Engineering & Science

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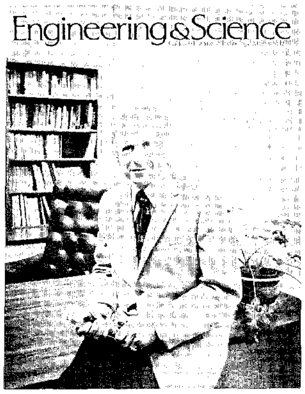
In This Issue



A New President

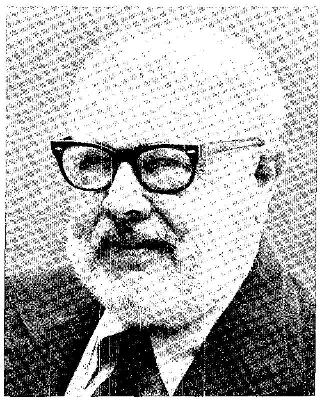
On the cover—Marvin L. Goldberger, Joseph Henry Professor of Physics at Princeton University. On July 1 he will become President of Caltech. On page 11, an introduction to the new president and his wife. Though they came to the campus to meet the faculty at a reception on May 8, they will not take up permanent residence in the President's house until July 1. Dr. Goldberger's formal inauguration takes place on October 27.

Sherlock Fowler

Playing detective is the name of the game in scientific research, and William A. Fowler, Institute Professor of Physics, is a real pro at it. He is also effective at describing for the layman what's going on. So when he recently gave a Watson Lecture on the discrepancy between theory about and observation of solar neutrinos, we had the talk transcribed. With minor editing, it appears on page 4 as "The Case of the Missing Solar Neutrinos."

Neutrinos have not been the only subjects of Fowler's investigations in the course of a distinguished career. He has done research on nuclear forces and reaction rates, nuclear spectroscopy, the structure of light nuclei, thermonuclear sources of stellar energy, the synthesis of chemical elements in stars, and general relativistic effects in quasar and pulsar models.

All this started professionally when Fowler received his PhD from Caltech in 1936. He joined the faculty that same year and became Institute Professor in 1970. Most recently the Royal Astronomical Society honored Fowler with its prestigious Eddington Medal. He has also received the Vetlesen Prize from Columbia University, the Tom W. Bonner Prize of the American Physical Society, the Medal for Merit from President Truman, and the National Medal of Science from President Ford. He is a member of the National Academy of Sciences, and in 1976 he served as president of the American Physical Society.



Fowler

Prescription for the Future

David A. Hamburg, MD, is a psychiatrist, whose main research interests are in coping and adaptation; behavioral,

Hamburg

endocrine, and genetic aspects of stress; and the biological basis and development of aggressive behavior. He is currently president of the National Academy of Sciences' Institute of Medicine. He is also Reed-Hodgson Professor of Human Biology and professor of psychiatry of the Stanford University School of Medicine, a position he has held since 1972. For 11 years before that he was chairman of the department of psychiatry, coming to Stanford's Medical School from the National Institutes of Health where he was chief of the adult psychiatry branch. And he spent the year 1974-75 at Caltech as a Sherman Fairchild Distinguished Scholar.

When The Next Eighty Years conference was held at Caltech last year, the speaker for the dinner meeting was Hamburg. He took the opportunity to take a wide-ranging look at the medical possibilities and problems ahead, particularly in the light of what has been accomplished in the developed countries in the last 100 years or so. "Health in the Decades Ahead" on page 14 was adapted from that speech by Hamburg and Sarah Spaght Brown, MPH, who is special assistant to the president and director of the Division of Sciences Policy of the Institute of Medicine.

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Books

THE PHYSICISTS
The History of a Scientific Community in Modern America

by Daniel J. Kevles

Alfred A. Knopf $15.95

Reviewed by Robert F. Bacher

Some years ago when Daniel Kevles met I. I. Rabi, the much respected physicist, Rabi asked him, "Why doesn't someone write about my generation of physicists? . . . After all we changed the world." His special twinkle accompanied this purposely provocative and exaggerated statement, and their further discussion did much to encourage the author to write this book.

Daniel Kevles started out "to study the scientists who came to professional maturity after World War I, mastered the atom, then built the bomb and rushed the world for better or worse into a fundamentally new era." He came to realize that to get a proper perspective he needed to go back to the earlier days of physical science when it was just beginning in America after the Civil War. His digression for perspective comes close to taking over the book from his original purpose.

Most research in physics in the last quarter of the 19th century, with the exception of the work of Willard Gibbs and a very few others, was carried out in Europe, and the education of most physicists was completed there. Kevles has written a most interesting and lively history of this early period including much not known even to the older generation of present-day physicists. He has carefully outlined the heavy dependence of physics in America on the work of the Europeans, especially on their theoretical work. Just before the turn of the century X-rays were discovered by Roentgen and radioactivity by Becquerel, and the latter discovery was greatly extended by the Curies. Soon thereafter J. J. Thomson discovered the electron, and the revolution accelerated with Planck's quantum ideas and Einstein's special theory of relativity. Soon came Rutherford's brilliant experiments leading to the nuclear atom, and then came Bohr's revolutionary theory of the atom.

The account of what physicists were doing meanwhile in the United States and how they related to the physical science revolution in Europe is a thorough and scholarly job, with many references to then current accounts and private papers. Kevles particularly focuses on the people and their interactions with each other, with the federal government, and with society in general.

At about the same time as the physical science revolution in Europe, physics in the United States had reached a stage where there were enough interested physicists to start the American Physical Society. Kevles focuses particularly on one of the Society's founders, Henry Rowland of Johns Hopkins, an extraordinary experimenter who ingeniously made diffraction gratings that were in demand all over the world. Rowland was a strong believer in quality in physics—best science, or scientific elitism as Kevles calls it. This is a theme that Kevles follows throughout the book, pointing out the conflicts which increasingly arose with the use of federal money. Political representatives demanded that federal funds be distributed widely geographically and used for purposes that were deemed socially desirable. The conflict thus generated had been experienced by John Wesley Powell, the colorful conqueror of the Colorado, who had used his considerable popularity to keep the western arid lands reserved.

During the first 20 years of this century there was a rapid growth of physics in the United States, both in research and teaching. The account of the contributions of the better known scientists of the day—Hale, Lyman, Trowbridge, Michelson, Millikan, Langmuir, Nichols, Webster, and numerous others—to the advance of physics, and of their efforts to make contributions to the First World War is set forth well.

After the First World War physics, stimulated by the scientific revolution in Europe and by vigorous entrepreneurial scientific leaders in the United States, grew by leaps and bounds. In the twenties, physics in the United States, especially experimental physics research, began to be more nearly comparable with physics in Europe. This was promoted by numerous visits from famous European physicists, including Bohr, Einstein, Planck, Sommerfeld, Schroedinger, and others, and by the advent of quantum mechanics, which was quickly taken up by many European-trained U.S. physicists. It was also helped by the immigration of many excellent young European physicists, and this influx was greatly accelerated when the Nazis came to power. By the early thirties, physics research in the United States was close to the best in Europe in spite of the serious setback due to the Great Depression. All this is recounted by Kevles with thoughtful perspective and documentation.

By the time of Pearl Harbor, the United States was leading in physics research, and in addition a few engineering schools had added sophisticated applications of science to their training, as had the leading industrial research laboratories. Well before Pearl Harbor, scientists were being mobilized by the NDRC and later by the OSRD, led by Bush, Conant, Karl Compton, and others. The projects that were immediately taken up—microwave radar, the proximity fuze, ordnance and rocket research, loran, and the speculations about a nuclear chain reaction and an atomic explosive—enlisted mainly physicists, since some of these subjects were unknown to most engineers. Furthermore, the engineers were all employed on immediate projects in airplane design, ordnance, electronics, and other fields.

Physicists who had learned to be hardheaded during the Depression quickly took to these new developments, and the rate of technical advance was phenomenal. As a result neither physics nor physicists have ever been quite the same as they were before World War II. The war forced physicists to work on practical problems that needed immediate solutions. The transition from basic science to applied research to development and manufacture, which previously went at a snail's pace, accelerated and this has continued.

The Kevles account of World War II hardly does justice to much of the technical development except radar and the atomic bomb. Even though proximity fuzes, rockets, and many other developments made an enormous impact on the war, they are scarcely mentioned. The whole treatment is comparable in length to that of the First World War, although the technical contribution to the war effort was much greater. Even this treatment is relatively more extensive than the entire period from the end of the war to the present, which is compressed into less than 20 percent of the text proper. Inasmuch as this covers a period in which there have been enormous advances in solid state, low temperature, quantum optics, astrophysics, as well as nuclear and high energy physics and, in addition, applications to other sciences and to technology and industry, the compression puts the treatment out of balance with the earlier history.

Kevles includes a thoughtful chapter on the attacks on science, especially during the late sixties when relatively large federal funds were devoted to research and development in the physical sciences. He notes that critics were advancing arguments that these funds might be better spent to solve social problems than for basic scientific research. He does not, however, make it adequately clear that most of these funds were allocated to specific projects directly determined by the government appropriation, and of these allocated funds most were earmarked for development, test, and evaluation related to these projects. Although it is difficult to be sharp in these categories, most of the funds are not for basic research. The funds for basic research comprise roughly 10 percent of the total and are directed at getting a better understanding of fundamentals on which to build for the future. Often during World War II, projects came against brick walls for lack of basic knowledge.

Daniel Kevles has written a good history of physicists, especially in the United States. It is a scholarly book, with interesting anecdotes that give a feeling for the human qualities. Accuracy is mostly good—although it would have been physically impossible, as stated (p. 368), for McMillan to use the direct current magnet, previously a part of the Berkeley cyclotron and the wartime calutron, for his first electron synchrotron. Also, Los Alamos is not located in the Sangre de Cristo Mountains (p. 329) but on the mesas below the Jemez range west of the Rio Grande.

The last third of the book is unfortunately greatly compressed in dealing with an enormously enlarged and strengthened physics community. Also it is mainly concerned with interactions with Washington and the federal government. Even the last chapter is mostly devoted to happenings of the mid-sixties. This is particularly unfortunate in view of the changing views in Washington, the reinstatement of a science adviser. and the realization expressed more than once recently in Washington that even the most needed applications cannot continue to go forward without understanding scientific fundamentals.

Robert F. Bacher is professor of physics, emeritus, at Caltech.

THE NEXT EIGHTY YEARS

California Institute of Technology $3.50

Reviewed by Bruce E. Cain

The Next Eighty Years is the third study in a series initiated by James Bonner, John Weir, and Harrison Brown in 1957. The intent of the first book, *The Next Hundred Years,* was to identify world trends in population, natural resources, food, industrialization, and technological change. Subsequent studies have tried to revise earlier forecasts and, in the process, to refine the art of prediction by asking where and why previous estimates went wrong.

