molecular pattern, such as a cancer cell, and the lymphocyte itself mediates the killing of the foreign cell. Clinically, the humoral and cellular immune systems carry out distinct functions. The humoral immune system is concerned with fighting acute bacterial and viral infections for which the pathogenic organisms are found mainly in the blood. In contrast, the cellular system is involved with a variety of intracellular infections such as tuberculosis and many parasitic infections, and with cancer. Evidence for the discrete nature of these two branches of the immune system is provided by those rare individuals who lack either a cellular or humoral function. Let us now consider the anatomy of the immune system.

Anatomy of immunity. Lymphocytes in adults arise in the marrow of the bones (page 8). Lymphocytes from both the humoral and cellular systems arise from a single stem or progenitor cell. How then do these lymphocytes acquire their two very different sets of characteristics? Precursor cells of the cellular system arise in the bone marrow and migrate to the thymus where they undergo a diffentiation process that includes the acquisition of many new cell-surface molecules (page 8). After this maturational process, lymphocytes migrate into the blood circulation and are

Immunity, Disease, and Cancer



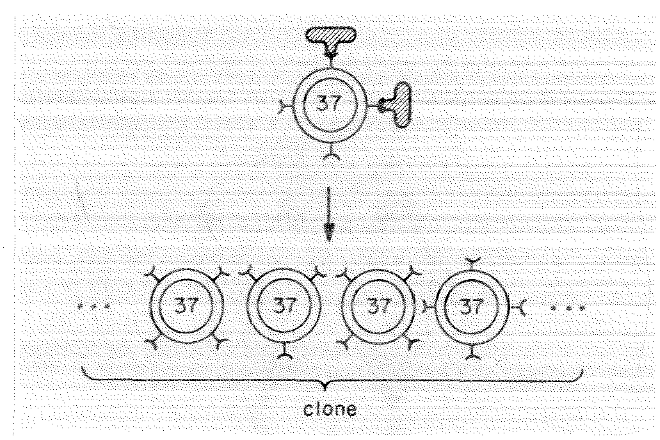
The organs and circulatory pathways of immunity

then capable of recognizing and destroying foreign patterns. Conversely, precursor lymphocytes of the humoral system mature in the bone marrow itself and then migrate into the circulation.

How do lymphocytes patrol the entire body and protect it against disease-causing or pathogenic organisms? Lymphocytes can circulate throughout either of two circulatory systems which pervade the entire body (above). The blood circulation is a closed system including the arteries, capillaries, veins, and its pump — the heart. Lymphocytes can migrate through the walls of certain blood vessels into the lymphatic system, which is comprised of thin-walled vessels and one-way valves. The pumping of the lymphatic fluid is carried out by the movement of nearby muscles. The blood and lymphatic systems have biological filters — the spleen and lymph nodes, respectively — where antigens are trapped and interact with lymphocytes to induce the immune response. For example, the swelling and soreness of nodules in the elbow in response to an infection of the hand represents an immune response occurring in that particular lymph node. These two circulatory systems extend throughout the entire human organism and permit the ever-circulating lymphocytes to patrol most of our body in their never-ending search for foreign patterns.

Immunization and clonal expansion. The immune system is capable of generating an enormous amount of information in the form of antibody molecules, which it employs to recognize and destroy millions of different foreign patterns. How then does the immune system express this information in an orderly and controlled fashion? How does it turn on the synthesis of those particular antibodies needed to respond to an individual pathogenic organism, and at the same time fail to turn on the synthesis of hundreds of useless antibody molecules?

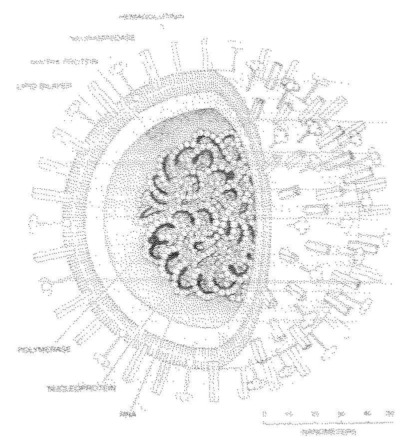
The answer to these questions is contained in two observations about the immune system. First, each lymphocyte is capable of synthesizing just a single type of antibody molecule (below). Some of these antibody molecules are placed on the surface of the lymphocyte and, upon interaction with a complementary antigen, they trigger the cell to divide and generate 1,000 to 10,000 daughter cells with identical antibody-synthesizing capacities (below). The functionally identical progeny of a single lymphocyte are termed a clone. Thus, exposure to an antigen — which is called immunization or vaccination — causes a 1,000-fold expansion of the lymphocytes that can respond to that particular antigen. Clonal expansion, then, is the cellular basis for the enhanced immunological responses that come with immunizations for smallpox, measles, or influenza. Second, the human organism has about 10^{12} lymphocytes that



Clonal expansion of a lymphocyte by antigen. The shaded entity denotes an antigen. The Y designates a cell-surface receptor antibody. The number 37 indicates that each of each of these lymphocytes synthesizes the same type of antibody molecule.

are capable of responding to virtually all foreign patterns. So different antigens will cause distinct lymphocytes — those synthesizing complementary antibodies — to undergo clonal expansion. Thus humans have a vast library of lymphocytes poised and ready to react with a multitude of different foreign patterns.

In brief summary, the antibody molecule is responsible for the specificity of the immune system. Humans can synthesize perhaps a million different antibody molecules that collectively can respond to most foreign patterns. Clonal expansion allows the immune system to respond effectively to invasions by foreign organisms. Let us now consider infectious disease and immunity.



The structure of the influenza virus with a portion of the shell removed to reveal its inner proteins (polymerase and nucleoprotein) and genes (RNA).

INFECTIONS AND IMMUNITY

Infectious diseases are caused by the invasion of disease-producing micro-organisms such as bacteria or viruses. The foreign organism may be pathogenic because it produces a toxic substance which, for example, may paralyze the heart or destroy certain cells of the brain. Alternatively, the organism may directly invade and destroy specific tissues such as the lung or kidney. Let us consider the immunology of two infectious diseases.

The eradication of smallpox. Immunology as a science began with a partial understanding of the immunology of smallpox. It is estimated that this disease killed between 10 and 20 percent of the English population in the 17th and 18th centuries. A surgeon, Edward Jenner, noted in 1796 that one group among the English population — milkmaids — remained free of the pox marks characteristic of the nonlethal form of smallpox. Jenner reasoned that the milkmaids' protection was in some manner derived from their early exposure to cowpox, a related but much milder pox-like disease. He then immunized an 8-year-old with pus from a cowpox infection and later demonstrated that the boy was totally resistant to subsequent infection by smallpox. The general acceptance of this medical advance was slow to come, however, and it was not until the 20th century that smallpox vaccinations were widely employed as a public health measure.

In 1967 approximately 10 to 15 million cases of smallpox were distributed throughout 42 countries of the world. At this time the World Health Organization (WHO) established a program to eradicate smallpox within 10 years. Several factors led to this first optimistic proposal to eliminate one of mankind's major diseases. First, the virus that causes smallpox has but a single host — man. Moreover, smallpox infections within an individual are of limited duration, and therefore the virus must move to a new host or die. Second, immunization prevents the smallpox virus from living in the vaccinated host. Accordingly, once a case of smallpox is identified and those people around the diseased host are vaccinated, the smallpox virus dies out because it has no unprotected host into which it can spread. Once the WHO program was initiated, the number of countries reporting smallpox infections dropped rapidly from 42 to 16, then to 5, and, finally, in 1978 smallpox was totally eradicated as a disease — certainly a major triumph in the annals of modern medicine. Unfortunately, this elegant approach cannot be applied to most other infectious diseases. Let us consider a second example, the viral infection influenza.

Influenza – cyclic and recurrent infections. The structure of the influenza virus is shown above. Basically the eight small chromosomes that encode this virus are surrounded by a membrane shell which has several types of spikes projecting from the virus. These spikes carry the foreign antigenic patterns against which the human immune system reacts. Two factors explain the cyclic and recurrent infections of influenza throughout human populations. First, when two influenza viruses with distinct foreign patterns infect the same host, the small chromosomes may exchange (recombine) genetic information to generate entirely new foreign patterns heretofore unseen by human hosts. Accordingly, there is a continual race between the human immune system that immunizes one against the foreign patterns of particular influenza viruses and the ability of these viruses to undergo recombination and generate entirely new foreign patterns. Second, the influenza virus can live in a wide spectrum of hosts including many domestic animals and birds. Hence there are enormous animal reservoirs from which influenza viruses with new and distinct foreign patterns may emerge. What marks each of the great pandemics of influenza that mankind has suffered in the last 50 years is the emergence of entirely new types of foreign patterns for the antigenic spikes. As rapidly as the human immune system develops antibodies that react against an established influenza pattern, a new type of influenza virus emerges to reinfect mankind.

Resistant infections. Certain infectious diseases have been notoriously resistant to the immunological approach. For example, the gonococcus, a bacterial organism causing veneral disease in approximately 10 percent of the juvenile population of California, has resisted all attempts to generate effective immunization procedures. This failure underscores the need to understand the fundamental aspects of the immune response and the means by which difficult antigens like the gonococcus may be rendered more immunogenic. These kinds of fundamental studies are under way in many laboratories throughout the world.

Let us now turn to cancer and consider the biology of this complex disease before considering how immunology may be employed to fight cancer.

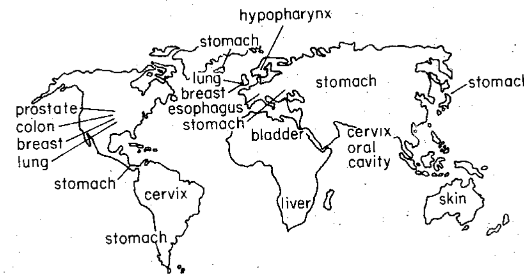
CANCER

Cancer biology. The statistics of cancer are awesome. Last year more than 400,000 United States citizens died of cancer. Cancer will kill every fifth American. A very high percentage of those who acquire this disease will eventually die from it.

Cancer is not a single disease; rather, it is a spectrum of different but related diseases. Cancer may arise in virtually any tissue or cell type. Cancerous cells lose their ability to control their rate of cell division, and they divide again and again in an unchecked fashion. Thus a large cancerous mass or tumor is generated. A fundamental property of cancerous or neoplastic cells is that they acquire the ability to invade surrounding tissues. Often cancer cells separate from the main tumor and pass via the blood or lymphatic systems to seed new tumors in distant parts of the body. These secondary cancer foci are termed metastases, and they probably result in the majority of cancer deaths by destroying the functions of vital organs.

There are three general categories of cancer. Carcinomas are cancers that arise in the tissue coverings of the body — the skin, the gastrointestinal tract, the respiratory tract, and the ducts of various glands. Sarcomas arise in the connective tissues of the organism. Leukemias and lymphomas are tumors of the blood cells — the lymphocytes, red blood cells, and white blood cells.

Many cancer biologists believe that the majority of cancers — perhaps as many as 90 percent — arise because of

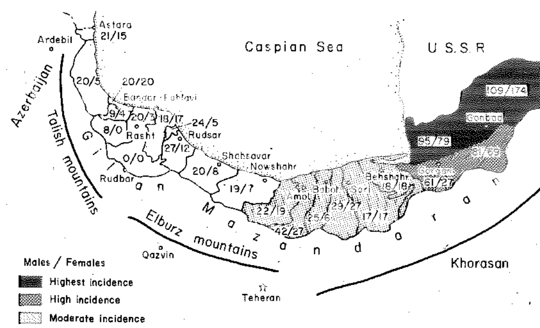


The geography of cancer. The types of cancer most frequently found in specific areas are indicated.

exposure to environmental cancer-causing (carcinogenic) agents. This is consistent with the observation that the vast majority of cancers are carcinomas that arise in those tissues most directly exposed to the environment — the body coverings. Let us now consider the case for environmental carcinogens.

Environmental cancer. There is a distinct geographical distribution to certain types of cancer; that is, distinct types of cancer are prevalent in different countries (above). For example, in Japan cancer of the stomach is prevalent, whereas in the United States more than 50 percent of cancer deaths are caused by three types of cancer — lung, breast, and colon.

There are two possible explanations for these distinct geographical distributions of tumors. Obviously humans may be exposed to different environmental carcinogens in different environments. Particular carcinogens will cause specific types of cancer. Alternatively, perhaps different gene pools lead to the tendency of different types of cancer to arise in various countries. Careful analysis of this latter possibility suggests that genetic differences are an unlikely explanation for the asymmetric geographic distributions of



Incidence rates of esophageal cancer in the Caspian Littoral of Iran. Numbers indicate the cancer rate per 100,000 individuals, with male incidence on the left and female on the right.

cancer. For example, portions of Iran have an extremely high incidence of cancer of the esophagus (below left). Other regions have a very low incidence of this same cancer. When migrants move from an area of low to high cancer incidence, their children acquire the high incidence of esophageal cancer characteristic of the new area. The inverse also is true. Hence genetic factors do not control the rate of this cancer; rather, there appears to be some unknown environmental carcinogen that causes a high incidence of esophageal cancer in certain areas of Iran.

Cancer Death Rates in Groups of Males Throughout the World*

	High	Low
Mouth	61.3	1.3
Nasopharynx	35.9	0.0
Esophagus	110.5	2.1
Stomach	172.2	6.6
Colon	30.6	0.0
Rectum	23.3	0.0
Pancreas	18.3	0.4
Larynx	15.6	0.7
Lung	154.3	1.9
Prostate	40.8	0.7
Bladder	34.6	1.9
Thyroid	17.0	0.0
Leukemia	15.6	1.3
Total	730.0	17.0

*Average annual death rate per 100,000 for 35-54 age group.

A fundamental feature of environmental cancers is that they appear to have a long latent period between the time of first exposure to the carcinogen and the acquisition of this disease. For example, the incidence of smoking among men in the United States increased exponentially during the early 1900's. After a lag period of about 20 years, the incidence of lung cancer also rose in an identical exponential fashion. Indeed, a significant increase in smoking among women 15 to 20 years ago is just now being followed by a corresponding increase in lung cancer among women smokers. The latent period in the acquisition of environmental cancers obviously makes it difficult to trace the causes of particular cancers and to predict what effect a new widely distributed potential carcinogen might eventually have.

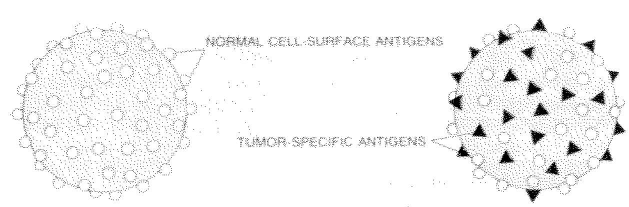
The highest and lowest rates of specific types of cancer in various countries are shown above. If one could assemble the ideal environment from each of those countries with the lowest rate of cancer, the cancer incidence would be roughly 40 times less frequent than for countries with the higher incidences. Indeed, individuals belonging to the Seventh Day Adventists have roughly half the incidence of cancer of the average American population, a statistic probably related to the Adventists' strict views on smoking, eating, and drinking. These observations raise provocative questions. Once potent environmental carcinogens are identified, how can we deal with them? For example, virtually all lung cancers in the United States are directly caused by cigarette smoking. The elimination of cigarette smoking would save more lives than the abolition of all other forms of cancer put together. Does the government have a responsibility to control more effectively this unequivocal environmental carcinogen? These same arguments will be raised for other carcinogens as we identify them.

Once an individual has acquired cancer, how is it treated?

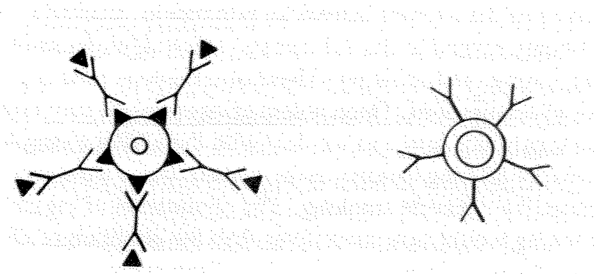
Cancer therapy. There are three classic treatments for cancer — surgery, irradiation, and chemotherapy. Highly localized tumors are excised by surgery. Tumors that have invaded surrounding tissues may be treated with irradiation. Widely disseminated cancers such as leukemias must be treated by anticancer agents injected into the blood (chemotherapy). Each of these three forms of treatment is nonspecific in nature; that is, these approaches kill or destroy normal as well as cancerous cells. Immunology offers the hope of eventually being able to develop cancer therapies that are highly specific only for the cancer cells.

Immunology of cancer. A cancer cell is distinguished from its normal counterpart by the presence of special cancer antigens on the surface of the cancer cell (below). All types of tumor cells appear to acquire these new cancer antigens. Hence cancer antigens appear to be an inevitable consequence of the neoplastic transformation of individual cells.

Some immunologists believe that the immune system evolved in complex and multicelled organisms in order to destroy continually arising cancer cells. This line of reasoning suggests that in any complex organism, normal cells such as those of the intestine or bone marrow are con-



Cancer antigens. A cancer cell is distinguished from its normal counterpart by virtue of newly acquired cell-surface molecules called tumor (cancer) antigens.



Humoral antibody molecules may shield a tumor cell (left) from destruction by the cellular immune system (right).

tinually dividing. Occasionally neoplastic cells arise from these dividing cells and express foreign cell-surface antigens. The cellular immune system can then destroy these newly emerging cancer cells by recognizing the foreign nature of their cancer antigens. By this view, the immune system evolved as a surveillance system for destroying neoplastic cells before they proliferate and destroy the organism. Accordingly, clinically diagnosable cancers must in some fashion escape this surveillance system.

The rationale for immunotherapy is that the immune system of one individual may be activated to attack the particular type of cancer he has acquired. In principle, the humoral and cellular immune systems could be immunized or activated against a particular cancer. In practice, immunotherapy has not been successful to date for several reasons. First, immunizations against cancer antigens have not been very effective for a variety of technical reasons. Second, most cancers are not susceptible to destruction by humoral antibodies. Indeed, humoral antibodies may "block" the beneficial effects of the cellular immune response to tumors by covering up the foreign antigenic patterns on the surface of the cancer cell (above) and thus preventing the cellular lymphocytes from attacking the cancer cells. Accordingly, successful cancer therapy in the future will require the fundamental understanding of two general problem areas. First, how can tumor antigens be isolated and rendered more immunogenic? Second, how can the cellular but not the humoral immune response be stimulated by immunization with cancer antigens?

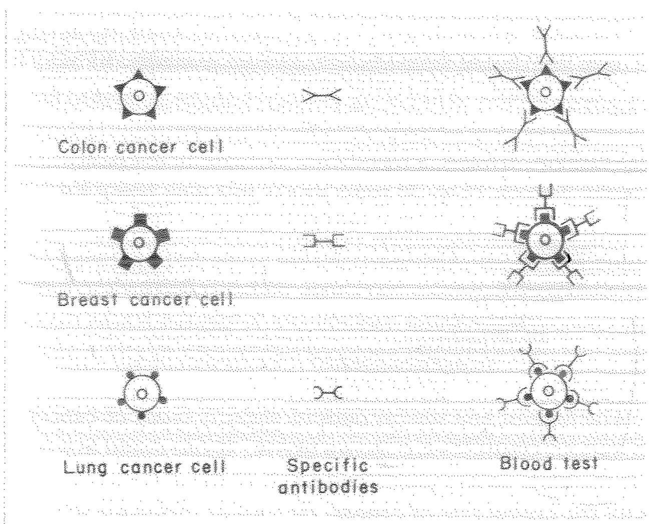
It is now possible to make antibodies that detect certain types of cancer antigens. These antibodies can be used as diagnostic reagents to search for very low levels of cancer antigens in the blood of apparently normal individuals. A future goal is to make specific antibodies for each of the major types of human cancer and to use these antibodies as routine diagnostic agents to detect cancer at its very earliest stage — for the early detection of cancer often leads to its successful cure (right). Perhaps in the future these diagnostic cancer antibodies will be a routine part of the periodic medical examinations that older individuals should undergo.

Immunotherapy and immunodiagnosis offer exciting future prospects for dealing with the cancer problem. However, additional fundamental research is required before these techniques can be effectively and widely applied. We must not expect too much too soon.

CALTECH'S MEDICAL SCIENCES PROGRAM

Caltech has initiated a new program termed the Medical Sciences Program. This program will entail the appointment of three new professors and the construction of a new building — the Braun Laboratories of Cell Biology and Chemistry. The focus of this program will be immunology, a discipline which, as you can now appreciate, interfaces beautifully with fundamental and clinical research. The newly recruited professors also are to be interdisciplinary; they will be outstanding fundamental researchers as well as individuals with medical backgrounds. One hope is that fundamental discoveries can be rapidly translated into the applied realm of medicine.

Caltech offers a unique environment for this new program with its small size, its scientific excellence, its superb students, its access to the high technology of the Jet Propulsion Laboratory, and its close relationships with several local medical institutions, including the Huntington Memorial Hospital and the City of Hope. This program insures that Caltech will remain at the cutting edge of fundamental biology and medicine for years to come. □



Immunodiagnostic reagents. In the future, specific antibody reagents may become available for blood tests to detect particular types of cancer at their very earliest stages.

Caltech Goes to China

Entries from a Diary

by Rodman W. Paul

In the November-December issue of E&S, *Rodman Paul reported on the first ten days of a very unusual trip to China by a group of Caltech men this fall. The delegation included:*

Marvin L. Goldberger, *President of Caltech*
R. Stanton Avery, *Chairman of the Board of Trustees*
Arnold O. Beckman, *Chairman Emeritus of the Board of Trustees*
Bruce C. Murray, *Director of the Jet Propulsion Laboratory*
Seymour Benzer, *James G. Boswell Professor of Neuroscience, representing the Division of Biology*
Robert F. Christy, *Vice President and Provost, representing the Division of Chemistry and Chemical Engineering*
Robert H. Cannon, Jr., *Chairman of the Division of Engineering and Applied Science*
Barclay Kamb, *Chairman of the Division of Geological and Planetary Sciences*
Rodman W. Paul, *Acting Chairman of the Division of the Humanities and Social Sciences*
Rochus E. Vogt, *Chairman of the Division of Physics,. Mathematics and Astronomy*

The second, and final, installment of Paul's diary appears here.

September 17, Peking: Up early so as to go at 8 a.m. to the big new mausoleum where Mao Tse-tung lies in state. We filed into a high-ceilinged chamber where a huge white marble statue of Mao dominates the room, rather in the manner of Daniel Chester French's statue of Lincoln at the Lincoln Memorial. But there the comparison stops, for as we were carried past the statue by the pressure of the silent crowd around us, we found ourselves in an inner room where Mao himself lies in a glass or transparent plastic case — his body, save for the face, covered by a vivid red cloth that bears the emblems of the hammer and sickle and red star. The face is well preserved.

After seeing Bruce Murray and Murph Goldberger off to the airport, we headed for a day of sightseeing (in the rain) at the Summer Palace, which is on the outskirts of Peking. We have already spent quite a bit of time at the Forbidden City, with its Imperial Palace and extensive museums. At both of these palaces room after room is filled with intricate, ornate, vividly decorated treasures that were designed originally to please the favored few who so mercilessly exploited the people they ruled.

It speaks well for the sophistication and self-confidence of the present regime, and for its ultimate sense of beauty, that today money is being spent to restore these treasures, and that there are no attempts to discourage the long

The three-week visit ended with a "Dancing Opera," staged by graduates of the Shanghai Academy of Performing Arts.

queues of Mao-suited modern equalitarians that wait so patiently to see them. I suppose the leaders reason that, after all, they have totally eliminated the privileged minority — emperors, landlords, Mandarin elite, and merchants — for whom these wonders were created, and therefore the new society might as well enjoy the artistic heritage of the old. There have been some casualties. Old China Hands would point out that since 1949 a vast open space, suitable for political mass meetings, has been created by bulldozing the whole area in Tian'anmen Square, directly in front of the Forbidden City complex. The new structures that face into this big central space include the Great Hall of the People, the Working People's Palace of Culture, and the Monument to the People's Heroes, all done in massive neo-Stalinist style.

At the Forbidden City we passed through the Hall of Sublime Tranquility, the Hall of Middle Tranquility, and the Hall of Complete Tranquility. It was suggested that Millikan Board Room be rechristened with one of these names, in the belief that such action would surely inspire the Faculty Board, IAC, and Board of Trustees to magnificent achievements.

Notes on things experienced and heard:

When Bob Christy and I got on a crowded public bus to go shopping, to our embarrassment the Chinese passengers insisted on getting up and giving us a seat. Everywhere we have met this good-tempered courtesy and kindness. At night one can walk about Peking with a sense of safety unknown in today's American or European cities. All is quiet, there is no sign of crime or dubious-looking characters. A few men can be seen asleep on the sidewalk, from what cause I know not. A few young couples can be seen seeking partial privacy behind park bushes; privacy is scarce in this society. It is rare to see young couples holding hands or having their arms around each other as they walk, although in a very few instances we have noticed it, including one or two cases where the couple were of the same sex.

We have come to know some of our regular faculty escorts well enough to have talks about the more intimate aspects of life. Late marriage, as a means of reducing the birth rate, is now standard. The young man should be 27, the girl 25. One child per family is considered right; two is maximum. When a woman becomes visibly pregnant for a third time, the group she is associated with will reason with her and urge an abortion — i.e., apply group pressure. Out in the more distant rural areas the traditional large Chinese family is more prevalent.

Divorce is possible, although apparently infrequent, and remarriage after divorce is possible. The new husband must assume responsibility for his new wife's children by her former marriage, although the ex-husband must pay toward the support of the children.

Birth control practices are used in the attempt to keep down the size of families. One need only spend a few days among the crowds that throng the city streets to understand why the Chinese government wants a lower birth rate.

Instrumental music is one of the activities at the "Children's Palace," a day-care center in Shanghai.