Apparently, as Harrison Brown tells us in his introductory essay, where they went wrong was not so much in what they said, but in what they did not say. In particular, the two previous studies neglected environmental problems, such as the effects of increasing carbon dioxide in the atmosphere, and underestimated the vulnerability of industrialized societies to disruptions like the Arab oil embargo of 1973.

The present volume, based on a conference held in April 1977, attempts to remedy these shortcomings with essays on the effects of climatic change by Stephen Schneider, solutions to the energy crisis by John Teem, and the future of Japan and the United Kingdom by Michio Nagai and Lord Ritchie-Calder respectively. In addition, *The Next Eighty Years* further develops some topics introduced 10 and 20 years ago with discussions of population and poverty by James Bonner and James D. Grant; health care by David Hamburg and Sarah Spaght Brown; and problems of the third world by Marin Maydon, Marcus Franda, and Thayer Scudder.

Given the diversity of topics, authors, approaches, and disciplines

continued on page 26

Engineering & Science
MAY-JUNE 1978

The Case of the Missing Solar Neutrinos

by WILLIAM A. FOWLER

We live on planet earth, warmed by the energy of a nearby star, the sun. In its deep interior, nuclear fusion powers that star. At least, that is the conventional point of view. Fusion produces penetrating radiations but fortunately the nuclear radiations from fusion in the sun penetrate only a short distance from their place of origin before being changed into internal thermal energy. After perhaps as much as ten million years, this energy diffuses to the solar surface and is converted there into earth-warming light rays.

There is one exception. Certain types of elementary particles called neutrinos are also generated in solar fusion. They penetrate the one million kilometers of solar material and reach the earth in approximately eight minutes, traveling at the speed of light—except for one in 100 million neutrinos that is intercepted on the way to the surface of the sun. Each second, 60 billion neutrinos penetrate every square centimeter of the earth and pass on, just as they pass through the sun, without producing any damage.

That is what physicists and astronomers believe, but we have no positive proof, and, in fact, observations have not found enough of one rare type of neutrino, which we should be able to observe with sensitive detectors already in operation here on the earth. This is "The Case of the Missing Solar Neutrinos."

Briefly, the case is this. Raymond Davis Jr. of the Brookhaven National Laboratory, one of the greatest experimentalists in the world, observes at most only one-third as many neutrinos as theorists compute there should be, using the best physical model of the sun (we call it the standard model) plus numerical data from the Kellogg Radiation Laboratory at Caltech and other experimental laboratories around the world. The numerical nuclear data are almost entirely from Kellogg and are primarily the work of Professors Ralph Kavanagh and Thomas Tombrello and of Dr. Mirmira Dwarakanath, now at the Bell Telephone Laboratories.

I have to come clean with you right here: I'm not going to give you the solution because the case is still open. What fascinates us in the business is the possibility that the eventual solution may be new knowledge about the neutrinos or other elementary particles, or new ideas about the structure and evolution of the sun, or new knowledge about plasma physics in the solar interior. In any case it could be very exciting.

Why do we want to know about solar neutrinos? The sun is an enormous fusion reactor that converts light hydrogen into helium. We know that we will never be able to do that here on earth, but we may be able to convert heavy hydrogen into helium. If terrestrial fusion can be made to work, we will have an almost limitless supply of energy from the heavy water of the oceans if we wish to use it. The processes are different in detail, but the same in principle. We know that the fusion of light hydrogen in the sun produces neutrinos along with energy. Thus if we cannot find these neutrinos, it may mean that we do not understand solar fusion, and maybe not even the processes proposed for terrestrial fusion. No one really believes the puzzle is that serious, but all of us would breathe a lot easier if the neutrinos from the sun could be found.

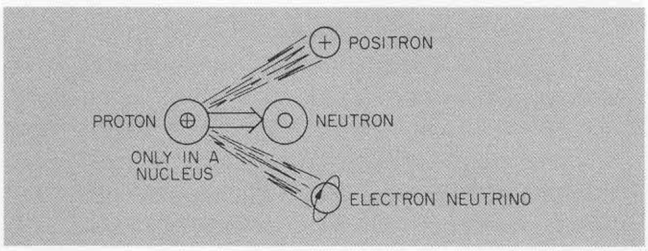
Much more important from the scientific standpoint is the fact that the neutrinos tell us what is going on in the interior of the sun essentially right now—just over eight minutes ago when they left the center of the sun. (The light from the sun tells us about its surface, not its interior, and the energy that was transformed into that light was generated many millions of years ago, even before the advent of humankind here on earth.) Moreover, the number of certain neutrinos we expect is very dependent on the central temperature of the sun. Thus neutrinos serve as a solar thermometer. Our theories, plus experiments we can make in the laboratory, tell us that the central temperature of the sun should be 15 million degrees Kelvin. Ray Davis and his neutrino observations indicate that this temperature is too high by more than a million degrees. Finally, all life here on earth depends on light and heat from the sun. Philosophically and aesthetically it would be very satisfying to understand in detail how that light and heat are being produced.

The first thing you can say about neutrinos is that they've got plenty of nothing. If we disregard the inevitable uncertainties in our experimental measurements, we can make some strong negative statements about neutrinos and their antiparticles, the antineutrinos. They have no mass, and in that they are like photons, the quanta of ordinary light. They have no electric charge, and they have no magnetic moment, so they have no electromagnetic interactions—unlike electrons, protons, and other particles. Furthermore, they do not take part in what we call the strong nuclear interaction—the interaction that holds the nuclei of atoms together, linking protons with neutrons.

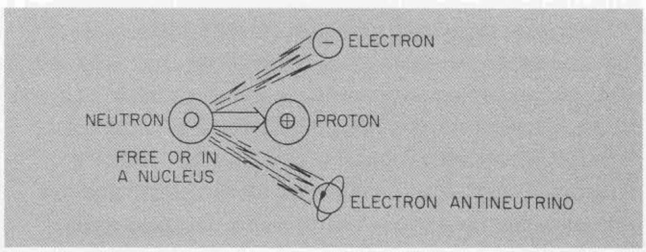
What properties do neutrinos have? Since they have no mass, they travel with the velocity of light, just like photons, and that is why it takes them only about two seconds to get to the surface of the sun and then 8 minutes and 20 seconds to get to the earth. They can carry momentum—that is, they can push other particles around. Because they don't take part in the electromagnetic and the strong nuclear interaction, they do this infrequently. They can carry energy, which means they can transform nuclei. They do take part in the weak nuclear interaction, and in that they are like electrons and muons (the muons that Carl Anderson and Seth Neddermeyer discovered in the Bridge Laboratory at Caltech many years ago). Finally, they have rotation, or spin. Neutrinos are left-handed, which means that they spin while advancing like a left-handed screw. Antineutrinos are right-handed, and this is the way we tell the difference between neutrinos and antineutrinos. Neutrinos and antineutrinos are uncharged so it is not as easy to tell them apart as in the case of the electron, which is negative, and its antiparticle, the positron, which is positive. All we can use for the neutrino and the antineutrino, except for some other subtle effects in the weak interaction, is their direction or sense of spin.

How are neutrinos produced in the sun? The sun consists primarily of hydrogen, and the nucleus of the hydrogen atom is the proton. Due to the high temperature at the center of the sun, the protons are rushing madly about, and two protons can collide and fuse into a deuteron (the nucleus of an atom of deuterium, which is an isotope of hydrogen). In this collision, one of the protons transforms into a neutron (the neutral particle of practically the same mass as the proton), and the positive charge comes off as a positive electron, or positron. At the same time as the positron comes off, we know that a neutrino is given off and zips toward

VARIETIES OF NEUTRINOS

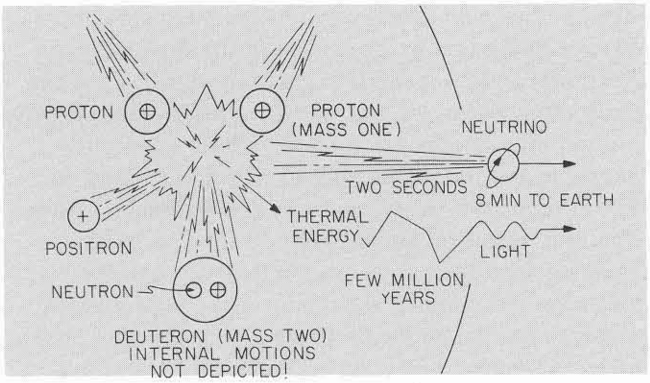


A proton in a nucleus transforms into a neutron and a positron plus an electron neutrino spinning in the left-handed sense relative to its direction of motion.



A neutron, free or in a nucleus, transforms into a proton and an electron plus an electron antineutrino spinning in the right-handed sense relative to its direction of motion.

NEUTRINO PRODUCTION IN THE SUN
PROTON-PROTON REACTION



This illustration (and the other similar diagrams) must not be taken too literally. The rapid internal motion of the neutron and proton in the deuteron is not depicted (even the "motion" is only a useful classical mechanics concept). The fact that the neutron and proton consist of Murray Gell-Mann's "quarks" or George Zweig's "aces" is ignored. These illustrations are only a form of "bookkeeping" for what goes into nuclear fusion and what comes out.

earth or out into space. We will dub this the proton-proton or pp neutrino.

After the fusion of light hydrogen into deuterium, what happens? The deuterons are also in violent motion because of the high temperature at the center of the sun, and they can collide with a proton and fuse, producing a nucleus with two plus charges—two protons—and a neutron. This nucleus has a mass three times that of the proton, and it has an electrical charge of plus two, so it is an isotope or form of helium and is called helium 3. Helium 3 is a very rare constituent of terrestrial helium, most of which is helium 4. The energy that comes off in the fusion of a deuteron with a proton to form helium 3 is gamma radiation, and it soon gets thermalized. No neutrino is produced in this.