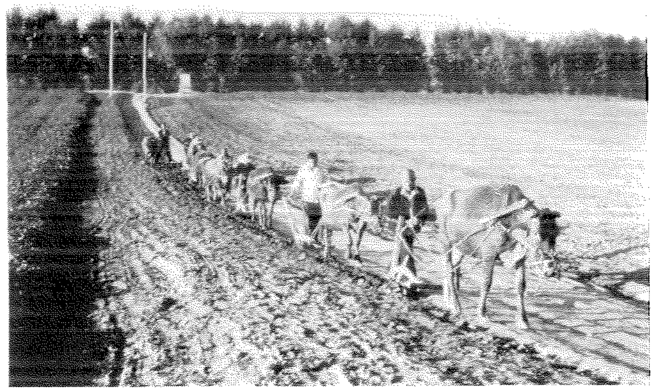
September 18: Up at 5:30 a.m. to make an early departure for Sian, or Xi'an. Typically of the Chinese, a good-sized group of the Tsinghua University faculty came to the hotel to say good-bye, and several of the faculty accompanied us on the hour and a half flight. The courtesies are always observed. Quite charmingly, one of the faculty said, with reference to this uncomfortably early hour, "You must be very tiresome." English is a treacherous language.

Sian, in Shensi Province, is an old city filled with historic sites and buildings. Its history runs back for 3,000 years. It was the capital of China throughout 11 dynasties, and near it is the remarkable burial site recently written up in the *National Geographic*. We were very eager to see this burial place, but first we were taken to the hot springs, scene of the "Sian incident" in which Chiang Kai-shek was captured by his own people and held prisoner until he would agree to lead a united front in the war against the Japanese invaders. We were given a long lecture by a very stern young communist who felt strongly about Chiang Kai-shek's failings. Considerable stress was laid upon the fact that when captured Chiang was clad only in his bathrobe and shorts, and had fled barefoot up the rocky hill above the hot springs. We were marched up the hill to see in person the little cave in which the Generalissimo hid cowering. As the lecture-demonstration continued, in the face of a growing impatience among the listeners, an amusing collision of values became apparent. To young Chinese communists, accustomed to regard Chiang with the same affection that Americans might feel for Benedict Arnold, every detail of the humiliation of the leader manqué was important, but to American visitors, the prospective charms of a tomb 2,000 years old were far superior.

When we got to the burial site, in the late afternoon of a lovely autumn day, we found that excavation had ceased because experience had shown that these long-buried treasures quickly deteriorated when exposed to the atmosphere. Therefore a big building like an aircraft hangar is being erected over the site, and digging will be resumed only when this protective shell is finished. Meantime examples of the hidden treasures were on exhibit in a cement-floored shed built for that purpose. Included were life-size pottery or terra cotta soldiers, officers, a general, a crossbowman, a chariot driver, and two horses. The workmanship was remarkable; no two human figures had the same facial expression, and all were thoroughly believable as human beings. When made originally, they were painted in bright colors. The date has been set as earlier than 200 B.C., in the period when China was unified for the first time, which would be roughly contemporaneous in the Western world with the wars between Rome and Carthage. Nearby is a large artificial hill, or tumulus, under which even more spectacular discoveries are anticipated.

Being out here in the country is a very different experience from the streets of Peking. Peasant life seems not much changed from what it must have been for centuries, save in the key respect that no one is starving. We happened upon an illuminating example of plowing: A long string of draught animals was loosely hitched in single file to a plow made exclusively of wood save for a small steel blade. We received another insight when we were told that the farmers here must deal with a problem of soil compacting, caused by centuries of feet walking up and down the same rows.

September 19, Sian: We spent all morning at Sian Chiaotung University, which proved to be a technical institute. Although built only in 1956, the buildings seemed older because they had been neglected. Like all Chinese universities, this campus had a bad time during the Cultural Revolution and the Gang of Four. Before the Cultural Revolution they had 8,000 students; this fall, when they receive their first major contingent of new students in many years, they hope to be back to 4,500. Because promotions were



Tilling the soil has not changed much over the centuries. Draught animals still pull plows made almost entirely of wood.

frozen for years, the faculty is unbalanced: There are 1,500 teachers but only about 100 professors. About 15 percent of the students are women, which is better than we have been able to achieve at Caltech. English is the first foreign language, and must be studied before the student can go on to a second foreign language. Here, as at other universities we have visited, English-language materials were prominent in the library. There was formerly a strong Russian influence at Sian, but things Russian rate very low just now.

In the afternoon we were taken on a tour of historic buildings, such as the Bell Tower and the Big Wild Goose Pagoda, and the Shensi Provincial Museum. The latter has the most unusual "library" I've ever seen: a collection of big stone tablets, each taller than a man, on which are chiseled voluminous Buddhist texts. We watched rubbings being made from one of the tablets, and Barclay Kamb, who has become intrigued by Chinese calligraphy, bought a handsome example of such a rubbing.

September 20, Sian: This was a splendid day! Unexpectedly Mr. Wu announced that he had arranged for us to visit the Peak Fire Commune, two hours drive from Sian. More specifically, we were to go to one of the "brigades" into which the commune was organized. This was a unit of 250 families, totaling about 1,500 people. The vice chairman of the brigade proved to be a highly articulate, vigorous person who spoke with the confidence and authority of a self-made man.

His story was that this used to be a notoriously poor region where the land was owned by a rich peasant. The men worked as underpaid laborers, or begged for a living, or

The Shensi Provincial Museum has an unusual "library" of tall stone tablets, chiseled with voluminous Buddhist texts.

sold their wives and daughters into prostitution. Today the place is flourishing as a commune. The fields are beautifully cultivated, and no space is wasted anywhere. The wives of the farmers served us a bountiful lunch and proudly told us that everything they were putting before us except the beer had been grown by the brigade. As another index of how well they are doing, we were told that the head of the brigade now owns a bicycle, an alarm clock, and a wrist watch. What better evidence could you have?

In addition to feeding themselves, the brigade's farmers produce a surplus that goes partly to the state and partly to pay for farm machinery. Everyone has his own living quarters, which in most cases are big enough to house a family of five on the prevailing modest standards. We visited several homes. The main room in each was a sleeping room that doubled as the sitting room, but was not crowded because the furniture was limited to a big raised area — a kind of broad shelf — that served as a double bed, two or three plain wooden chairs, and a small wooden table. The kitchen was outside, across a little alley. A storeroom and additional sleeping space were upstairs.

Even more persuasive was the story of why the school buildings had been inconveniently located on terraces carved out of the loess soil of a steep ridge above the houses and workshops. The school was put there partly to avoid taking valuable flat land out of production, but partly for emotional reasons. Under the present school buildings there used to be a trench known as the Ditch of the Dead Children. Back in the bad old days children by the dozen were buried there as they died of malnutrition and disease. The commune resolved to build their simple classroom buildings right on top of this former disaster area and rechristen it the Ditch of Education.

As the vice chairman finished telling us this, the kindergarten children came marching past, singing lustily. They looked chubby, healthy, happy, and quite adequately clothed. The moral to the story was inescapable.

We were given license to go anywhere. As we walked through the classrooms and study halls of the older children, we were unanimous in thinking them remarkably well disciplined by American standards. Their mathematics problems, the only part of the school work that we could grasp across the language barrier, were fairly impressive for the age group and for a rural school. All children attend both elementary and middle school, the latter being equivalent to five years of junior high and high school in America.

Today we also visited a country museum that is being developed to show Tang dynasty relics at the site, instead of carting them off to a distant city. The valley around the museum was dotted with burial hills, but we weren't allowed to visit any where digging was taking place. They had on exhibit some striking pottery figures and bronze artifacts, together with some large, partly deteriorated murals found along the tunnels that lead into the tombs.

Looking at the problems they have encountered, especially the question of how to preserve the murals, one couldn't help but wonder whether the Chinese are in touch with archaeologists who have been dealing with comparable difficulties in other parts of the world.

I had the same uneasy doubt at the museum yesterday. When a country has been so isolated for 30 years, it must have been impossible to keep up with what your professional compeers have been learning recently — in archaeology as in science.

September 21: The day started awkwardly when we were told that our plane's departure time for Nanking had been advanced from 1:30 p.m. to 11 a.m. This meant speeding up our one remaining event, which was to visit the Banpo Museum, where a big shell has been erected over a paleolithic dwelling site. Carbon 14 tests indicate that this Stone Age site must have been occupied from about 6000 to 3000 B.C. As the archaeologists have had the mud dug away, traces of a whole village have been disclosed, a village of round houses with sloping roofs.

We flew out of Sian in a noisy old turboprop that was probably of Russian design and Chinese construction. There was a pleasant informality about the whole venture. We put down at Chengchow (or Zhengzhou), on the southern bank of the Yellow River, because the pilot said that he needed more gasoline. While the plane refueled at this isolated airport, we were served a good Chinese lunch.

At our destination, Nanking, we were greeted by the usual courteous delegation and had the usual tea ceremony while the program for our visit was discussed. Then we were driven to our hotel, which had the wonderful name of The Inn with the Double Gates to Heaven. My bedroom pretty nearly lived up to the hotel's title, for it was a light, airy, cheerful room that contrasted happily with our depressingly heavy quarters back at Sian. There we had been housed in a compound built for the Russians, whose taste was doubtless to blame for the heavy draperies, dark brown paint, and heavy furniture. The BBC could have shot *Anna Karenina* there.

But even the Gates to Heaven have their imperfections. In the middle of the night the people upstairs took baths, and when they pulled the plugs out of their tubs, there was a roar of water in the Caltech bathrooms immediately below, as dirty bathwater came spouting out of the drains in our tubs, sinks, and in the floor itself. Robbie Vogt, ever the man of action, went steaming down the hall to protest to the night clerk that there was an inch of dirty water all over the bathroom floor. The clerk looked at him with a beaming smile and said, "Good! Good!"

September 22, Nanking: This is a lovely old city with wide boulevards lined with sycamores that are trained to arch clear across the street. There is less horn blowing and a generally quieter pace than in previous cities we have visited. Visually it sometimes reminds one of Paris.

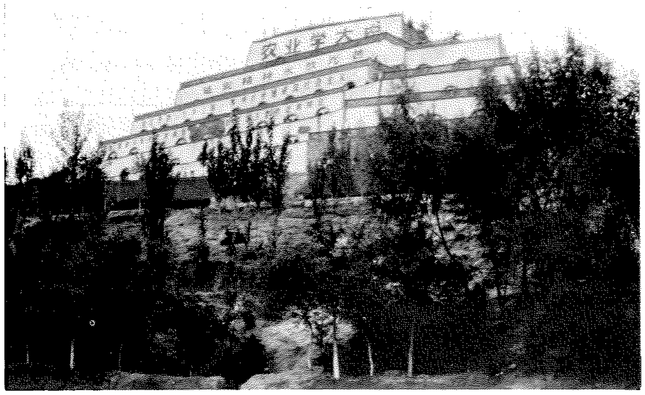
Nanking, or Nanjing, has the lower reaches of China's mightiest river, the Yangtze, at its foot, and a range of mountains at its back. Last night, immediately after our arrival, our hosts took us to the foothills of those mountains to see Sun Yat-sen's tomb. Unlike Mao's mausoleum in Peking, Sun Yat-sen's has been designed in traditional Chinese architecture and has been set into the natural beauty of this heavily wooded hillside. There are 400 steps to the top, but all of us made it. Much was said by the Chinese about Arnold Beckman's insisting upon making the ascent. The traditional Chinese respect for age has survived the revolution. Having discovered that Arnold was born in 1900, they never fail to mention his age and refer to him with a well-deserved veneration. But when our hosts finished off the evening by taking us to a Buddhist pagoda seven stories high, only Barclay, our youngest, had the reserve left to climb it.

Last night was a bit difficult because we were suffering from a combination of a virus infection and diarrhea. Our hosts had planned a welcoming banquet for us, and it proved to be a very pleasant affair marked by excellent food and good conversation. I was proud of the way our delegation marched in and participated. Stan Avery, with his diarrhea under self-treatment, led the procession, followed by Bob Christy, with diarrhea and temperature of 100½°, then Robbie, temperature of 102½°, then the rest of us with our varying degrees of bowel and fever complaint. But the fine thing was that we enjoyed the evening. Even Seymour Benzer, our roving gourmet, conceded that the food was very good. Our inner condition was suggested only by the fact that we declined the green apples that were offered for dessert.

Today's sightseeing began with a trip to the impressive Changjiang Bridge over the Yangtze. This is a long double-decker that handles railroad trains on its lower level and automobiles above. What makes the Chinese so proud is the fact that they built it themselves after the Russians broke their contract and quit supplying the special steel that was needed. Instead of taking two hours to be ferried across the Yangtze, a railroad train now crosses in two minutes.

Then we headed up into the mountains to inspect the observatory that is operated there under the jurisdiction of the Academia Sinica. This went so well that it was arranged to have Robbie, Barclay, Bob Christy, and Bob Cannon put on a three-hour session this evening for the astronomers and astrophysicists of the observatory and Nanking University. While they were thus gainfully employed, the remaining four of us went to see a play staged by the provincial affiliate of the Peking Opera Troupe. This play was characterized by brilliantly colored costumes and by a theme that was important under the old regime: A young man who had scored No. 1 in the examinations for the civil service was chosen to marry the king's daughter. Not being quite honest, the young man tried to conceal the tri-

Members of the Caltech party make their way up a steep slope to the Peak Fire Commune school. Behind them are the residences and workshops, and behind those, orderly rows of fields and trees.



The school sits high on a terrace carved out of the ridge. Beneath the building there used to be a trench in which were buried the many children who died of malnutrition and disease.

fling detail that he already had a wife and two daughters who were starving while he crammed for his exams.

A very full afternoon at Nanking University demonstrated that the university is making a gallant attempt to pull itself up from its present position. The 6,000 students that they had before the Cultural Revolution have shrunk to 1,600 today, although they hope that next month, with their first crop of new students who have taken entrance examinations, they will be back to 3,500. Their list of 1,600 teachers is very misleading, because the university has no retirement policy and thus has people who, by age or ill health, are quite unable to teach.

Determined attempts are now being made to raise standards for both faculty and students. Hitherto students were told what they would study before they arrived at the gates to the university! The new plan will specify that a student must accumulate 120 credits to graduate, and then will permit the student more than one way to achieve that total. Research at the postgraduate level was killed by the Cultural Revolution and Gang of Four, but will be reinstituted this fall. Under questioning by us, the administrators explained that most of the basic plans are made by the state, but some leeway is left to the university.

I had a good separate session with the senior man in history and the corresponding man in philosophy. The historians have the interesting idea of centering their teaching around Nanking itself, because Nanking is an old city that was the capital of China through six dynasties and has a well-documented history that illustrates the role of feudalism, capitalism, and the peasantry. But they assured me that they also teach British and United States history, though their American history stresses events *after* the Second World War. In response to my question, the philosopher said that while of course they teach Marxism-Leninism, they also teach Confucianism and Buddhism, together with European philosophy and symbolic logic. The comment about Confucianism interested me, because Confucianism has been much out of favor politically since the revolution, since it is regarded as a prop of the old regime.

September 23: Before leaving Nanking, we visited the tomb of the first Ming emperor and the museum of the ill-fated Taiping Rebellion, a 19th century peasant revolt that is regarded now as the precursor of the present People's Republic, and is honored accordingly.

The five-hour train ride to Shanghai seemed restful after the activity of the past two weeks. The pattern outside the train windows was one of neat fields and irrigation canals, with only an occasional indication of industrial plants. At Shanghai, the second-class passengers were unloaded first, then the train was backed off to a separate and uncrowded platform so that we lordly folk could descend in style. In an egalitarian country! Our hosts from Fu Tan University were on hand to greet us and to escort us to our hotel, where we slept well save for occasional interruptions by a noisy Iranian soccer team.

September 24, Shanghai: We were taken first to the Shanghai Industrial Exhibition. China is very dependent upon Shanghai for heavy equipment and technologically sophisticated machines. But when you really studied the exhibits, you came to realize that most of what we were seeing were prototypes or working models. Included was a potentially important machine for transplanting rice, but we were told that only 45 of them are in use.

Then we went to a lovely but hopelessly overcrowded park that was once owned by a very rich man. This being Sunday, a good percentage of the population had the day off, and this seemed to be one of the few places to which they could go. In Los Angeles terms, it was as if the grounds and art galleries of the Huntington Library were being forced to serve a crowd that would prefer to be at Disneyland or Knott's Berry Farm.

In the evening we were given a fine welcoming banquet, with many toasts and many courses. I've become intrigued by the position of women in regard to these very nice entertainments. The announced dedication of the People's Republic to equality between all humans naturally includes equality between the sexes, and where we have dealt with women as faculty members, administrators, or interpreters, they have been included in the lunches and dinners given for us, but faculty wives have never been present; nor, indeed, have we ever met faculty wives or seen faculty homes. The custom of the country, then, seems to draw a distinction between family life and official activities.

September 25, Shanghai: We spent a full morning at Fu Tan University, where C.C. Tan, who took his PhD in biology at Caltech (1936), presided in impressive fashion. Fu Tan, which was founded in 1905, is a comprehensive university that covers both the arts and sciences. It suffered severely under the policies of the Gang of Four. Classroom teaching was reduced, science was required to produce useful products, open enrollment of students was established, and students were not examined while in residence. Half the laboratories were destroyed, and the other half damaged. Most teaching and research have now been restored, and the hope is that by 1980 the university will be back at the level it had before the Cultural Revolution.

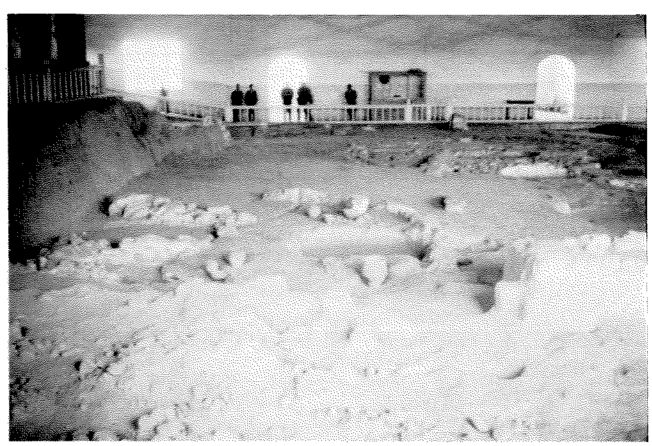
As we sat listening, in a reception room where the breeze through the open windows kept billowing the curtains, I became conscious of two sounds that suggested some of the opposing pressures to which a Chinese university is now subject. The one was the blaring of martial music played over a public address system, the other the periodic scream of jet engines as planes approached the airport. The first was a reminder that this is a controlled society with a large military element, the other an evidence of China's need to bring its basic science up to date so that it can cope with modern technology.

In the afternoon we had a most interesting visit to a workers' housing project. Before going inside, we walked through the stores that serve the residents. Owned and operated by the state, the stores offer most kinds of basic food, clothing, and household goods. There were plenty of customers. We visited also the two elementary schools that look after the rather large crop of children. Then we went to the modest little home of a chemical worker. This man and his wife, and their married son and daughter-in-law, live in two rooms of this multi-residence building. The physical arrangement of the apartment reminded me very much of the agricultural commune we visited outside Sian. The main room was a combined sitting room and bedroom, with a large double bed, three simple chairs, and a wooden table. A smaller inner room contained little save another double bed. This apartment shares with its neighbor the use of a grubby little kitchen across the hall (two small stoves with a total of four gas burners), plus a sink for doing laundry and a bathroom containing a toilet and tub.

The chemical worker expressed great satisfaction with his home. Before the liberation in 1949, his family lived in poverty and in a small fraction of the living space they now enjoy. As was true of the agricultural commune at Sian, it's a question of where you start from. Having grown up in a large family that had to squeeze into one very small room, and still were very poor, this man regards his present two rooms plus kitchen-laundry-bath facilities as most luxurious. What's more, he can afford it. He is paid 70 yuan per month while his rent is only 7 yuan — a ratio of 10 to one. His rent and some of the controlled prices at the stores have actually been reduced recently, while his salary has been increased slightly.

He apologized for the absence of his wife, who has a full-time job just as he has. Her job gives her Sundays off duty, while his makes Mondays his free day, which was why he was at home. I asked whether the two of them ever shared the same days off, so that they could do something together. With apparent surprise, he replied that once a year they enjoy a three-day holiday at the Chinese New Year, and there are two additional national holidays. So they have five days together; what more could you want? Both work eight hours per day, six days a week.

While the chemical worker made us tea, the man who is called "the cadre" of the project explained how things work. In referring to this man as "the cadre," the Chinese mean that he is the political leader and administrator. This building was put up in 1960 and has been whitewashed since, though the maintenance did not seem good. There are 16,000 family units in the project, housing about 61,000 people. New buildings are being put up, but demand exceeds supply. I pressed the question of how does a worker get admitted to a housing project. The answer was that an applicant must go to the local housing board or committee, which will try to help him. Not enough hous-



At the Banpo Museum in Sian a protective shell has been erected over a Stone Age dwelling site, which was probably occupied from about 6000 to 3000 B.C.

ing is available, and the state is hard put to find the resources to build more. We got the impression that through lack of funds and supplies, the state is probably putting less reinforcing steel into these projects than modern earthquake standards would require.

September 26, Shanghai: In the morning we went to a hospital to witness an acupuncture operation to remove a woman's thyroid. Throughout the 45 minutes of this successful operation we were surrounded by a visiting delegation of Belgian surgeons, physicians, and anesthetists, who broke into a cheer when the operating surgeon triumphantly held up the removed thyroid gland. I am sure the patient must have been conscious throughout, because I saw her eyes move frequently.

During a session with the chief acupuncture surgeon after the operation, we were told that the percentage of operations using acupuncture at this hospital has been declining sharply, from a former 40 to 50 percent to only 15 percent today. As in Christian Science, the patient must have faith in the process for it to work. The patient this morning was given Demerol as a sedative, in accordance with their usual practice here. As the surgeons have gained in experience, they have greatly reduced the number of electric needles used in an operation. Where formerly 20 to 40 were standard, today only 2 or 4 are employed.

In the afternoon we had a fine visit to the Institute for Traditional (Chinese) Art, which is part of the Shanghai Academy of Art. Elsewhere in Shanghai there is a unit devoted to modern art. During the days of the Gang of Four, most kinds of art were prohibited here, and the Institute was virtually closed. The artists showed us the whole

At the Institute for Traditional Art in Shanghai, an artist demonstrates the whole process of traditional Chinese painting.

process of traditional Chinese painting, starting with what they called the Four Friends of the Artist: brushes, black ink, a stone to grind the ink on, and tissue-thin paper made of a cotton base. Painting is necessarily done on a flat surface rather than an easel, because otherwise the ink or paint would run. Other colors are used in addition to shades of black and gray. When finished, the painting is hung up to dry, then is pasted onto a paper backing with a paste made of fine-ground wheat. To get rid of the wrinkles, this is mounted temporarily on a board while the wrinkles are smoothed out. The final result is then transferred to a new paper backing and framed in silk matting.

Some famous artists let us watch them at work. Theirs was a fascinating combination of the literal and the impressionistic. The artists are by no means unaware of Western trends, for some of their paintings showed a clear Western influence, especially in the depiction of people.

September 27, Shanghai: After spending hours shopping in the department stores of this lively and relatively modern city (quite different in flavor from other cities we have visited), we were taken to see a "Children's Palace," which is one of Shanghai's proudest displays. This is a combination recreation and day-care center that tries to cope with the problem of looking after children of all ages while their two parents are at work. The "Palace" serves 1,000 children per day, which sounds impressive until you stop to think how many tens of thousands of children there must be here. But we were told that there are other "Palaces," only not so big or so rich in their offerings. This particular palace provides everything from a penny arcade, where there are mechanized horses to ride and toy rifles to shoot, to all kinds of arts and crafts involving wood or metal or painting, plus a great deal of instrumental and vocal music, ballet dancing, and amateur drama. What they were doing was very good, but applications for admission are so heavy that each child is permitted to have only one or two days per week here. What happens to them on the other days?

In the evening we were taken to a most attractive "Dancing Opera," as they termed it, put on by young graduates of the Shanghai Academy of Performing Arts. The performers were beautifully trained, and they staged a very finished performance. It was interesting to note that the traditional heavy Chinese makeup had been applied less thickly, and the ballet-type dances were less formal than at the Peking Opera, perhaps because of Western influences. The leading lady's dances, with a long silk scarf flowing behind her as if suspended in midair, were superbly graceful. It was a lovely way to end our three-week visit to China. □

Our galaxy is a member of a minor cluster of about 20 similar systems — like these four galaxies in the constellation Leo.

From the Outside In

by George Seielstad

The reason we human beings have trouble grappling with some of the larger social issues may be that we restrict ourselves to personal observations of our own immediate surroundings. Sometimes, of course, we extend these through reading and travel, but we still risk thinking too small. I suggest that it is time to try to acquire a cosmic approach, perhaps by taking an imaginary journey outward from Earth until we locate our place in space.

If we begin our journey by looking at our home planet from one of the LANDSAT or EROS satellites that orbit the Earth at a distance of a few hundred miles, a lot of the problems that plague us become insignificant. For example, a boundary dispute with a neighbor has no meaning when we try to view our property from this height.

At a distance of a few thousand miles, there is no way to determine where one country ends and another begins, which makes geopolitical boundaries completely arbitrary — and hardly worth all the international acrimony they generate.

Finally, at a distance of 240,000 miles — on the Moon — we can look back to our lonely little planet suspended magically in the dark. From this vantage point, there are at least three things to note about Earth. The first is its great beauty. It is dazzling, jewel-like, and brilliant against the black, cold, empty backdrop of interplanetary space.

Second, seen from this distance Earth looks delicate, fragile, and vulnerable. It seems especially so when you consider that all life on Earth is confined to a thin membrane encasing the planet — a membrane of air and water about as thick in relative scale as the skin on an apple.

The third point to notice — and appreciation of this fact may be the most important contribution of the entire space program — is that from the Moon we can see our planet as a single unit. It is a whole. We are all members of one family traveling on Spaceship Earth.