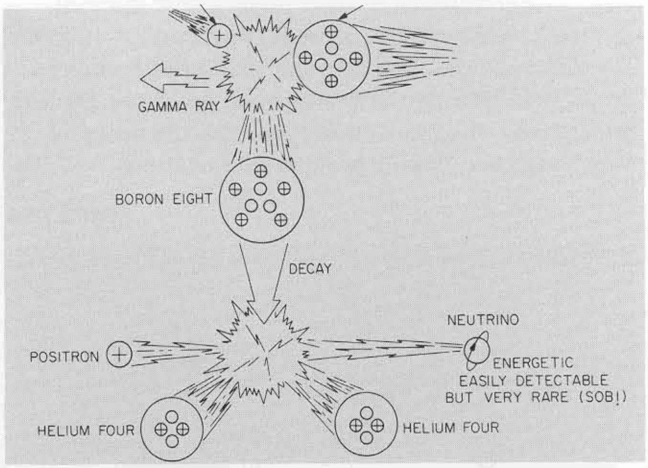
Of course, the helium 3's share in the motion, but laboratory measurements show that they cannot fuse with hydrogen. What does happen is that two helium 3's collide, with rather strange results. After the collision, there are six particles—two free protons that are very energetic, plus two other protons and two neutrons fused together to form a nucleus with charge 2 and mass 4. This is the normal, abundant isotope of the element helium. Overall, four protons have been converted into helium 4, and we get a positron and a neutrino every time a proton converts into neutrons. That happened twice in producing the two intermediate helium 3's, so we get two positrons and two neutrinos. That is, in the basic fusion process in the sun, 4 protons are converted into helium, 2 positrons, and 2 neutrinos.

That's not the whole story, because the helium 3 can also interact with the helium 4 to make a nucleus with mass 7 and 4 charges, which makes it an isotope of the element beryllium. We call it beryllium 7. In the process, a gamma ray is emitted and is transformed into thermal energy, but no neutrino is produced. However the beryllium 7 can capture electrons and give off neutrinos. Unfortunately the helium 3 interacts much more frequently with helium 3 than with helium 4 so the production and subsequent decay of the beryllium 7 happen relatively infrequently.

When an electron is captured by beryllium 7, one of the protons changes back into a neutron. The result is a nucleus of mass 7 and charge 3, which is an isotope of lithium. We call it lithium 7. Lithium 7 can capture a proton and transforms to two helium 4's. A large amount of thermal energy is produced but the main point is that in spite of all this complication the final result is the conversion of hydrogen into helium.

Thus beryllium 7 can capture an electron and give off a neutrino. It can do something else even more interesting. It can capture a proton to produce a nucleus of charge 5, which makes it an isotope of the element boron. The masses add up to 8, so we call it boron 8. Boron 8 is radioactive; it decays within a second or so, gives off a positron and a neutrino, and reverts to two of those ubiquitous helium 4's. The nice

PROTON CAPTURE BY BERYLLIUM 7



One way in which beryllium 7 interacts in the laboratory and in the sun. The radioactive nucleus boron 8 is produced and subsequently decays with the emission of the most easily detectable neutrinos from the sun.

things about these neutrinos is that they are very energetic, and are thus easily detected. The not-so-nice thing is that they are very rare.

The point of all this story is that there is competition in the nuclear reactions. The competition is expressed as the ratio of these processes—whether helium 3 interacts with another helium 3 or with a helium 4, or whether beryllium 7 interacts with an electron or with a proton. Those competition ratios—the relative frequencies with which each of these interactions occur—are very sensitive to temperature, and we have no way of calculating accurately what the ratios should be. Measurements must be made in the laboratory. In Kellogg, protons, deuterons, helium 3 nuclei, and helium 4 nuclei are accelerated to high energy in electrostatic accelerators and are then shunted through high vacuum systems to an observation room where they are allowed to impinge on a target. With sensitive detectors we study the reactions that take place. We are able to duplicate—one at a time, mind you—the very processes that are going on in the center of the sun. The laboratory measurements show that the rates at which the processes occur increase rapidly as the energy of the accelerated particles is increased. This translates into a rapid increase with increasing temperature in the sun.

To capture the elusive neutrinos, Ray Davis uses the chlorine-argon technique. The target for capturing the neutrinos is the heavy form of chlorine, which has a mass 37 times that of hydrogen—it is called chlorine 37. Since chlorine is a gas—and not a very pleasant one—perchloroethylene, ordinary cleaning fluid, is used in Davis's experiment. It is a molecule consisting of two carbon atoms and four chlorine atoms. One of the four chlorine atoms is chlorine 37. When a neutrino from the sun hits the clorine 37, it knocks out an electron and transforms the chlorine 37 into argon 37, which is a radioactive isotope of the rare gas, argon.

The argon 37 is ejected from the perchloroethylene molecule and soon forms a neutral atom surrounded by orbital electrons. It decays with a half-life of 35 days by capturing one of these orbital electrons and ejecting a neutrino and is transformed back into chlorine 37. This would seem to put us back on square one, but the important point is that the chlorine 37 atom is produced in a highly excited state. In the de-excitation process the chlorine 37 ejects one of its orbital electrons. This orbital electron has enough energy that it can produce ionization in what is called a proportional counter. This ionizing event can be recorded electronically and thus the decay of each argon 37 can be counted. Each argon 37 decay so counted is an indication that a chlorine 37 atom in the perchloroethylene has previously captured a neutrino.

Because Davis needs an enormous number of targets to capture the elusive neutrinos, he uses a tank that holds about 100,000 gallons of cleaning fluid in a chamber about a mile deep in the Homestake gold mine in South Dakota. The reason for going into the mine is because on the surface of the earth the cosmic rays that bombard us all the time can transform the chlorine into argon, just like neutrinos can. Terrestrial rocks absorb the cosmic radiation so it is necessary to go deep enough in a mine to reduce the cosmic ray effects below those expected from the solar neutrinos.

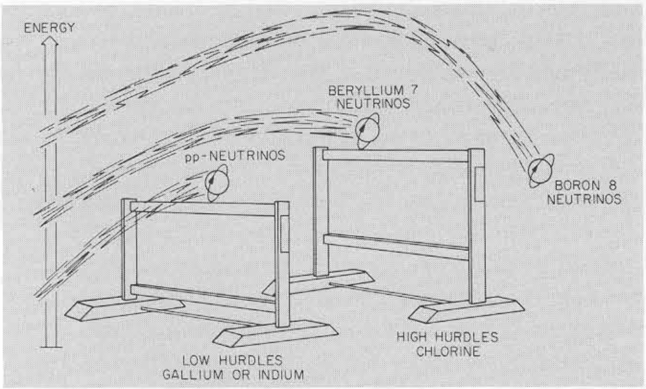
How does Davis get the argon out of the perchloroethylene and into a counter? First of all he introduces a non-radioactive form of argon, either argon 36 or argon 38, into his tank so that he has a reasonable amount of argon gas to work with. The few atoms of argon 37 produced by solar neutrinos mix with the inert argon. He flushes helium through the perchloroethylene about once a month. The helium bubbles collect the argon. He pipes the argon-laden helium over a cooling trap and, because argon freezes out at a higher temperature than helium, he can collect the argon in the trap and separate it from the helium. He heats up the argon and introduces it as a gas into a proportional counter and counts the argon 37 decay events for several months. He thus obtains a measure of how many chlorine 37 atoms in the perchloroethylene in the tank have been transformed into argon 37 by neutrinos.

By a number of clever tests using radioactive argon and chlorine, Davis has shown that he is able to recover argon 37 quantitatively from the perchloroethylene. He is then able to translate his measurements into the flux of neutrinos passing per second through each square centimeter of projected area of his tank. In doing this he uses a large body of theoretical and empirical information on the weak nuclear interaction that has been applied to the chlorine 37-argon 37 transition, largely by John Bahcall, once at Caltech but now at the Institute for Advanced Study in Princeton. It is of course an *assumption* that the neutrinos are from the sun. If the neutrino flux he does detect is from some other source, then the case of the missing solar neutrinos is even more puzzling.

At this point, it is necessary to discuss the predictions of the standard model of the sun. Of course, many sophisticated theoretical considerations enter into this model, but for our purposes the main point is that the sun is clearly in a stable situation—in spite of the fact that enormous gravitational forces are tending to collapse it. In the standard model, it is gas pressure outward that is in balance against the inward-directed gravitational forces. This is just like the gas pressure in an automobile tire that holds the tire from collapsing. The most important thing from our point of view is that the pressure in the sun is proportional to the temperature—also just like in a tire. Suppose you measure the pressure when the tire is cold and you obtain 20 pounds per square inch. You drive the car for a while and the tire gets hot. If you measure the pressure then, it is perhaps 25 pounds per square inch. It turns out that the necessary temperature for the standard model of the sun is 15 million degrees Kelvin.

What are the predictions of the standard solar model for the proton-proton neutrinos, those that are emitted in the primary fusion process that produces deuterium? We are interested in their flux; that is, the number that hit every square centimeter of the earth every second. The standard model yields a flux of 60 billion per square centimeter per second. Actually this result is practically model-independent. It is much the same for all solar models, provided the assumption is made that the sun is powered by the fusion of hydrogen into helium. One knows the energy flux in sunlight at the earth. The fusion of four protons into helium 4 yields a known amount of energy plus two neutrinos. The calculation is straightforward, and the result is 60 billion neutrinos per square centimeter per second at the earth.

THE NEUTRINO HURDLES



The proton-proton, or pp, neutrinos cannot get over the high energy hurdle in chlorine 37 but can get over the low energy hurdle in gallium 71 or indium 115.

How many capture events per month should Davis get in his 100,000 gallons of perchloroethylene from this enormous neutrino flux? Unfortunately, none! The reason is that the energy hurdle in the transformation of chlorine to argon is too high for the proton-proton neutrinos to get over it. They do not have enough energy. The beryllium 7 neutrinos can just barely make it, while the boron 8 neutrinos, which have greater energy, can go over the hurdle easily.

The predictions for the beryllium 7 and boron 8 neutrinos are very dependent on the temperature calculated for the center of the sun and are thus very model-dependent. The standard model yields a central temperature of 15 million degrees and corresponding to this a beryllium 7 neutrino flux of 4 billion per square centimeter per second at the earth. These neutrinos just barely surmount the chlorine-argon energy hurdle, and they result in only five capture events per month. The standard model yields a boron 8 neutrino flux of only 3 million per square centimeter per second, but with their larger energy a much greater fraction surmount the energy hurdle and produce 20 capture events per month. Thus Davis should be observing a total of 25 capture events per month with a statistical uncertainty or standard deviation of plus or minus 8. What he has observed in approximately 30 observational runs since 1970 is an average, *above known background,* of 9 capture events per month with an uncertainty of plus or minus 2. In other words Davis observes about one-third of the counting rate predicted by the standard model.

There is very small probability that this discrepancy is a statistical one. If this possibility is ignored, the results would seem to indicate the standard model is faulty. Thus other models have been developed, and everybody and his brother in the business has one. Many of the variants suggest that the central temperature of the sun is lower than 15 million degrees since that decreases the predicted flux of the temperature-sensitive beryllium 7 and boron 8 neutrinos. The necessary lowering is relatively small but is still a million degrees or more, and the variant model must compensate for this decrease in central temperature and the consequent decrease in pressure or otherwise the sun will collapse. This it is obviously not doing!

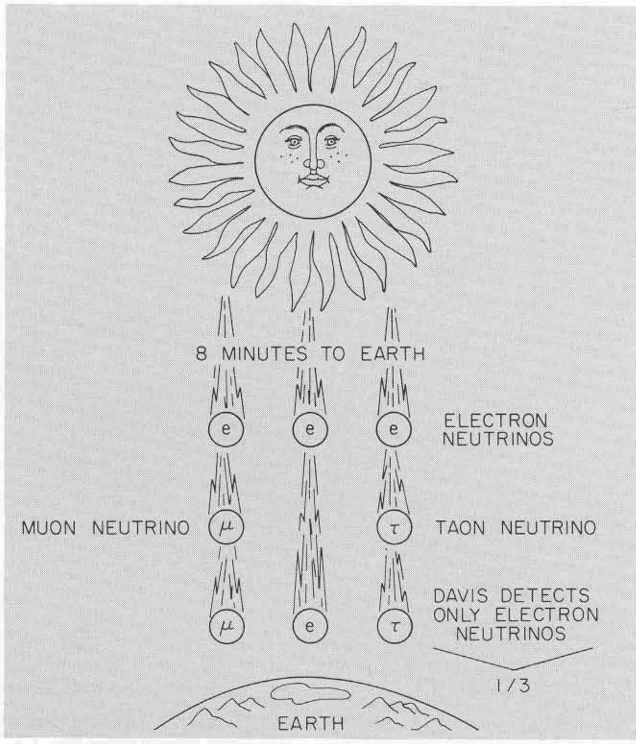
All of these variant models basically attempt to maintain the sun's stability against gravitational collapse in spite of a lower central temperature and pressure. One model assumes rapid internal rotation, so that centrifugal force due to rotation keeps the sun from collapsing against gravity. If this is indeed the solution, the sun should have an oblate shape; it should be bigger at the equator than it is at the poles. And although some observations by Robert Dicke of Princeton University indicate that there may be a very small solar oblateness, other measurements show there is none.

Another model postulates a high internal magnetic field. Magnetic fields can withstand compression and can withstand the forces of gravity. But again oblateness should result. It is true that one can conjecture a very exotic internal magnetic field, especially combined with rotation, to remove oblateness. However, large magnetic fields in the center of the sun would reside in a bubble where the density is lower than that of the surrounding material. Eugene Parker of the University of Chicago and an alumnus of Caltech, has shown that such a magnetic bubble will rise within a few million years. Thus it is impossible to maintain the large magnetic field necessary to cure the solar neutrino problem.

There are many other models, but all of them raise more questions than they solve. So we have begun to think that perhaps there is another avenue for understanding the case of the solar neutrinos. And that is through a question concerning the properties of the neutrinos themselves.

We know there are other kinds of neutrinos than the electron neutrinos that are produced in the sun. For example, there are neutrinos that are associated with the muons. Just recently at Stanford another new elementary particle has been discovered—the taon—and there should be a neutrino associated with it. So we know that there are at least two kinds of neutrinos, those associated with electrons and the muons, and perhaps a third kind, the taon neutrino. Many years ago Pontecorvo, the once Italian, now Russian, physicist suggested that, in the eight minutes it takes to get from the sun to the earth, electron neutrinos might transform into muon neutrinos, and this transformation can be extended to taon neutrinos. Work by John Bahcall and Steven Frautschi, professor of theoretical physics at Caltech, and by Mann and Primacoff of the University of Pennsylvania and many others has shown that when this transformation occurs it is possible, starting with one kind of neutrinos, to wind up with an equal number of all three. This is an extreme but possible result. In this case, what happens to three electron neutrinos starting off from the sun? One turns into a muon neutrino, one turns into a taon neutrino, and one survives as an electron neutrino. But Davis's techniques can only detect electron neutrinos. It's almost too good to be true—one out of three survives, and we get just one-third the number of capture events we expect, which is what Davis observes.

TRANSFORMATION OF NEUTRINOS



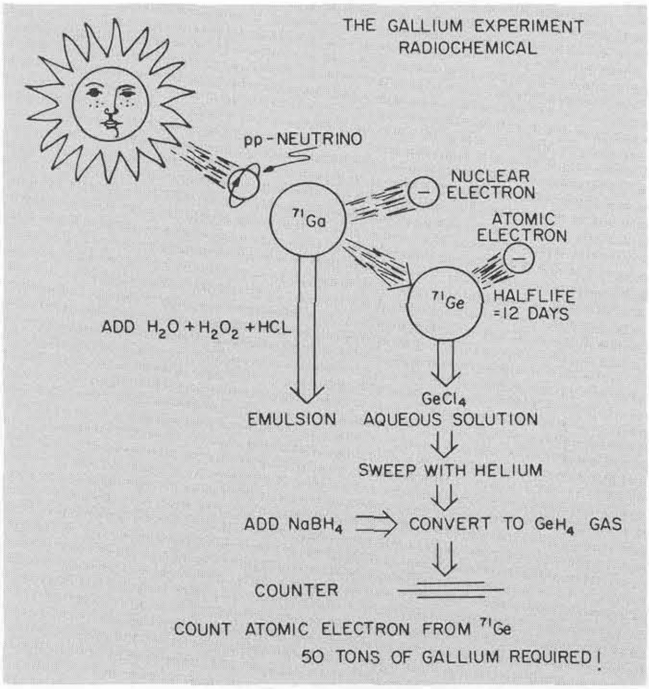
If three electron neutrinos transform on the way from the sun to the earth into one muon neutrino and one taon neutrino, leaving one electron neutrino, then the results of the Davis chlorine-argon observations are explained. This is an intriguing possibility, but is viewed with great skepticism by many elementary particle theorists.

There's a great deal of skepticism about this idea, but many accelerator and reactor laboratories are planning experiments to test it. Felix Boehm, professor at Caltech, is now engaged in an experiment in Grenoble, France, in which he is actually looking for the transformation of electron antineutrinos coming out of a reactor into muon antineutrinos and perhaps taon antineutrinos.

A promising lead in the case of the missing solar neutrinos is to make a search for the proton-proton neutrinos. In the transformation of gallium 71 into

Solar Neutrinos

THE GALLIUM EXPERIMENT



The gallium 71-germanium 71 transformation can be used to detect the model-independent flux of pp neutrinos from the sun. It is a costly experiment that has been shown to be technically feasible in small-scale tests by Ray Davis and his collaborators at Brookhaven.

germanium 71, the energy hurdle is low enough for the proton-proton neutrinos to be effective. When gallium 71 captures a neutrino, it gives off an electron. This transforms it into germanium 71, which is radioactive just like argon 37 (except that its half-life is 12 days), and its decay produces an atomic orbital electron, which can be detected in a counter.

Gallium is a metal, and at room temperature it is a solid, but at just slightly above room temperature it is a liquid. The germanium 71 can be transformed by chemical treatment into germanium tetrachloride, a gas, which can be swept up by helium out of liquid gallium. After separation from the helium it can be converted into a combination of germanium and hydrogen, called germane, which is like methane with carbon replaced by germanium. Germane can be introduced into a proportional counter, and one has a measure of the proton-proton neutrinos from the sun. The only catch is that some 50 tons of gallium are required, and the present world production of gallium is only about 7 tons a year. (The yearly production in the Soviet Union is unknown.) Gallium is a fairly rare element that occurs in bauxite (from which we get aluminum). In the form of gallium arsenide it is used in the light-emitting diodes in pocket calculators. It is also beginning to be used in the magnetic memories of big computers, so the production is increasing. Fifty tons of gallium is not available now, but there is the possibility that this experiment can eventually be carried out by Davis and his colleagues at Brookhaven.

It is a crucial experiment because it can detect the basic proton-proton neutrinos if the sun produces them. A group at the Bell Telephone Laboratories is planning an indium-tin experiment that can also detect the proton-proton neutrinos. If the sun is powered by hydrogen-into-helium fusion, then we know the flux of these neutrinos at the earth—quite independently of our models of the solar structure. If the gallium (or indium) experiment finds nothing, then we will know the sun is not powered by fusion—and that would really throw us for a loop. If the gallium experiment yields one-third of what we expect, it will be strong evidence—not conclusive, but strong—that electron neutrinos transform in part to other types of neutrinos on their way from the sun to the earth. If the gallium experiment yields close to the full value of what we expect, then we will know from the chlorine experiment that our standard model of the sun is wrong, and we must go to some other model regardless of the consequences to our ideas. That is a strong statement. It may be that we just do not understand all the physics of the solar plasma (plasma is an almost completely ionized but neutral form of matter).

This is the end of the line. This scientific detective has reported on the still-unsolved case of the missing solar neutrinos. The only solution seems to be new experiments and observations, which will be long and difficult and costly. It must be clear that I think it would be a good investment. The new experiments promise to tell us whether we really understand the structure and the internal operation of our star, the sun. If it turns out that our understanding is correct, then the sun will have been telling us all these years that those elementary particles, the neutrinos, have fascinating transformation properties that we can look for in terrestrial experiments at the big accelerators and reactors. In any case, it's a sure way to new knowledge about the universe in which we live—new knowledge that spans the vast area between tiny particles and our massive sun. □

Caltech's New President

The Goldbergers meet the faculty at an Athenaeum reception on May 8.

Marvin L. Goldberger, a theoretical physicist, is now Joseph Henry Professor of Physics at Princeton. On July 1 he becomes President of Caltech.

Goldberger's Caltech appointment came after a faculty committee had searched for more than a year and considered more than 200 possible presidential candidates. During the search period, Goldberger visited the Caltech campus for three crowded days in January to meet with groups of students, faculty, and trustees. After his appointment was announced, he returned to the campus for two or three days of briefing sessions in March, and he was back on campus again for three days in May to meet with trustees and attend a faculty reception honoring him and Mrs. Goldberger. They will move into the President's house on Hill Avenue on July 1. His inauguration is set for October 27.

Born in Chicago in 1922, Goldberger received his BS in physics at the Carnegie Institute of Technology (now Carnegie-Mellon University) in 1943. He served in the United States Army from 1943 to 1946, mostly in the theoretical physics division of the Metallurgical Laboratory at Chicago, a part of the Manhattan Project, working on neutron diffraction and on nuclear reactor design. He got his PhD in physics from the University of Chicago in 1948, working under Enrico Fermi.

After a year at the Radiation Laboratory at Berkeley and a year as a research associate at MIT, Goldberger joined the faculty of the University of Chicago as assistant professor of physics in 1950. He became an associate professor in 1952 and a full professor in 1955. He was Higgins visiting associate professor at Princeton in 1953-54, and in 1957 he became Higgins Professor of Mathematical Physics at Princeton—a position he held until 1977 when he became Joseph Henry Professor of Physics. He was chairman of the physics department at Princeton from 1970 to 1976.