Our Sun is so large that if we could hollow out its sphere we could put about a million Earths inside it

For man, whose height seldom exceeds 2 meters, this journey of 384 million meters represents the extreme limit of his physical travels. Yet it nowhere approaches the limit of his imaginary travels, and within a cosmic context the distance is minuscule. Our nearest stellar neighbor, the Sun, is almost 400 times as far from Earth as the Moon. It is the Sun's sheer bulk that binds us in an orderly path through the heavens. It is so large that if we could hollow out its sphere, we could put about a million Earths inside it. In addition, the massive outpouring of its energy makes possible our very existence.

Despite its supremely critical role for earthbound creatures, our Sun is actually only ordinary. In terms of mass, size, temperature, chemical composition, power output, or countless other stellar variables, it typically exhibits rather average values. Even the Sun's possession of planetary companions is quite probably just one more property that it shares with innumerable other stars.

Within the confines of our local stellar family — the Milky Way Galaxy — lie hundreds of billions of like bodies. Many of them are so large that millions of Earths could fit comfortably within their interiors; yet from another vantage point they are so small that tens of millions of them could be strung like beads along a chain between the two nearest neighbors.

To comprehend the scale of our disk-shaped home galaxy, we need a very large unit of length. If we adopt as a measure the nearly 30 million solar diameters that separate the Sun from its closest stellar companion, Alpha Centauri, we need more than 20,000 such intervals laid end to end to span the entire disk. Within this colossal ensemble, our not-so-mighty Sun has an inconspicuous galactic address. It is located in one of the outer spiral arms of the galaxy about ⅔ of the way from the center to the disk's outer edge, and it orbits about the center once each 250 million years.

It might be nice if we could feel that our galaxy is somehow special, but I don't think it is. The Milky Way is a member of a minor cluster of about 20 similar galaxies — called the Local Group — existing together in space. Other groups, some many times larger and more populous — and perhaps groups of groups — stretch on and on and on, reaching distances of at least 3,000 times the diameter of the Local Group.

If our place in space is nothing special, what about our moment in time? Here again we tend to distort reality by working from the inside out. Historically, man has always viewed the sky as eternal and immutable. In periods of rapid and often turbulent change, people have found comfort in the dependability of the heavens, with their rhythmic, cyclic events that repeat faithfully and precisely. But this is another example of measuring epochs against a human standard. Our puny 70-year lifespans, while relatively long for an animal species here on Earth, are hopelessly inadequate for gauging the flow of cosmic history. In reality, the whole history of the universe has been one of constant change; it is an evolving, dynamic system.

To the best of our present knowledge, the universe began with a bang less than 20 billion years ago, and it has been expanding ever since. That means that the energy in it is getting more and more dilute, which is another way of saying that the universe is always getting cooler. Even today, however, we can recognize a faint afterglow of the ferocious heat that must have existed at that moment when all matter and energy exploded from a single point in space. This remnant radiation, which is at a temperature of approximately 3 degrees centigrade above absolute zero, can be measured with our radio telescopes, and it is the same no matter what direction we point them. This discovery, incidentally, resulted in the award of the Nobel Prize in physics last October, and one of the recipients was Robert Wilson, an alumnus of Caltech (see page 26).

The original matter in the universe was almost entirely hydrogen, but under the incredible conditions of density and temperature that existed in the early minutes, about 10 percent of the hydrogen fused into helium. Then for the first several billion years, the universe was a gaseous "sea" of these two simplest chemical elements intermixed with gradually cooling radiation.

These particles of matter were probably never spread perfectly uniformly throughout the whole universe, and any fluctuations in density that exceeded the average tended to feed upon themselves, creating regions of still greater density. Every atom within such an anomaly felt the gravitational attraction of every companion atom, and atoms passing by were sucked in. Eventually the aggregation of atoms grew so massive and heavy that it collapsed, isolating itself against the dispersive effects of expansion. These gigantic collections, containing hundreds or thousands of billions times more atoms than are present in our Sun, became galaxies. The formation of each required perhaps a billion years and took place about 10 to 15 billion years ago.

The situation inside a condensing proto-galaxy resembled, on a sharply diminished scale, the processes occurring in the universe at large; that is, aggregates built up around random increases in atomic density. The resultant ensembles quickly (usually in millions or tens of millions of years) collapsed under their own weight into stars. Within a given galaxy, the process first began shortly after its formation, and in many galaxies it continues today. Thus the stellar population of the Milky Way includes senior citizens 13 billion years old, as well as prenatal stars struggling to be born — and all ages in between.

The process of gravitational collapse of a proto-stellar cloud is unlikely to be perfectly efficient; that is, all the matter within such a cloud is not going to form into stars. The leftover matter may itself almost simultaneously condense into planets, and the leftovers of that process may in turn become planetary satellites.

We believe this is how the Sun and its minor companions of the Solar System came into existence some 4½ billion years ago. The history of our home planet, it seems, occupies only about a quarter of all of cosmic history.

The process of star formation is a continuing one in a galaxy, taking place in dark, dusty clouds where the density is so great that the regions are opaque. As the density of matter in a collapsing cloud increases, so do its pressure and temperature. Collisions between atoms become more frequent and more violent. Eventually some of the hydrogen atoms, of which such a cloud is mostly composed, will collide so hard that they will stick together, fusing into the next lightest element, helium.

The history of our home planet occupies only about a quarter of the totality of cosmic history

Each quartet of hydrogen atoms that is forged in the process of nuclear fusion into a single helium atom weighs *in toto* more than the product it creates. The difference in mass never disappears; it is converted into a form of energy — electromagnetic radiation or, more simply, light. And that energy, created in the star's center and subsequently released from its surface into the surrounding space, provides sustenance for the chemical reactions that constitute the living process.

This is not the only debt that living systems owe to the stars, because living matter consists of more than hydrogen and helium. The richness and variety of living substances in our tiny fragment of the universe derive to a considerable extent from the sizable inventory of chemical elements with which our planet is endowed. And this is bequeathed to us by previous stellar generations in whose mighty furnaces the hydrogen fuel is eventually exhausted.

In the case of the Sun, about 660 million tons of hydrogen are consumed every second — a process that has been going on for 4½ billion years and that will continue for another 4 to 5 billion years before the hydrogen is depleted. Other stars, formed earlier and/or more consumptive of their primordial fuel, reached their demise long ago. When this happened, the balance between the inward crush of gravity and the outward flux of energy was destroyed. A series of internal convulsions followed, each raising the star's central temperature, pressure, and density until the ash of the preceding reaction could become the fusion fuel of the successor. Thus, inside some stars, helium was combined into carbon, carbon and helium into oxygen, carbon into magnesium, and oxygen into sulfur, and so on all the way up to the element iron.

The trouble with iron is that there is no way to fuse iron atoms into a unit that is lighter than the sum of the atoms of which it is made. So the star stops burning altogether, touching off a catastrophe. The core implodes violently, locking up some of its matter forever in exotically constituted stellar corpses. The star's outer layers are spewed into space, the expelling explosion also triggering some exotic nuclear reactions to produce elements heavier than iron. Future stars will therefore coalesce from a chemically enriched environment.

Thus stars are continually being born, living to advanced ages, and then dying. The net results of such cycles are to remove some matter from the pool future stellar generations must draw upon, while enhancing the chemical variety of the remainder. As time goes on, the chemical composition of the universe grows richer.

When these chemical elements are mixed for a long enough time in close proximity, the inevitable happens: They link together to form molecules. The next step up in the organizational structure of matter occurs. Radio astronomers are detecting in space a rapidly growing number of molecular species, more than 30 to date. Most of them are organic, which are the types peculiar to living organisms, and some are surprisingly complex — ethyl alcohol, for example, a compound of nine atoms. Equally remarkable is the ubiquity of these molecules. These crucial links of the chain that represents evolutionary life itself are scattered throughout the Milky Way and in other galaxies as well. In short, the raw materials from which living systems derive exist at a vast number of locations within the universe.

Of course, multi-atom molecules — even organic ones — are a very long way from being living systems. But we know that adding some energy to a broth of fairly simple molecules produces amino acids, life's fundamental building blocks. In one of the classic experiments, an electric spark discharged in a mixture of steam, ammonia, methane, and hydrogen sufficed. Presumably these ingredients — energy from a parent star and molecules inherited from earlier stellar generations — were present in Earth's primitive atmosphere some 4½ billion years ago. And there is no reason to suppose that these conditions were unique to our planet. Analyses of meteorites that come to Earth from distant reaches of the solar system reveal that amino acids have formed elsewhere as well.

How have we progressed from relatively short chains of amino acid molecules to the long, intricate spiral arrangements that constitute the essence of today's living systems? Slowly, to be sure. In fact, it has taken billions of years in the case of Earth, and it is doubtful that the process can be significantly speedier elsewhere. Although many details of the exact sequence by which life evolved here remain to be discovered, there is a growing conviction that living matter originated from the nonliving; that, having once done so, all life has sprung from other life; and that the process seems universal, given only some precursory molecules, an energy input, and ample time in a suitable environment.

I don't mean to suggest that other people — other humans exactly like ourselves — are scattered about the universe. Every living system interacts with the environment in which it lives. It draws energy and raw materials from the environment and returns different by-products to it. So the things that live within each environment depend on the nature of that environment, which depends in turn on what lives within it. This interdependence means that each such interacting biosystem will be unique.

We humans can therefore properly view ourselves as natural — or even inevitable — products of a cosmic evolutionary scheme that was set in motion nearly 20 billion years ago. Possibly we are members of a "family of living matter" that in richness and variety exceeds our wildest speculations. After all, we are limited by knowledge of only that tiny spectrum of life adapted to survival in one particular environment, the Earth's biosphere.

In this view, life is a continuum traceable to the beginning of all space and time at the Big Bang itself. While each of us, and all other individual living systems as well, lives only momentarily, a pattern and structure persists in our descendants. As individuals we are insignificant and momentary participants in a dynamic, evolving system that vastly transcends us; but as a species we are a necessary link between the cosmic past and all that is yet to come.

Among all the living organisms here on Earth, man does possess one unique ability. He can accumulate knowledge and transmit it to successive generations. Communication itself is not unique to man; whales and dolphins, for example, are masters of it. But man's ability to communicate across generations is unique; it is a function of his intelligence. Each generation of human beings starts from an informational base and adds to it. Like an inverted pyramid, the entire structure continues to expand. Consequently human society — linked together by an intricate communications network binding man not only to his contemporaries but also to his predecessors — has evolved more rapidly than has the human species itself. Together we can perform tasks of which no individual is capable.

Communication itself is not unique to man, but man's ability to communicate across generations is unique

Consider our ability to construct modern aircraft. Of the thousands of workers it takes to assemble an airplane, no one individual can claim he knows how to do all the tasks required. Nor can any one among the designers and planners successfully operate all the machinery involved in the aircraft's construction. Yet somehow an organizational structure — the modern aerospace corporation — has evolved, and it can produce an aircraft that flies.

Now, of course, bees can also jointly accomplish goals that are impossible for individual bees — building a hive, for example. But there is something chillingly 1984-ish about the activity of a bee, because he has no choice about what he will build or how it will be designed. He is preprogrammed to build a hive exactly like the hives of all generations of bees before him. Man, on the contrary, can alter his design at will, or choose not to build airplanes at all, or decide — perhaps using the same individuals — to build instead mass transit systems or grand pianos. And therein lies our unique potential for greatness — and for folly.

Again, let's not be parochial. Intelligence is so great an advantage in coping with an environment that it may be developed in every biosystem blessed with sufficient evolutionary time to acquire it. All living things are wholly dependent upon their surroundings, so they will have powerful incentives to acquire sensory apparatus for mapping out those surroundings. Then they will need some greater capacity for processing the flood of incoming sensory data, plus a memory bank to store possible reactions to the different sensations, and a decision-making capacity for selecting among these possible reactions. May we not at least speculate that this sequence leads toward intelligence, and that it has a certain inevitability wherever evolving living systems interact with a changing environment?

This view of the entire universe from the outside in has revealed abundant, widely distributed supplies of the raw materials of which living matter consists. Likewise omnipresent, we believe, are sites suitable for harboring and nurturing these "seeds" of life. Wherever the seeds take root, they most likely will grow steadily toward higher levels of complexity and greater intelligence. Ultimately, if there is time, species will evolve whose intelligence will permit an expanding knowledge of their surroundings. With that knowledge will come power.

In this progression, there are certain thresholds, some of them critical. In every such "biocivilization" the dominant species may eventually acquire enough potential power to modify the entire biosystem. At this critical juncture, that species either learns to channel its power to useful purposes, or it self-destructs — and retrogresses drastically in an evolutionary sense.