Goldberger is the author of about 150 scientific papers, and his research has included work on neutron diffraction, nuclear physics, plasma physics, collision theory, methods to determine properties of scattering systems by intensity correlations, dispersion theory, multi-peripheral models of high-energy phenomena, the relation between Regge poles and elementary particles, and quantum field theory. He is probably best known for his work on the application of dispersion methods to a wide variety of problems in the weak and strong interactions among elementary particles and for his monograph, with K. M. Watson, *Collision Theory*.

Since 1955 he has been an adviser to a number of government agencies on national security and arms control affairs. He was one of the founders of the JASON group in 1959. Originally associated with the Institute for Defense Analyses and now with SRI International, this group of about 35 prominent scientists (mainly physicists) works for the Department of Defense and other agencies on problems involving advanced technological concepts. From 1965 to 1969 he was a member of the President's Science Advisory Committee, and in 1972 and 1973 he served as chairman of the Federation of American Scientists. He was a member of the recent Ford Foundation-Mitre corporation study, *Nuclear Power—Issues and Choices*.

Goldberger has been active in international scientific affairs for many years. From 1963 to 1969 he was chairman of the high-energy physics commission of the International Union of Pure and Applied Physics. In May 1972 he was head of the first scientific delegation to the People's Republic of China and arranged for the first delegation of Chinese scientists to visit the United States in the fall of 1972.

He is a Fellow and was chosen to be vice-president elect (a position he has now resigned) of the American Physical Society, having been a member of its Council from 1973 to 1977. He is also a Fellow of the American Academy of Arts and Sciences and of the American Association for the Advancement of Sciences. He is a member of the National Academy of Sciences and of its Council on Foreign Relations. He was awarded the Dannie Heineman Prize for Mathematical Physics in 1961.

Though he is no longer chairman, Goldberger is still active in a variety of affairs in the physics department at Princeton. He is also currently chairman of the university's committee on research that deals with potentially biohazardous materials. Despite his administrative duties, Goldberger has managed to keep some research going at Princeton—"not what I would like to have, but I am still working on some things in elementary particle physics." He also has some undergraduate thesis students, and he teaches the undergraduate course in quantum mechanics—55 students in all. He hopes to be able to teach undergraduates at Caltech too, "but everybody says it's unlikely I'll have time. The first year I wouldn't even try it, but I haven't given up the idea if it's technically possible. Whether I can meet a class regularly, or whether it will have to be something rather specialized, I still want to do it."

He is also interested in the possibility of establishing something like a senior thesis program, and junior independent work, at Caltech. "Of course, I have to learn a great deal more about what exists before I propose modifications," says Goldberger. "But I come from this deep tradition of devotion to and involvement with undergraduates. I just saw a survey that evaluated some 68 colleges and universities on their undergraduate programs, and Princeton rated number 1. I would like to see them become number 2."

A soft-spoken man, with the pleasant expression and reassuring manner of a trusted family doctor, Goldberger is known to his close friends, and most of his acquaintances, as "Murph."

Aside from his academic interests, he plays tennis, runs, and cooks. His cooking is eclectic—Chinese, Italian, French, and Basic, but "I cook from cookbooks; I don't invent."

Mildred Goldberger is a professional economist who has worked for the New Jersey State Department of Labor and Industry. She is now with the Princeton Center for Environmental Studies. She is also working with a Princeton group writing a cooperative novel. And for many years she has been involved with the improvisational theater. This is an interest that goes back to the Goldbergers' Chicago days, when Mildred wrote scripts for the Compass Players, a group that included Mike Nichols, Elaine May, and Shelley Berman.

The Goldbergers have two sons—Joel, 25, working toward a master's degree in computer science at the State University of New York at Stony Brook, and Samuel, 29, who has a PhD in physiological psychology from Stony Brook and is currently working as a psychologist at a hospital in San Francisco.

In their brief visits to Caltech this year the Goldbergers have been "impressed with the general enthusiasm for the institution that the faculty had," and with "their concerns and involvement in Caltech affairs."

"People seemed to like each other," Goldberger says. "We both noticed it—that people were very warm and friendly. We felt we were guests at interesting parties rather than that we were being looked over. It was a nice feeling."

And what's even nicer—it's mutual. □

Health in the Decades Ahead

by DAVID HAMBURG, M.D.,
and SARAH SPAGHT BROWN

We must develop a broader science base and a more compassionate society, not only to cope with disease and disability but to improve the quality of life—and perhaps even to survive as a species

This is a perplexing time in which to consider health care. The current health sector is in great ferment and, consequently, glimpses into the future are particularly clouded. It is a time of satisfactions and concerns, of progress and poverty, of hope and apprehension. From this ferment, important changes in the health care system will probably occur in the next decade, though the outlines of these changes are still somewhat unfocused. As a consequence, a look toward the health care system in 80 years is especially difficult; we don't really know what even the next 10 years will bring, let alone 80. But some general observations can be made nonetheless.

Before elaborating on the future, it might be helpful to review very briefly certain aspects of the health sector in both the present and in the past. Certainly there are many sources of satisfactions from such a survey. The public health progress made in this country and other industrialized countries in the 19th and 20th centuries has had an enormous impact on health. Progress in sanitation and the hygiene sciences—particularly in the handling of excreta and in the recognition of the need for uncontaminated water—has improved the human condition immensely. Research in recent decades has also aided in bringing many of the most destructive infectious diseases under control—some by the immunization process, others by the use of antibiotics.

Similarly, progress in agricultural production has led to an unprecedented adequacy and dependability of nutrition in the Western world. This strengthened food supply and dissemination has done much to limit infectious diseases. Resistance to an even wider range of diseases beyond the infectious ones has also been encouraged by these agricultural developments. There have also been changes in reproductive practices, which hold out at last the twin possibilities of a better balance between population and resources, and of adequate care for every child.

In addition to these broad movements in agriculture, sanitation, and population, there have also been truly extraordinary advances in the life sciences, many of which have occurred only within the past quarter century. The revolution in modern biology—or, more accurately, the revolutions in modern biology—have been described at length by others. Our understanding of basic life processes at both the cellular and subcellular level has expanded enormously in recent years; often, though not always, this increased understanding has been translated into new diagnostic, therapeutic, and preventive interventions in the health care sector. For example, the health care system is now able to offer the detection of genetic defects in a human fetus through prenatal diagnosis.

These many advances in the biomedical sciences

This article is adapted from Dr. Hamburg's speech at The Next Eighty Years conference, held at Caltech in April 1977.

have also been joined by recent strides in the behavioral and social sciences. Individually and in concert with the biomedical sciences, these disciplines are demonstrating their great potential for the protection and improvement of human health, as is suggested, for example, by studies on the relationship of stress to disease. The long-standing sciences of epidemiology and biostatistics—the core disciplines of public health—have proven continuously in recent years their relevance to health, as have the newer sciences of nutrition, and environmental and occupational health.

So, altogether, the health sciences are stronger today than ever, with the major strides in health being in the areas of infectious diseases, and the development of immunizations and antibiotics. Of course, new developments growing out of our sizable investment in health sciences research continue to appear on the horizon. For example, comprehensive treatment for both hypertension and schizophrenia are almost within our grasp.

Beyond these scientific and technical achievements, recent decades have seen great changes as well in the structures and processes through which health and medical care are provided. Though some view these system changes as a net loss—such as those who mourn the apparent passing of the family physician—surely there have been extraordinary gains. In 1974, roughly 88 percent of the population of the United States was covered by at least some form of health insurance, either privately purchased, or through the massive Medicare and Medicaid programs. The availability of physician care to individuals has increased, as has hospital-based care and that provided by various long-term-care facilities. Life expectancy in the United States is at an all-time high—68 for men and 76 for women. In 1900 the comparable figures were 46 and 48.

This same glance at the past and present, and the changes between, also reveals deficiencies in the health sector. For example, there is still reason for concern that some population groups—particularly the poor and socially deprived—do not benefit adequately from the medical advances and health care improvements alluded to earlier. It is also clear that certain age groups, such as the elderly and adolescents, do not receive adequate health supervision, irrespective of income or social status. This younger group in particular is almost invisible in terms of special health care services, research, or education focused on the prevention of disease. And yet it is during this key transitional period that so many habits—both health-enhancing and health-compromising—are developed and carried into adulthood. These behaviors hold significant consequences for health and well-being in both the short and long term.

Another deficit of great concern is that the health sciences research effort has not been in reasonable relation to burden-of-illness indices, either in this country or in the world at large. Even though specific disease categories rank differently depending on the measure used, it is clear that the funding of research does not relate in a rational way to the illness burdens of the nation. The mental illnesses, for example, are a great burden in terms of hospitalized individuals and economic costs, and yet the funds expended on mental health research in this country are limited. This lack of "fit" is also true in professional education. The education and specialty training of physicians and other health professionals has not been structured to take account of the burden of illness. These discrepancies are currently generating growing interest in medical and scientific communities.

Another lack that is apparent in surveying the current health scene is the insufficient emphasis placed on research that assesses both the risks and benefits of diagnostic and treatment interventions—particularly before such interventions come into widespread use. Most of what is actually done in medical care has not previously been evaluated in the most thoroughgoing scientific way. It is necessary to determine more than has been done in the past about the efficacy of diagnostic, treatment, and preventive interventions. The cost and ethical implications of not conducting such research are most serious, though there are hopeful signs that this assessment issue is being widely discussed in both the public and private sectors and that corrective actions are being considered. If research is envisioned as a series of related disciplines that are linked to each other along a continuum and contribute to each other, it become clear that these links between and among the disciplines must be strong in order for developing knowledge to move smoothly and efficiently from the basic research sector into actual applications. Feedback loops from practitioners to basic scientists and to clinical investigators need to be strong. There also need to be improved mechanisms for milking all basic and clinical science advances for their application to real-world problems, particularly for very burdensome problems. It is probably unwise to assume that the potential applications of many research advances are systematically assessed and implemented—often, in fact, the various portions of the research continuum function in isolation from one another. Such fragmentation, then, is yet another problem that is of concern in the current health scene.

The field of international health also is seriously problematic, particularly as regards the developing countries. The burden of early death and long-term disability in most countries of the world today is staggering. Putting exceptions like Sri Lanka aside, it is fair to say that the burden of illness may become truly crushing unless major research programs leading to better treatment and prevention strategies are undertaken. Health problems go right to the heart of the matter of development. Development will probably be impaired if a large proportion of the people are ill or debilitated, or at least lacking in stamina. And yet that is the situation in many of the developing countries, which may become the never-to-be-developed countries unless the burden of illness can be eased.