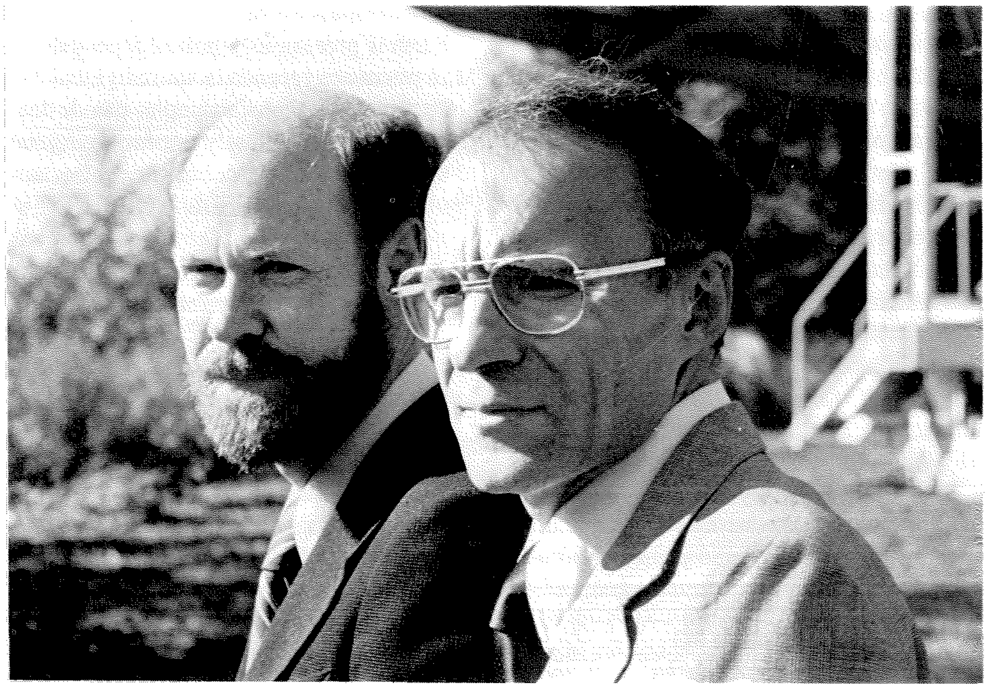
Earth is precariously poised at exactly this point today. Man possesses recently acquired global capabilities. His collective arsenal, for example, can destroy all life on the planet. His exponentially mushrooming numbers threaten to overburden the entire biosphere. Because of his insatiable appetite for material resources, he may irreparably scar the Earth's surface and then flood it with unwanted debris. He can alter the global climate or poison its entire air and water supply.

Does the long evolutionary thread leading to our existence end here and now on this one small planet?

These global powers have multiplied so rapidly that man's social, cultural, economic, and political systems have not kept pace. In just 100 years the rate of communicating messages has accelerated from the speed of the Pony Express to the speed of light. Military encounters have changed from cavalry charges to nuclear holocausts. Agriculture has shifted from using beasts of burden to air-conditioned tractors. Organizationally, the family farm has largely given way to the corporate enterprise.

It is hard to conceptualize this astonishing rate of change, but it may help to imagine Earth's entire history condensed into a single year ending just now. In those terms, man's earliest, most primitive ancestors appeared only 8 hours ago. Fire was unknown until just the last hour, and art — cave paintings, stone engravings, and the like — began within the last 5 minutes. The Christian era has been with us for a mere 14 seconds; the Industrial Revolution for just 2. The last 100 years occupy ⅔ of a second on this scale. But in that fleeting interval — two-millionths of one percent of Earth's history — man's population has doubled and then redoubled.

Surely we have come to a fork in the road. Can we accelerate our social adjustments to this pace, learn to channel our awesome global powers to useful purposes? Or does the long, long evolutionary thread leading to our existence end here and now on this one small planet? It is possible that the seeds of higher systems are scattered in great abundance throughout the universe, but it is likely that very few will survive to become mature biocivilizations. Ours could be one of the lucky ones. It's up to this generation on this planet to make the choice. □



Caltech alumnus Robert W. Wilson and his colleague Arno A. Penzias shared half of the 1978 Nobel Prize in physics for their discovery of cosmic background radiation.

Robert Wilson

Nobel Laureate

For the last 18 billion years — give or take a few billion — our universe has been flying apart as the result of the cataclysmic explosion astronomers call the "big bang." In the course of expansion and cooling over the aeons since, the flash of radiation from that explosion has become more and more dilute. It now permeates the whole universe and has a temperature of approximately 3 degrees K. Discovering that radiation and recognizing its source earned the 1978 Nobel Prize in physics for Arno A. Penzias and Caltech alumnus Robert W. Wilson. This is the 18th Nobel Prize awarded to a Caltech faculty member or alumnus, and the first in an area of astronomy.

Penzias and Wilson made their discovery while working at Bell Telephone Laboratories. In 1963 and 1964 they were using for radio astronomical observations a 20-foot horn antenna located in Holmdel, New Jersey. The antenna had been built for receiving Telstar satellite signals with a minimum of noise interference. The less noise, the clearer the satellite voice and pictures would be. This receiving system, which used a maser cooled by liquid helium as an amplifier, had very low noise. But regardless of the direction in which they pointed the antenna, they received a low, steady hissing. Was this noise really from the sky, or was it generated in their receiver? Penzias and Wilson decided to make an all-out search for the source and, if it was in the antenna, to try to eliminate it.

First they measured the noisiness of the maser very precisely, using as a calibration standard a resistor immersed in liquid helium. They also evicted a pair of pigeons that had built a nest in the horn. Wilson climbed inside the horn and masked all the rivets and joints with metallic tape. All this effort reduced the noise only slightly — perhaps half a degree — and they were forced to conclude that though the hiss was real they couldn't explain it. It was, said Penzias later, like "cigar smoke in a room where there is no cigar."

At this point, chance stepped in. In the course of a casual conversation Penzias learned of the existence of an unpublished paper reporting on some research at Princeton. A group at that university, trying to detect evidence of the big bang, had determined that such an explosion ought to have left a detectable remnant in the form of microwave radiation (which it is convenient to characterize by its temperature) that would uniformly permeate space. Further, some 18 billion years afterwards, the radiation temperature should be about 3.5 degrees Kelvin. With this theoretical explanation, Wilson and Penzias at last realized that the noise they were hearing was the residual evidence of the primordial fireball — an echo of creation.

Penzias and Wilson announced their discovery in a letter to the *Astrophysical Journal* in the spring of 1965, in which they described their measurement of excess antenna temperature. In the same issue, the Princeton group — Robert Dicke, P. G. Roll, David Wilkinson, and James Peebles — provided the cosmological explanation for the excess. (It also turned out that in the late 1940's George Gamow and his co-workers Alpher and Hermann had predicted radio noise as a result of the big bang.) Describing the importance of the discovery 13 years later, the Royal Swedish Academy of Sciences said, "This has made it possible to obtain information about cosmic processes that took place a very long time ago, at the time of the creation of the universe. The work has opened up a whole new horizon in cosmology. It gives us an absolute system of measuring movements of the earth and other heavenly bodies."

Subsequent studies of the microwave background radiation have shown that it fits very well the theoretical spectrum of a black body at a temperature of about 2.9 K. The radiation is very uniform; that is, small-scale variations in the temperature are less than a few milliKelvin, while a small difference (of $\pm$ 0.0035 K) in temperature in opposite directions in the sky is interpreted as evidence that the Sun is moving at a velocity of about 390 km/sec with respect to the radiation field.

Alumnus Robert Wilson lives in Holmdel with his wife, two sons, and a daughter. A native of Houston, Texas, he is at 42 the youngest of this year's Nobel Prize winners. He graduated from Rice University in 1957 with honors in physics and received his PhD from Caltech in 1962 for research in radio astronomy. After spending a postdoctoral year at the Owens Valley Radio Observatory, he went to Bell Labs in 1963. He is now head of Bell's Radio Physics Research Department, and he also does research in radio astronomy, being particularly interested in investigation of dark clouds in the galaxy through measurements on molecules. He is a member of a number of professional astrophysical societies.

Outside astrophysics, the only hobbies Wilson claims are "pecking at the piano" and ice skating. That's probably plenty for a man who says, "Science is my life, and I'm very deeply involved in my work. Otherwise, I'm a rather quiet fellow." Quiet enough, as a matter of fact, to have heard an 18-billion-year-old echo. □

The Nobel Prize ceremonies in Stockholm last December gave Penzias and Wilson a special occasion to wear white ties, tailcoats, and broad smiles — and to congratulate each other on the rewarding outcome of their collaboration.

Oral History

Henry Borsook–

How It Was

The Institute Archives, borrowing a page from Herodotus, has now initiated an oral history program. The staff, under the direction of Judith Goodstein, began by inviting a number of emeritus professors to share their memories with them. Recollections of childhood, anecdotes about others, and memories of the Caltech that once was are the stuff out of which these oral histories come.

An oral history, however, is made up of more than memories. It takes the diverse skills of the researcher, interviewer, transcriber, editor, and typist to produce an edited, indexed, and bound transcript from the interviews. The two people, interviewer and subject, typically spend three or four sessions, each an hour or so in length, talking to each other. Once transcribed, the manuscript is read and edited by both people; the subject signs an agreement regarding its use; and the transcript is then deposited in the archives.

One of the first completed accounts in this program is from Henry Borsook, professor of biochemistry emeritus, who was interviewed by Mary Terrall. Borsook, noted for his work in protein synthesis and for his contributions to the field of nutrition, was born in London, England, in 1897, and came to Caltech in 1929. After his retirement from Caltech in 1968, he continued his research until 1978 at the University of California at Berkeley on the function and production of red blood cells. The Borsooks are now living in Santa Barbara.

E&S *has made a shortened version of the original transcript and presents here Part One (of two parts).*

Mary Terrall: I'd like to start with your childhood and educational background. I know you were born in London. What did your parents do there?

Henry Borsook: My father was a tailor. My mother was a housewife. My father was born in Russia. My mother was born in Romania. They emigrated to Canada in either 1906 or 1907 and, of course, I went with them. So my early schooling was in London and in those days you went to school at the age of three and it wasn't a kindergarten. You started right off learning to read and do arithmetic and such things. So when I went to school in Toronto, Canada, I was a year ahead of the other children as far as schooling was concerned. But otherwise I had all my schooling in Toronto. Public school, high school, university, medical school.

MT: When did you first get interested in science?

HB: Well, even as a child I had intended to become a doctor. And so I first went to the university. The course I took first was in physiology and biochemistry, which was really a kind of premed course. It was then that I became interested in science and specifically in biochemistry. If you ask me why, I can't tell you. It was just one of those things. So I stayed in the department of biochemistry and took my PhD there. But I went on to the medical school afterwards to get a medical degree as a grubstake. That is, I wasn't sure that I could make a living in academic work, but as a doctor, well, the chances were I could. And so after I graduated in medicine, I rejoined the department of biochemistry at Toronto for one year. The man I worked with for my PhD was a friend of Dr. Thomas Hunt Morgan in New York, and when he learned that Dr. Morgan was going out to Caltech to start a division of biology there, he wrote him about me, and Dr. Morgan offered me a job.

MT: What were you working on in those days?

HB: Well, for my PhD I worked on the synthesis of protein. It was a subject that had always interested me, and in my last 15 years at Caltech I took it up again. When isotopes became available, it began to be really possible to study the synthesis of protein, which it really wasn't before. For my PhD I was working under difficulties; the system I studied was, as we now realize, an artificial system. It wasn't really one that normally operates in animals, plants, or bacteria.

MT: Were there many people back then working on this system?

HB: No, I was all alone in that field until isotopes became available.

MT: What did you know of Caltech?

HB: Nothing, except that it was a famous place for physics because Millikan was a famous man.

MT: Was Morgan personally interested in biochemistry?

HB: No, and apropos of that I think I might tell you a story. When Einstein came to Caltech, in 1931 or 1932, everybody wanted to meet him. But Morgan was a reticent person and didn't seek out people. So Einstein came to see Morgan, and they spent most of an afternoon together. After Einstein left, Morgan felt he had to talk to somebody about it so he came in and talked to me. The first thing Einstein said to him (and this is in answer to your question) was, "What in hell are you doing in a place like this?" And Morgan said, "Well, my belief is that the future of biology rests in the application of the methods and ideas of physics, chemistry, and mathematics." And Einstein shook his head and said, "No, that trick won't work. Look, even in physics we can handle only the very simplest molecules — hydrogen and helium and a few others. We can't do anything about organic chemistry. Do you really think you will ever be able to explain in terms of chemistry or physics so important a biological phenomenon as first love?" So I said to Morgan, "Well, what did you say to that one?" and he said, "Well, I tried to explain something about the connection between sense organs and the brain and hormones." And I said, "You didn't believe that yourself, did you?" And he said, "No, but I had to say something to him."

Morgan was like that. He was a witty person and he could pick up like that, quickly.

MT: You were the only biochemist?

HB: I was the only biochemist. Of course, he brought with him, as you know, his whole genetics group. But he felt that he had to have biochemistry, animal physiology, plant physiology, experimental embryology, and that's why he got me.

MT: Were there plans to expand the biochemistry?

HB: No, there were no plans to expand anything in biology. As budgets go, it was relatively small. It was nothing compared to physics or chemistry, for example. You see, the budget in those days was $75,000 a year. And so you can see how much would be spent on all the others. No. Morgan thought that was enough and, of course, time would tell.

MT: How closely did he follow the work that was being done by these different people?