But the focus here is on future trends, so let us turn to others that are encouraging. Of great significance will be new understanding of the possibilities for preventing many of this nation's most crippling, disabling diseases. In California recently, studies by Breslow and Bellock of about 7,000 adults, followed for about six years, showed that life expectancy, health, and chronic disease are related to some basic, very simple health habits. Factors that emerged as highly health-relevant in this large-scale study of mid-life included: three meals a day at regular times and no large snacks in between, breakfast every day, moderate exercise two or three times a week, seven or eight hours of sleep a night, no smoking, moderate weight, little or no alcohol intake. A 45-year-old man who practices zero to three of these habits has a remainng life expectancy of about 22 years. He can expect to live to age 67. But a 45-year-old man with six or seven of these habits has a life expectancy of 33 additional years—to age 78. Such research suggests that 11 years could be added to life expectancy at age 45 by an alteration in life style.

Based on this type of analysis, it will probably become increasingly clear that the health system has all kinds of interdigitations with other systems—such as housing, transportation, and the general environment —going beyond the realm of medical practice. Such evidence puts more emphasis on what individuals can do for themselves—partly with the doctor's guidance, stimulus, and encouragement, and partly with an individual's own knowledge and judgment. Research in the future will probably (we hope) pay much more attention to the behavioral aspects of health, such as diet and exercise, tobacco and alcohol use, and much more attention to the possibilities for prevention of disease.

Related to these observations is another piece of evidence, from quite a different sphere. Experiments in several animal species, including some primates, show that the lesions of atherosclerosis do in fact regress, diminish, or even disappear with changes in diet. That is, if a chronic high-fat diet is reversed to a low-fat diet, the actual lesions in the arteries, including those of the coronary arteries, will regress.

Future research will focus much more sharply on these issues. Another interesting bit of evidence from studies of people in mid-life suggests that there is ample capacity for learning in mid-life and beyond. It appears that our folklore about inability to learn in later ages is mostly nonsense. This new appreciation of our later-life learning capacity will be of great significance as the proportion of aged people in our society greatly increases in the next half century. Clearly, if an individual wishes to change his habits and would like to live longer, major changes in behavior are possible.

The basic orientation that flows from these observations is that the nation can and should begin to look toward primary disease prevention aimed at environmental and life-style factors that contribute to illness and death. Some of these are addressed to individual behavioral changes, and some are matters of social organization that involve the urban environment, education, transportation, and so on. They involve large issues of public education, and the need to give people more choice about how they will use their lives and, in effect, how long they want to live. This is an immense task that requires far more collaboration than we are accustomed to in medicine—not only collaboration across scientific and professional disciplines, but across government and educational sectors. Although there is going to be plenty of difficulty and a lot of hand-wringing, the next decades will no doubt see considerable progress in this area.

Two particular efforts at prevention research, which probably signal a future trend, deserve special mention. Although preventive interventions are typified by references to vaccines and medical screening techniques, the evidence is growing that other interventions hold important promise for savings in human life and health. The Stanford Heart Disease Prevention Program has done much to demonstrate that community-based health education campaigns can aid in prevention of cardiovascular diseases. The program mounted mass media campaigns in two California towns to teach about the risk factors of cardiovascular diseases and how to reduce them. Some of the highest risk residents in one of the towns also were given intensive instruction in person. Results were encouraging. Randomly selected individuals had a 12 percent reduction in total predicted heart attack scores after one year of the campaign, and a 24 percent reduction after the second year. Of the 24 percent risk reduction achieved in both towns, almost 15 percent in one town and 10 percent in the other were due to lowering of blood pressure, either through medication or diet or both. Cigarette smoking was markedly reduced.

Another preventive program that is not so well known, and which is very new, has been operating in a rural county of Finland during the last five years. The entire population of that county, 180,000 people, has been exposed to an intense health education campaign aimed at reducing the community's high rate of cardiovascular disease. Males in Finland have the highest mortality rates in the world from coronary heart disease, due in part to their tradition of high-fat dietary intake and in part to their tradition of heavy cigarette smoking. An interdisciplinary team involving clinical medicine, public health, and behavioral science has been working to diminish those risk factors. The public education program has involved the mobilization of private organizations in the communities and some legislation—particularly for the forbidding of smoking in public buildings and in public transportation. The cooperation of the dairy industry was enlisted, and the public has responded by reducing its fat intake substantially—switching from regular to low-fat milk, from butter to margarine, from regular high-fat sausages to sausages made with a large mushroom content. Fresh vegetable intake has increased, and the results show a considerable decrease in smoking and blood cholesterol levels. For the first time in 30 years in that county, the seemingly inexorable annual increase in the numbers of heart attacks has leveled off, and there is some evidence that the incidence of strokes may be decreasing as well.

These experiences in California and Finland suggest that community-based prevention programs combining clinical medicine, public health, and behavioral science can effectively reduce the risk of cardiovascular disease and some forms of cancer. Broad, interdisciplinary approaches such as these, focused on prevention, will probably increase throughout the world over the next several decades.

Before leaving this emphasis on the need for future work in prevention, special mention should be made of one particular age group that may prove to be crucial to the prevention effort—early adolescents. Young people in this developmental phase fall between pediatrics and adult medicine, between child and adult psychiatry, between grammar school and high school. As a special group they are largely ignored. And yet it is during early adolescence, roughly 10 to 15 years of age, that many behaviors with great relevance to health are initially explored and developed into habits that may be carried into adulthood. The use of alcohol and other drugs, cigarettes, the patterns of exercise, nutrition, sexual expression, and use of motor vehicles are often first addressed in this developmental stage. Some of these behaviors pose immediate risks and benefits to health; the health consequences of others become manifest only in later life. Smoking, for example, has relatively minor health consequences to a youngster when first begun; however, if smoking becomes a habit, the health consequences in 20 to 30 years are enormous. This "time bomb" concept may well become central to future research and programs directed at disease prevention. If ways can be found to encourage adolescents to adopt health-enhancing rather than health-compromising behaviors, the possibilities for preventing future and long-term chronic diseases in particular become most significant.

Laboratory-based research points to new future trends as well. One of the great advances in biomedical research having enormous significance for the future has to do with the delineation of some small molecules that are produced by the pituitary gland and that have far-reaching effects on the reproductive systems and on our experiences of pain, among other things. Work on the brain and pituitary peptides will probably lead to better treatment of pain, which will have great bearing on what life is like for the elderly with chronic diseases.

This research may also lead to a wider range of chemical, reversible contraceptives. Indeed, a whole new range of contraceptive techniques will probably be

continued on page 24

Caltech Revisited

Eleven years ago, Abraham Kaplan, a distinguished professor of philosophy from the University of Michigan, spent several days at Caltech as a guest of the Caltech Y. At the end of his visit he was interviewed by John Weir, associate professor of psychology, about his impressions of Caltech and its students. E&S *published an excerpt from that interview in its June 1967 issue.*

At that time Kaplan found Caltech students intellectually mature though emotionally hungry for human warmth. He saw the campus atmosphere as austere, with inadequate interaction between faculty and students. He admired the diversity of backgrounds of the students but pointed out that they shared a dedication to the life of the mind, with laboratories being much more important than libraries. Admitting undergraduate girls would, he felt, contribute greatly to campus life. He also hoped that—in the interests of variation from the campus norm—the expanding social sciences would not go in a "hard," or heavily mathematical, direction.

Last fall Kaplan, who has been professor of philosophy at Haifa University in Israel since 1972, returned to Caltech for two terms as Mellon Visiting Professor of Philosophy. His teaching assignment during that period was two sections of Pl 102: "Philosophy in the Old Testament" and "Asian Philosophies" first term; and "Post Biblical Jewish Thought: Hillel to Buber" and "The Logic of Social Values: Philosophic Issues in Public and Private Morality" second term.

At the end of this visit Jacquelyn Bonner asked him some of the same questions Weir had asked him in 1967 about his impressions of Caltech and its students. Here is an excerpt from that interview.

JB: Let's begin with the same question John Weir began with. How would you characterize the general nature of the student body at Caltech?

AK: First, I have to say that, paradoxically, I got to know the student body less in those two quarters than I did in those few days 11 years ago. I was probably exposed to many more students then; everything was arranged for a visitor to speak to many student groups. This year, as a member of the faculty, essentially I spoke only to the students in my classes, and they were very small classes.

It struck me that the students are considerably younger than they used to be. That's understandable, of course, but I think something more is involved than the obvious change in my perspective. In the interim, I have been teaching in Israel; my students there, because of compulsory military service, are two or three years older. At that age three years is an important interval.

I found my students here much more naive in the area of philosophy than I anticipated, but I want to make explicit that teaching them was a great joy. They came close to a teacher's dream of an ideal student—somebody who knows nothing and understands everything. Too often, especially among undergraduates, what we get is the opposite—students who know everything and understand nothing.

I regret that I had less to do with them than I've ever had with any students. They came to class and turned in their work, but I hardly ever saw them outside the class. If they came to my office, it was for a very specific matter—their term paper perhaps—and that was all I saw of them. One factor to which I attribute this is that what I was doing was on the periphery of their concerns. Since they were heavily occupied in other directions, it was a considerable investment of their time and energies to allow themselves even this much work with me.

With hindsight, I see some steps that might have been taken to overcome that difficulty. I did have students in my home once or twice, and I would have done so several more times had I lived anywhere near the university. Unfortunately, because I was unable to find housing in Pasadena, I lived a 40-minute freeway drive away, so I could be on campus only for the two days a week that I taught, and students could not easily visit me.

In this connection, I think universities in general don't sufficiently recognize that a university is a community of learners, but it makes no sense to speak of a community of any kind unless it has a geographic base. That means that helping find nearby housing is not just a fringe benefit to a faculty member, especially a visiting faculty member, but is really essential to the important work of the university.

I did take some steps on my own to be a part of the Pasadena community. I lectured to the local Jewish temple and at the Pasadena City College, and I offered my services to the campus Hillel. I spoke at a political science colloquium and for a humanities seminar, to a ladies' club at the Athenaeum, and for the campus Y, but I wish I had been taken advantage of more.

JB: How do you feel about the atmosphere on the campus and the attitudes of students?

AK: I'm going to put my answer in a comparative way. Higher education in Israel is very professionally oriented because the Israeli students can't afford a "liberal" education in the sense of an opportunity for personal growth. It struck me that Caltech is like an Israeli university in that respect. It does not seem to be a place where people are growing in all sorts of directions—intellectually, culturally, personally—but rather where people are pursuing very definite career lines.

The kind of thing I like to see in a university, certainly among undergraduates, is that somebody has suddenly discovered, say, Chinese art or Greek poetry and is excited about it. I did not have very much sense of that at Caltech. Witness the sort of things you see in the bookstore. There are lots of very fine books in physics, mathematics, and astronomy for sale, and those are marvelous and exciting fields. But there wasn't much of Greek poetry or Chinese art, so to speak.