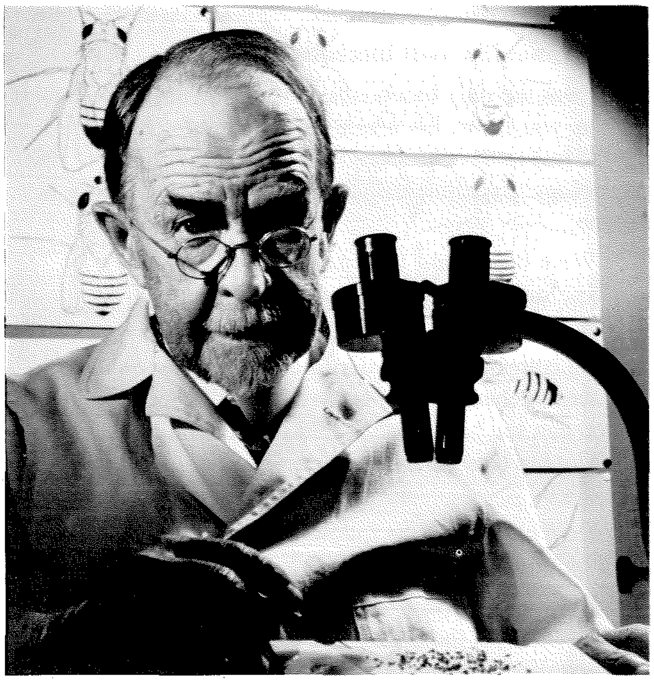
HB: He couldn't. He didn't have the background. Morgan really — he was the greatest biologist of his time and it's an interesting commentary that he knew very little chemistry, he knew very little physics, and he could only do the simplest statistics that he needed for genetics. I got to know him very well. We lived one block apart and I used to drop in often. I said to him once, "Look, why don't you take one of these Caltech graduates who are well schooled in physics, chemistry, and mathematics, to work with you for a year. They could do all these things that are hard for you to do, and it would be a wonderful experience for them." And he said, "No, my work isn't important enough." So he never did accept a graduate student. People would come to Caltech to do genetics, and they'd go to the other geneticists — Sturtevant or Emerson or Bridges or Schultz. But Morgan wouldn't have them with him.

Of course he could follow the genetics. But he couldn't really follow, except in its larger outlines, what the others of us — like in plant physiology, or I, or in animal physiology — were doing. But he was an extraordinarily intelligent person and even if he didn't know the details, he had a very sound judgment in the main about how valuable the work was. He made very few mistakes on that score. He was really a wise person.

MT: I guess part of what you're saying is that he was relatively old by the time he came to Caltech, and he had already done his major work.

HB: Well, Morgan's major work had been done between the years of 1911 and 1921. Before then he was doing experimental biology; that is, really, developmental biology.

Henry Borsook



Thomas Hunt Morgan

Actually he was the first professor of experimental biology in the world. No one had been appointed to such a position before. And then after 1921, as he told me, he had become bored with genetics. He said it was just algebra problems, so he went back to working on what he had worked on originally. He knew very well that it wasn't any way nearly as important, but that's what he was interested in and what he was going to do. So, let's see, how old was Morgan? Morgan came to Caltech in 1928.

MT: I think he was 62.

HB: Yes, and he died in 1946, when he was 81 or 82. Yes, so Morgan continued to work. He used to go every weekend to the marine biological lab at Corona del Mar and he worked during the week. He and I taught the first general course in biology to all students of science — it was a required course for all sophomores regardless of what science they were going to major in. He gave the first ten classes, and I took the rest. That pattern went on until 1935 when we thought it would be time to change and get somebody else.

MT: Was he a popular teacher?

'B: I don't know. I can't recall now any comment. But he s such an interesting and commanding person. And of se they knew he was a great biologist, and that's all as necessary. What made it particularly interesting is that Morgan's own career spanned the development of biology from Darwin to experimental biology, and he lived through that whole time as well as living through the time of the rediscovery of Mendel's work. I don't know whether someone has already told you this but Morgan, after he had a job at Bryn Mawr, used to go every summer to the marine biological station at Naples to carry on his own research. The teaching load at Bryn Mawr was too heavy to do much work there. At the end of the summer, first he would spend a week in Siena, and then he went to a friend, an amateur biologist in Basel who kept all the current journals in biology. And that's how Morgan caught up with what was going on, because at Bryn Mawr biology was a relatively backward subject. It was there that he learned about the rediscovery of Mendel, and this is how his interest in genetics was first aroused. But he didn't work at it until about 1911 and then he worked at it very hard, with Bridges and Sturtevant especially and with Muller, a pupil of his at that time. That's when the great development in modern genetics occurred — until recent times, with the relation of genetics to DNA and all of that, which Morgan didn't understand and had nothing to do with.

MT: Morgan was also on Caltech's Executive Council.

HB: Yes — right from the time he came. Naturally, I know nothing about that, but it was one of the remarkable features of Caltech that it was run with almost no administration. If anybody on the executive council wanted any information, he would never think of going through channels, but just call up the person who had the information. He could be a graduate student or a professor, and you would go over and talk to him. And that's the way Morgan was in relation to the administration of the biology division. I'm sure that his contributions to the proceedings of the Executive Council were important because he was such a wise person. He had such good sense, and he was quick to understand even things that he wasn't really schooled in, and I think they appreciated that.

MT: Was he easy to get along with personally?

HB: Yes, oh yes! But if you put on any dog or any pretense, he was very quick to puncture it, and sometimes he would do it anyhow. And this is where Millikan found it difficult to understand Morgan because Morgan was such a tease. Let me give you two stories about the relationship between Morgan and Millikan. At the time when the biology division was founded, Millikan had been writing a number of articles in the *Atlantic Monthly* on the relation of science to religion, and Millikan was making the point that there was no necessary conflict. In those days at Caltech there was a Friday morning assembly where all the undergraduates came and different people talked to them. One morning Morgan talked to them about biology as a career. He started out by saying, "Well, there's this kind of a job that you might be qualified for and so on, but that is of secondary importance in your taking a course in biology. The important thing when you take a course in biology is that you will lose a lot of superstitions." Millikan was sitting right in the front row, and Morgan said, "One of the superstitions that you will lose is that there is no conflict between science and religion." Everybody appreciated what was going on.

Another time the National Academy of Sciences was meeting in Pasadena. Morgan at that time was president of the National Academy and so he was presiding and papers were being presented in chemistry and biology. And he said, "Now I'm going to turn the chair over to Dr. Millikan because the next group of papers," and then he looked at Millikan and said, "are on celestial rays — and Millikan is a lot nearer to heaven than I am."

I like to talk about Morgan. He was a really important person — and a humble person. To finish this off, this side of Morgan, I had a book on vitamins published by the Viking Press *(Vitamins: What They Are and What They Will Do For You*. New York: The Viking Press, 1940). The president of Viking, Ben Huebsch, was coming out to see Upton Sinclair. (They published Upton Sinclair.) So we asked him to come to dinner, just himself. And I surmised that Ben Huebsch and the Morgans must have had a number of mutual friends in New York, so I thought it might be pleasant, and I called the Morgans up and said Huebsch was here and wouldn't they come up. So they came, and it developed that they did have a number of mutual friends, and they had a very good time together. Then the Morgans left, and Huebsch said to me, "We would like to publish Dr. Morgan's memoirs, so will you put this proposal to him? Let him choose a secretary and she could come and he could talk and she would type it up. He could check it over and have the secretary send us the bill, to make it as little bother as possible." I said I would, but I thought I had better speak to Mrs. Morgan first. And Mrs. Morgan shook her head. She said, "He won't do it, but I'll tell him anyhow." So a few days later we met in the corridor. (She was still working in genetics herself then.) And she saw me and she shook her head, no.

Well, Morgan was already getting on by then, and since I had medical training and I was a friend, I used to come in when he was ill to see what was up and what I could do. So I was with him in the hospital in his last illness. He sensed this was the end for him, but he was a brave man, and he was witty even though he knew he was dying. He said to me (by then, he called me by my first name, but I always called him Dr. Morgan; I couldn't do otherwise), and he said, "Henry, you get yourself a good secretary and you write my biography, but you must make me a promise that it won't be published for a hundred years."

And that was the only remark that he had ever made about the offer of Mr. Huebsch.

MT: What about the other geneticists, the younger people who had come with Morgan?

HB: The two principal ones were Sturtevant and Bridges and they were distinguished geneticsts in their own right. By the time they came to Caltech, they were working independently. Morgan wasn't working in genetics any more, but Morgan felt that he should continue the genetics group. A younger man who came along with them was Jack Schultz, and he also brought along Albert Tyler whose field was, like Morgan's, experimental embryology on invertebrate forms. Tyler kept on working on that but independently of Morgan. Morgan wouldn't work with anybody else and, of course, from the very beginning he insisted that Mrs. Morgan should work independently and not with him. She had learned genetics from him, but after that she worked by herself, and published by herself.

MT: Did the group of you have discussions about the direction the biology division should go in? Was there any discussion about changes?

HB: Each of us did what he liked, but we had certain teaching responsibilities. The geneticists divided up the genetics, I taught biochemistry, Wiersma and Van Harreveld taught animal physiology, Went taught plant physiology. That's the way it went, but that's all. And our staff meetings consisted really only of the approval of applications for graduate students. We all went over them, and we all had a say in who was chosen and who not, as well as new appointments.

MT: What about contact with faculty in other divisions?

HB: Oh well, that was one of the great features of Caltech when I first came. See, it was a community, and everybody knew everybody else. In those days we often had lunch together in what was called the Greasy Spoon before the Athenaeum was built. One of the things that struck me was that everybody was really intelligent, quite apart from their professional competence, with wide-ranging interests in other people's work and in politics or literature and in art. The chairman of the humanities division, Clinton Judy, who was very good, used to run once a month in his house a seminar open to everybody. Everybody took turns at giving a review of a book or an author, and there would be active discussion and so on, which is indicative of the smallness of the place and of the wide-ranging interests of everybody.

You probably have heard this story, but it's worth retelling. As an example, again, of the mutual interest in what everybody else was doing, Charlie Lauritsen had just finished building the first of what we used to call "the million volt X-ray tube," the high voltage X-ray tube. And that morning there had been a piece in the *Los Angeles Times* that Joliot in Paris had created artificial radioactivity. So we were talking about that at lunchtime and around the luncheon table a long telegram was drafted to be sent by Charlie to Joliot asking for more details, and the next day Joliot's reply came. That was discussed, and then that afternoon Lauritsen went and did an experiment to check up on Joliot. That's the kind of place Caltech was in those days. And although we all respected each other, there was no deference. Millikan was there, and if he'd get into an argument, he had to take his chances like anybody else, and it was the same all the way through. And Millikan often came. You sat down wherever you could. Of course when the Athenaeum came, with separate small tables, that relation was broken. It was really better in the old Greasy Spoon with a long table where you just sat down.

About the only administration that we knew was Ned Barrett, who was the comptroller, and he would come too and we all knew him. The administration was there to do things for us but one didn't sense it was administration. And this was one of the wonderful things about Caltech, this closely knit community — faculty, Executive Council, Board of Trustees. We all trusted each other and knew each other, and it went very harmoniously.

MT: Was there a reaction to having biology at the Institute as a new division?

HB: The reaction was that they were interested, and they wanted to know what it was about. They could easily understand. You see these people were interested in lots of things. They were interested in understanding, and sometimes they would drop in and talk to one another. We were friends, you see. They'd keep asking "why?" I must tell you in this connection — and it's indicative of the relation — about our daughter when she was very small. I used to walk to school with her, and like all young children she would always be asking questions. One day she said, "What does Mr. Millikan do?" So I said, "He's a physicist." And she said, "What's physics?" I began to talk about the relation between energy and matter, and she became impatient and she said, "Is it asking 'how' and 'what' and 'why' back and back and back?" And I said, "Yes. That's a good answer to all science."

MT: Can you tell me something about Morgan's style?

HB: Morgan was the first non-medical person to get the Nobel Prize in medicine. I happened to drop in one Sunday at Corona del Mar and watched him working. He was working on a certain invertebrate that produces both eggs and sperm and yet they could not fertilize themselves; the sperm of one animal could only fertilize the egg of another. He had found out that if he suspended the eggs in an acid solution, it would break down their resistance to self-fertilization. He told me the acid did not always work. And how was he making the acid solution? He had an eye dropper and a dish of seawater, and he would drop a certain number of drops from the eye dropper into this dish of sea water. So I said, "Well no wonder it doesn't always work." I didn't say anything but went back to the lab and made him a set of standards, so he could measure the acidity colorimetrically. I brought the whole set to him, and he said, "Goodness gracious! Nobody has ever done this to me before in my whole life." I thought he might be offended, because I was interfering in his affairs, so I said, "Well, really, Dr. Morgan, you know yourself you were getting variable responses, and that's the reason, but if you will use this, then you will know." And then the following week he came down — my lab was in the basement then — and he said, "If you will promise me that it won't interfere at all with your work, I would like another set of those standards."

MT: He didn't want to impose on you.