Now, to say the students were just going through their courses to get a BS would no doubt do them an injustice. Rather, they were getting through their courses to master astronomy or physics or chemistry. I think there was a very healthy orientation to what they were doing, but what they were doing was more narrowly defined than might be optimum.

One thing that did strike me was a gratifying amount of creativity, and I am referring to creativity as something distinct from intelligence. In my students' papers there were qualities of originality, imagination, and playfulness that I very much cherish. I don't expect, in a class of ten or so, to have five or six papers that show those qualities. Of course, I expected the students to be bright, but it was an unexpected joy to find them looking at things in a different way, giving themselves the freedom to write a little verse or making a drawing and obviously enjoying it.

JB: Do you feel we are educating for such creativity?

AK: It's hard to say, except that what I noted was in their work rather than in other sorts of areas where it might be more likely. I am not talking about wearing weird clothing. But it would be surprising to find creativity limited to just one area; you more commonly expect it to spill over. Somebody who allows himself to think imaginatively about a subject matter may also be thinking imaginatively about what he would like to eat or how he would like to spend his leisure time. Caltech is still very square in some ways, but I want not to be misunderstood about that. In the sixties a lot of people who thought of themselves as rebels were very square indeed; they were just conforming to a different norm, and I'm glad we're out of that—though I wouldn't suggest a return to the stereotype of the engineer.

JB: You were surprised 11 years ago at our attrition rate. It is still about the same—over a period of four years, about a third of a class will drop out for various reasons. Eventually, some of them will come back and finish, of course. Do you have any comments?

AK: I want to presume to express an opinion on an educational policy. I can very well understand that every university would like for its places to be occupied, as far as possible, by students who are progressing at a reasonable tempo toward some academic goal. But I believe it is not a proper function of a university, and certainly not of its faculty, to become disciplinarians of the personal habits and manners of the students, even with regard to learning.

It has always been my policy in some 35 years of teaching to allow students to turn in work whenever they have completed it, without any penalty because they did it at one date rather than another. To my dismay, I found that Caltech does not allow students to take incompletes and turn in their work after the close of the term. It would be more reasonable to require work to be completed within, say, six months of the end of a course, or by the end of the next term, or some such period. That means that we allow students some freedom to organize their own time.

I especially responded to this situation because the students who were taking my courses were taking something that was not central; whenever there was a conflict, they obviously had to devote themselves to the courses more important to their own educational objectives. As a result I had several students in each term withdraw in the last weeks. They simply could not plan to finish their work on time, and no other opportunities were being given. I fail to see that any good educational purposes were being served. A student who might have been able to learn and grow by making use of vacation time, or of other times when things weren't so pressing, is denied that opportunity when we say you must do your work at the time we say and not at the time you find most suitable for your learning. This may well be connected with the notion that discipline is good for the character. I don't want students to hang around who are just dilettantes, but I cannot believe that the only alternative is "hup, two, three."

JB: As a faculty member you would like to have the privilege of deciding who is a dilettante?

AK: Only of deciding when work can be completed, without having to go through rules and petitions, as though this were such a radical procedure as someone being asked to lend money without security.

JB: The expansion of the social sciences that you discussed 11 years ago has, as you know, taken place. What is your impression?

AK: I wouldn't presume to judge how it is working, but I do have the feeling that the "hard" approaches are still very much in the saddle. They are perfectly respectable and have a great deal to contribute, but I think they could do much more in another setting. To do it here is more of the same, and it misses out on a very important kind of contribution that could be made.

JB: That brings up the historical dichotomy between those who feel the humanities and social scienes at Caltech should stand on their own academically, and those who think of the division as basically to provide a service. Do you have an opinion on that?

AK: On that I have strong feelings. I do not believe that any department or division can flourish if it is only a service department. I couldn't really teach philosophy if it was only a service course, and the image of being somewhere where I would always be out on the fringe would be wholly intolerable to me, as I think it would be to anyone who was seriously concerned with his own field.

I don't think that issue should be confounded with that other issue of "hard" and "soft." If anything, I would say that the hardness at Caltech is a capitulation to the role of service. It says, "Let's talk to them in their lingo and do the kinds of things they do, because that's the kind of thing they understand best."

In a larger university I have always been in favor of balance as among these different kinds of approaches. If we can do only one, if the program can't be comprehensive and balanced, then a great deal depends upon the kind of university it is. When everything else around is hard, then I think it should be soft. Caltech is small enough that it really can't look to very great breadth. For instance, in a large enough philosophy department you would have Marxist, medieval Jewish and Arabic thought, and symbolic logic, but in a place like Caltech I wouldn't get into logic and set theory. There are plenty of places in mathematics where they can come as close to that as they need to. But I would do aesthetics and oriental philosophy because I don't know where else they can do that, and I would do it in a very serious way and not just as a gentleman's course.

JB: Dr. Kaplan, we've been talking for an hour, and I want to thank you very much for giving me that time.

AK: I appreciate your giving me this opportunity to look at my experiences and to give expression to some of my feelings. It strikes me that this is a minimum way of making better use of visitors. Perhaps it would be in the interest of the university in this period of transition to speak more with visitors about what they see in the educational scene. In any case, it is always nice to have people ask your opinion. Thank you. □

Retiring This Year

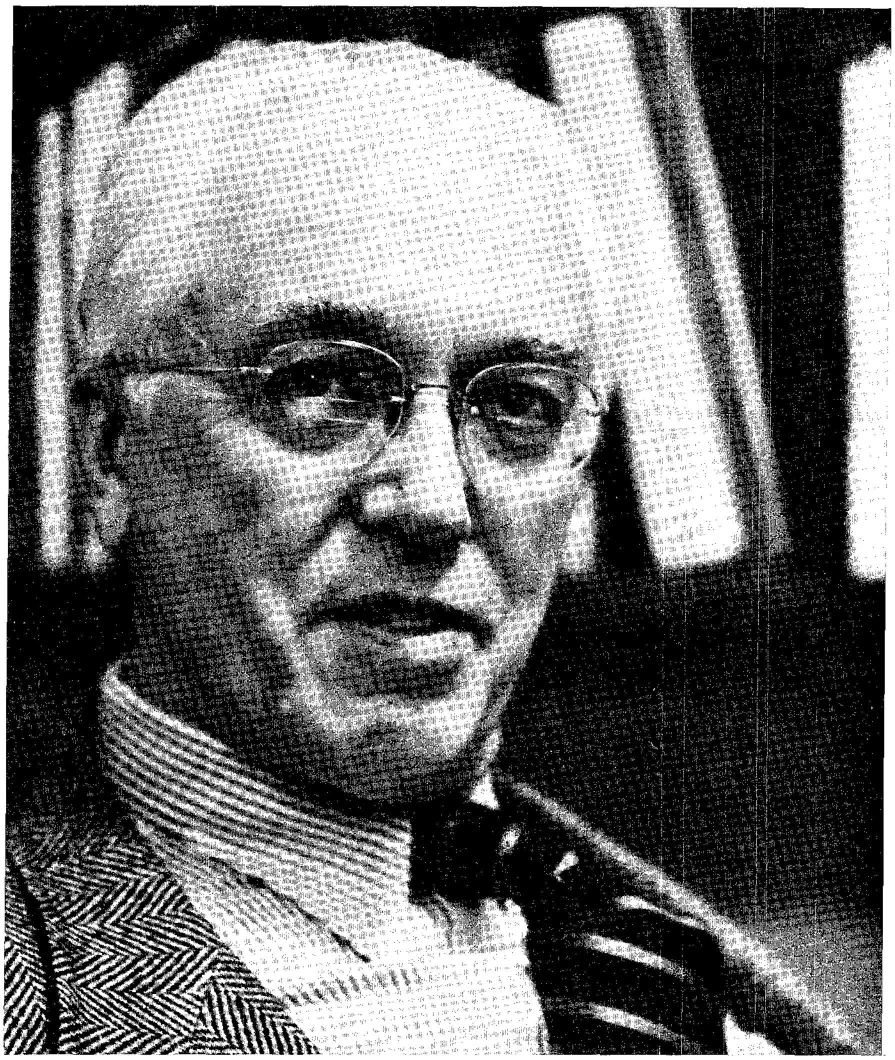
Pol Duwez
Professor of Applied Physics and Materials Science

Pol Duwez becomes professor emeritus this month after more than 30 years on the Caltech faculty. One of the world's leading scientists in the field of metals and materials, he has created a remarkable series of new alloys with unusual properties that are now widely used in industry. Born in Mons, Belgium, in 1907, Pol received his degree in metallurgical engineering at the School of Mines there in 1932, and his DSc in physics and mathematics from the University of Brussels in 1933. He was a research fellow in physics at Caltech from 1933 to 1935, then returned to Belgium as a Fellow of the National Foundation for Scientific Research at the School of Mines from 1935 to 1937. From 1937 to 1940 he was director of the National Laboratory for Silicate Research there. In 1941 he became a research engineer working on defense projects at Caltech, moving up to JPL in 1944, where he headed the Materials Section until 1954. He was an associate professor of materials science at Caltech from 1947 to 1952, when he became a full professor. As devoted to music as he is to metallurgy, Pol was destined for a career as a cellist until he was 10 years old and has continued to play the cello all his life.

Retiring This Year

Milton S. Plesset
Professor of Engineering Science

Milton S. Plesset becomes professor emeritus on July 1. Born in Pittsburgh, in 1908, he received his BS (1929) and MS (1930) from the University of Pittsburgh, then went to Yale for his PhD (1932) in physics. In 1932-33 he was a National Research Fellow at Caltech, then studied for a year at the Institute for Theoretical Physics in Copenhagen, and in 1934-35 was a C.R.B. Traveling Fellow. From 1935 to 1940 Plesset was an instructor in physics at the University of Rochester. He returned to Caltech as a research fellow in physics in 1941, but left in 1942 to head the Analytical Group of the Douglas Research Laboratories at the Douglas Aircraft Company. In 1945 he served as technical representative to the Air Force in the European theater. He became associate professor of applied mechanics at Caltech in 1948 and was made a full professor in 1951. In 1963 he became professor of engineering science. He served as consultant to the Science Division of the RAND Corporation from 1948 to 1972, and he has been a consultant to the Energy and Kinetics Department at UCLA where he was appointed adjunct professor this year.
An authority on the problems and progress of nuclear power, he served as a member of the US Advisory Committee for Reactor Safeguards since 1975.