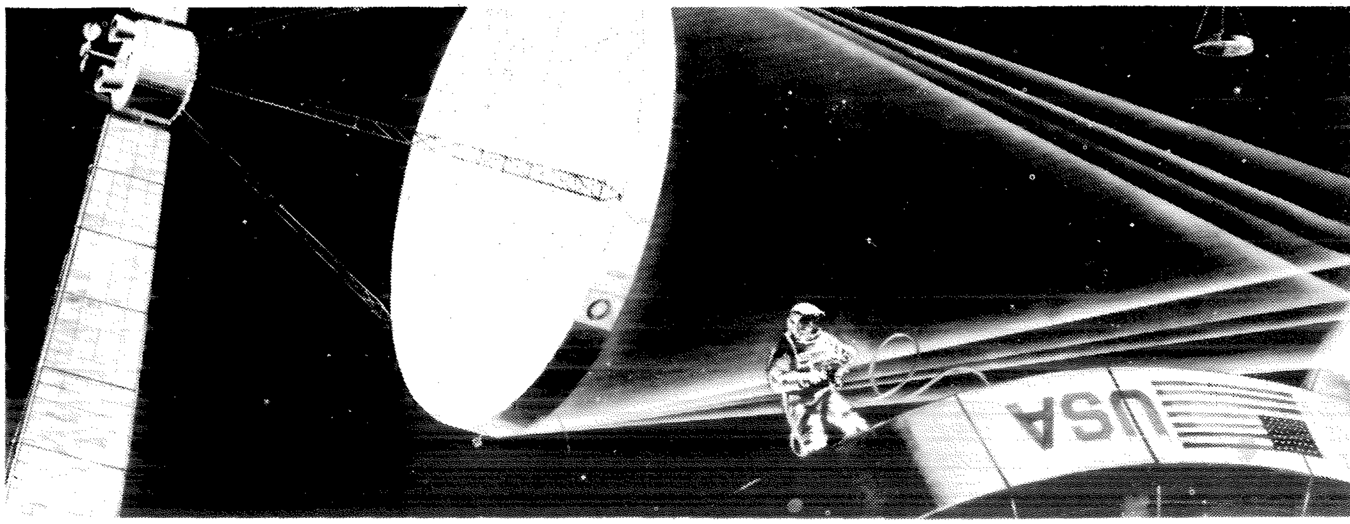
HB: Of course. He was most diffident about that. And that was when I asked him why didn't he take one of our young graduates and, of course, what I did would be nothing for them. But he wouldn't do it. But children often would come into the lab — his door was always open. Of course, they would come in and want to know what he was doing, and he would lift them up on his lap and have them look through the microscope and show them. He was wonderful with children.

MT: What about Millikan? Was he interested particularly in biology?

HB: No. When I first came, of course, I was introduced to him and he said he thought physics was finished and that the future of science was going to be in biology. He wasn't interested in the details of what anyone was doing except as, shall we say, a statesman of science. That was his interest in biology. Of course he was wrong, but so was many another. They couldn't see the future of things.

MT: When you came to the Institute in 1929, what were you working on?

continued on page 34



The Aerospace Corporation has defined advanced space concepts which are being used by the nation's space planners in considering uses of space to the year 2000.

Henry Borsook . . . continued from page 32

HB: I felt I had to leave behind what I was doing in Toronto and knowing how strong the Institute was in chemistry and physics, I began to teach myself the kind of chemistry that the undergraduates were getting. They knew much more chemistry than I did, especially physical chemistry. I was interested especially in thermodynamics, and they were very strong in that. And I began to apply thermodynamics to biological phenomena, which turned out to be very interesting.

Before then, the concept of an animal organism was that it was like an engine; it burned the fuel that you poured into it, and there was only a minimal amount of wear and tear. But by using thermodynamic data, I was able to show first that this wasn't so — that even the waste products, which you would think would just be degradation products, weren't that at all. They were synthetic products. There was urea, the chief waste product of nitrogen, that took a good deal of energy to build up. Before then it was taught that when protein was broken down to amino acids — there are 21 amino acids — then when they built up, the reaction was reversed. Well, I was able to show from thermodynamic data that this was impossible. It was too far uphill. To rebuild them into protein you had to put energy into the system. You had to couple an energy-donating system, like burning sugar or something like that, with the synthetic apparatus; and it was entirely different from the breakdown process.

Now the important thing about this was that it removed from physiological thinking what we call teleology. The organism was not a machine, and we were able to show that 55 percent of the urea that was daily excreted came from the breakdown of one's own tissue protein. So proteins were continually breaking down and continually being rebuilt, and this was a much more biological concept.

MT: When you were doing this work — applying thermodynamics to biology — was this being done also at other places?

HB: No, I was the only person doing it. It's not a virtue, but if anybody began to work in something I was working at, I would drop it and turn to something else. The big advances in all science are made in the fashionable branches because lots of people are working at it, but I couldn't do that. I have to do my own things in my way. Maybe it was an amateur's way of looking at science rather than a professional's, but that's the way I was.

This thing that I did — using thermodynamics and certain experimental devices was in 1932-1933, published in 1933. I had no isotopes then, and it was only in 1939, when isotopes became available, that my idea was proved.

MT: What kind of contact did you have with other people working in biochemistry around the country? Did you travel to meetings?

HB: Yes, but it was only afterwards that I realized that to be financially able to travel to meetings I, like all the other people at Caltech, owed it to Millikan. You know about that, that all of the fees he got for lectures was our travel fund. We didn't know that.

MT: What about funding when you first came?

HB: It just came out of the Institute budget.

MT: It was just for your salary?

HB: My salary and whatever expenses the work called for. There was no funding at all. It was only after the war that government funding came into it.

MT: So you didn't do any application for outside funds before the war?

HB: No, that was discouraged at Caltech. And I must say we didn't feel the need of it. If we needed equipment, we built it instead of buying it.

MT: What about salaries for, say, research staff, lab assistants?

HB: Salaries were low. I had one assistant and a couple of graduate students. The graduate students worked on their own, and it was understood that I would not put my name on any piece of work done by a graduate student, even though I may have told him what to do and guided him. That is, whatever I put my name to I had done the work myself. I don't think I was alone in this respect, in the biology division at any rate. I don't know about the other places. But I never felt the lack of money. I may have felt the lack of ideas, but not of money.

MT: I know that some private foundations gave Caltech money before the war, like the Rockefeller Foundation.

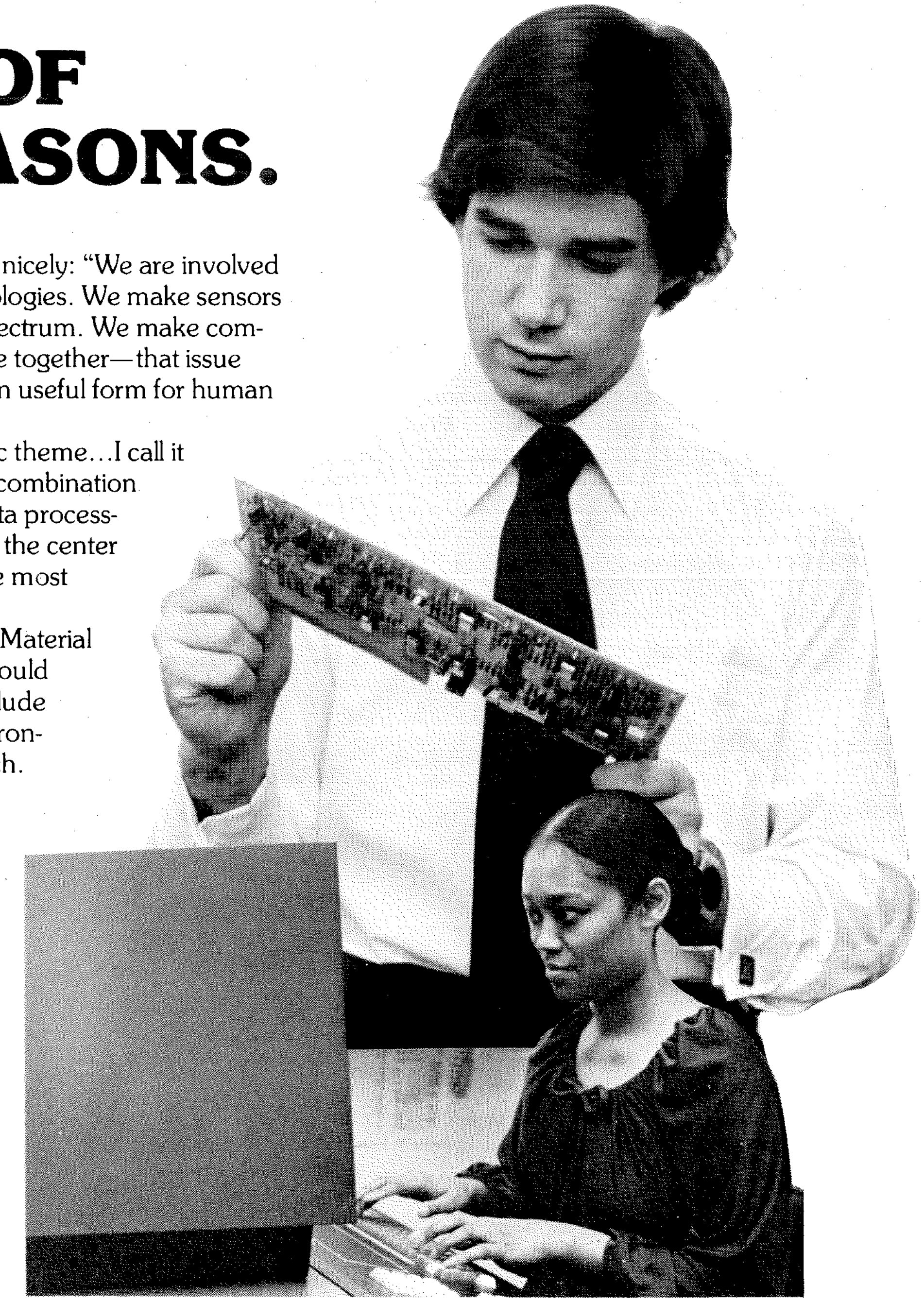
HB: Well, they were famous people and we weren't. And I think biological research, biochemical research, wasn't in those days the kind of thing that attracted money. I didn't really need it. Teaching wasn't heavy. I just taught for one term, and there was a seminar, of course. And so with one assistant — and I had a very good assistant, Jacob Dubnoff, for about ten years — we could do all that we wanted to do. Everybody else was working by himself — even Morgan was doing his own work and washing his own dishes, let alone the other people. So this was the style of the place. □

Part Two of Dr. Borsook's recollections of his years at Caltech will appear in our next issue.


We want men and women
with engineering
or other technical degrees
for careers in research.
Let's talk about it.
BETHLEHEM STEEL
an equal opportunity employer
The Loop's the way

MANY PEOPLE THINK VERY HIGHLY OF US.

FOR A LOT OF WRONG REASONS.



Our president, Allen E. Puckett, sums it up nicely: "We are involved in a wide variety of communications technologies. We make sensors that operate on all parts of the electronic spectrum. We make computers and signal processors that tie all these together—that issue commands, or that store and present data in useful form for human beings like you and me.

"There is another, even more dramatic theme...I call it the electronic information explosion. It is a combination of...data sensing, communications, and data processing and storage...We in Hughes are right in the center of this explosion...a vital factor in one of the most exciting periods in human history."

If you're an EE, ME, AE, IE, Physics, Material Science or Computer Science major, you could become part of all this. Areas of interest include aerospace, ground systems, industrial electronics, space and communications and research. But don't worry about getting lost; we work in small groups where individual initiative is valued highly.

Contact your placement office. Or, write to: Manager, College Relations, Hughes Aircraft Company, P.O. Box 90515, Bldg. 100/445, Los Angeles, CA 90009.

HUGHES

Creating a new world with electronics

An equal opportunity employer, M/F/HC

U.S. Citizenship required.

We're looking for engineers who can't wait to get to work.

We're looking for people who are looking for a real job. One that offers challenging work. Responsible work.

That's what you can expect at General Electric.

At GE, you'll be handed important assignments right from the start. You can do as much of the job as you're capable of doing. If you need help, it's there. If not, nobody butts in.

Here's the kind of thing we're talking about; some recent examples of jobs handled by new GE engineers:

1. *Charles P.* Aerospace systems manufacturing. Develop and document a direct numerical control system.
2. *Steve O.* Design engineering. Design test equipment for attitude control system of new communications satellite.
3. *Norma L.* Steam-turbine manufacturing. Investigate, analyze and obtain funds for solution of shop problems.
4. *Stephanie B.* Medical systems service engineering. Installation and test of new hospital radiographic and fluoroscopic x-ray system.
5. *Mel D.* Field engineering. Appraisal load testing of low and medium-voltage switchgear and power transformers for utility and industrial applications.

There's a good reason GE hands people like that – like you – real work assignments. It's the best way to develop the skills you will need throughout your career. You develop initiative and creativity. And responsibility. And GE also knows there's little to match the glow you feel when you make an important contribution.

You can make your contribution in just about any field of engineering at GE. We're that diversified in disciplines.

If you like the kind of challenge and responsibility that GE offers, we'd like to hear from you. Send for our free careers booklet. Just write:
General Electric, Educational Communications, WID, Fairfield, Connecticut 06431.

Progress for People

GENERAL ELECTRIC

An Equal Opportunity Employer