Robert D. Wayne

Associate Professor of German

Robert D. Wayne retires this month after 26 years on the Caltech faculty. He came to Caltech in 1952 as an instructor in German, became an assistant professor in 1962, and associate professor in 1969. Born in Seneca Falls, New York, in 1913, Bob got his BA degree from Dickinson College in Carlisle, Pa., in 1935, then spent a year in graduate study at the University of Tübingen in Germany. From 1936 to 1938 he was a casualty insurance adjuster with the Liberty Mutual Insurance Company in Boston. And in 1939-40 he worked in New York City and Washington for the Good Will Fund, as a translator on a research project investigating German subversive activities in the United States. In 1938 he became an instructor in German at Columbia University, where he received his MA in 1940. He joined the Army in 1941, was assigned to Military Intelligence in the North African, Mediterranean, and European theaters, and was released, as a Captain, in 1946. Before coming to Caltech, Bob served as a teaching assistant and lecturer in German at UCLA, where he was a doctoral candidate. Neatly enough, Bob's wife, Mary Helen, is also retiring this June as City Librarian of South Pasadena, and the first thing the Waynes are going to do about their joint retirements is take a trip to England out of season.

 . . . continued from page 17

developed in the next decades. One promising direction at the present time involves putting small amounts of hormones into the uterus to prevent pregnancy. These hormones are released very slowly so that the doses involved are safer than current ovulatory suppressants and the effective time spans longer than present techniques allow. Another approach involves the development of a safe, reversible chemical intervention in males—a step forward that should be a welcomed divergence from the over-concentration on contraceptives for women. Still another involves practical applications of prostaglandins.

Even given this future promise, however, we will need a deeper understanding of the reasons why present contraceptive technology has been taken up so slowly and haltingly in many parts of the world. It has become increasingly clear that the introduction and dissemination of contraceptives have often come into direct conflict with deep-seated traditions and cultural norms. In many societies, for example, it has long been believed that it is very desirable, and even necessary, to have large families —or, more accurately, to produce many sons. That belief, taught early in life and invested with strong emotions, is very hard to change. Such attitudes are obviously antithetical to many contraceptive and population-control strategies. Increasingly aware of such problems, the World Health Organization (WHO) is now paying attention not just to the biological nature of contraceptive techniques, but to their more general acceptability as well—culturally and socially. Future work in this area is likely to be critical to the development of reproductive patterns that are compatible with decent standards of living and healthy populations.

The international health area is also likely to achieve much greater research and service attention in the next decades. It is already clear that many relatively simple public health measures would help ease the international burden of illness enormously. There are about a billion people in the world who cannot conveniently and safely drink or wash with water. There are hundreds of millions of people without even minimum sanitation facilities. In the future this problem will probably be tackled village by village with sanitary reform, as exemplified by the use of hand pumps in Pakistan and some other countries. These simple instruments do much to prevent disease by drawing needed water from underground rather than relying on the disease-laden surface water. Such combinations of medicine, engineering, and the behavioral sciences are hopeful signs. The science base of the biological revolution can and will be applied to tropical diseases. Another hopeful sign is that the WHO is establishing collaborating networks of laboratories around the world to address the massive health problems of the developing countries. One program that is quite successful is concerned with human reproductive biology, and another that is showing much promise focuses specifically on tropical diseases.

The whole field of vaccine development and use is of special promise in the next decades. We have seen just this year the culmination of a remarkable effort led by an American, D. A. Henderson, in the WHO, that seems to have virtually eradicated smallpox throughout the world. Yet this success story is still an exception in the vaccine area. Vaccines are clearly not being utilized to their full potential, particularly internationally. For example, measles is a much more serious problem in developing countries than it is in the United States. When measles occurs in the context of malnutrition, which is pandemic in much of the world, the probability of also suffering encephalitis and some lasting brain damage is relatively high. Therefore, the potential utility of the measles vaccine for furthering disease prevention in the developing world is even greater than in the U.S.—although the value to this nation of the vaccine is also high.

The U.S. record on vaccine utilization, incidentally, is rather grim. In 1974 only about 67 percent of white children and 45 percent of non-white children in this country from ages 1 to 4 had been vaccinated against polio. The comparable figure in northern European countries is above 90 percent. It thus seems that in our own nation there is a "less developed" subnation that shares many of the health deficits borne by other countries. In any event, the utilization of existing vaccines in developing countries is certainly a field in which much progress will be made in the years ahead.

We can hope that the role of the United States in tackling international health problems will increase. It is probably accurate to say that this country has more strength in biomedical and behavioral sciences pertinent to health than all the rest of the world. But only a tiny fraction of this capacity is directed toward the problems of the developing countries. If the United States were to shift a part of its health research attention to the needs of other nations—and have a sizable cadre of our most skillful health professionals working on these matters instead of just a handful—the impact on worldwide health status could be very great.

The hazards of predicting future trends in the biological and clinical realm are great enough; the hazards of such prediction in the social realm are greater still. The vast scale, the heterogeneity within and among societies, the great impact of scientific and technological change, and the consequent social ramifications are beyond any guidelines provided by human history. All these make predictions terribly difficult, and yet a few words should be added about future developments in this country in the area of the organization of medical care.

There appears to be a great determination in this nation at present that, one way or other, a system of national health insurance should be developed. The United States is the only industrialized country in the world that does not have either a system of national health insurance (NHI) or a directly operated national health service. While it is unlikely (for a variety of social and historical reasons) that a directly operated national health service will be established, even by the 21st century, the gradual phasing in of an NHI system over the next few decades is likely. The benefits provided will probably be narrowly defined at the outset. Some phrase like "a decent minimum" will limit benefits initially, although reasonably adequate care in many spheres will be covered, including at least modest coverage for those neglected twins, dental and mental care.

In the early years of this system, coverage will focus on curative efforts with less emphasis on prevention; later, the prevention approach will become more prominent. Protection against financial catastrophe resulting from health problems will probably be a cornerstone of the plan, although individuals would possibly be expected to bear some significant part of the cost in relation to personal income. For decades to come, a mixed public and private system, rather than a monolithic, totally public system, is envisioned. Because of this country's history of adapting existing institutions to new functions, national health insurance will probably build on current arrangements rather than construct wholly new ones.

The advent of national health insurance will bring multifaceted cost controls in the health area, linked in some way to simultaneous assurances of the quality of health care. An example of this coupling of cost control and quality assurance would be the completion of scientific studies indicating that the use of a certain high-technology, hospital-based technique is unnecessary in specific instances and also highly risky. Based on these findings, the administrators of the health insurance system might well deny coverage for inappropriate uses of the technology. From this action, use of the technology would diminish. This utilization decrease would reduce certain costs, and at the same time improve the quality of health care by avoidance of unnecessary risk. Not all cases will be so clear-cut, but the principle is one of growing importance.

One of the fundamental concepts that will undergird this future system is that the insurance coverage will apply only—or primarily—to services that have been validated scientifically, so that risks and benefits are clearly documented. The costs to the nation of paying for interventions that have not been proved effective, or have unacceptable risk/benefit ratios (a determination that is initially technical but ultimately social) will be of great concern. Consequently, as a cost-control as well as a quality-control measure, validation and assessments of interventions will be required before they are widely disseminated or covered under an insurance plan.

Today, of course, insistence on careful study of a technology before its widespread use is not generally the case. For example, the use of computed tomographic scanners, or "CT" scanners, has generated much public interest. CT scanning is a recently developed technique that combines radiographic and computer techniques to produce cross-sectional images of the head and body. Whereas conventional X-ray films show internal structures superimposed upon each other and, therefore, are best suited to high-contrast structures such as bone, the CT scanners can produce high-quality images of soft-tissue structure. CT scanners have not only been developed for diagnostic visualization of the head, but also for the full body.

This technology has been adopted in in this country on a massive scale (more than 800 head scanners are now in place), at great expense both at time of purchase and in maintenance and operation. This dissemination, however, has occurred prior to the completion of studies to determine appropriate use, accuracy of diagnosis, risks, and so forth. In the absence of such research, insurance companies and public third-party payers have faced difficult decisions in establishing policies for the reimbursement of scanner use, because the evidence for both the risk and benefit is sometimes no more than a clinical impression.

It has long been true in medicine that interventions have gained great popularity even in the absence of careful efficacy and safety assessment. Often society has relied on wise people making shrewd observations to adjudicate risks and benefits. Sometimes, however, this "wise man" approach leads to unfortunate mistakes. For example, radiation of the neck for various alleged preventive purposes many years ago now appears to cause cancer of the thyroid. Through hindsight, these risks became evident. With new awareness of costs and the need for assurances of benefit that a publicly financed health insurance scheme will bring, more casual and impressionistic standards of evidence will gradually give way to more rigorous methods.

Another example of this efficacy/cost issue is presented by linear accelerators. Small linear accelerators, which were constructed after the large accelerators such as that at Stanford University had been developed, have been used to treat cancer patients. One might logically wonder whether or not the larger linear accelerators or other high-energy physics machines would also be of use in cancer treatment. Years ago, the cost of constructing the two-mile Stanford Linear

Accelerator Center was about $114 million; in current dollars, the cost would be much greater. What will happen if it becomes clear that there are specific cancers which can be cured only by treatment with such enormous machines? Will they appear in every doctor's office, costing a quarter billion dollars? Clearly not. There will have to be some kind of system (a) to insure that the therapy is both efficacious and of an acceptable cost/benefit, risk/benefit ratio; (b) to spread that cost in some equitable fashion; and (c) to ration access to the machine in some appropriate way. Such requirements will probably mean that as new, expensive treatments are developed, reimbursement or even use of the treatment will be contingent on the provider and/or patient being enrolled in a national, carefully controlled clinical trial. Such trials are the only mechanism currently available to generate the risk/benefit data required for the rational use of health care resources. They can also assist in controlling the dissemination and proliferation of technologies that have not been adequately assessed.

One further aspect of the organization of health care that is likely to be increasingly important in the future is the multi-specialty group practice concept; one branch of this tree has come to be called "health maintenance organizations," or HMO's. The pooling of physicians and other health professionals is clearly a concept that will gain increasing utility in the years ahead. It is easier for health professionals to keep up with new developments if a collective approach is taken. It is easier to provide 24-hour, 7-day coverage and emergency services through a group practice rather than through a solo practitioner. At the same time, it is possible to preserve to a large extent the individual doctor-patient relationship. Group practices seem to produce a kind of mutual-aid ethic, which will probably continue to grow, in the form of more health maintenance organizations, and other forms of organized health care settings will increasingly be linked to the workplace. In any event, both the workplace and the school are likely to be used more for preventive medicine and health education.

While the developments sketched here seem reasonable to project over the next several decades, it is possible that transforming influences beyond our present vision may have impacts far beyond those noted. The world we have made through science and technology since the Industrial Revolution has little precedent. As we move into a complex future at rates of change unknown to our early ancestors, we must develop a broader science base and a more compassionate society, not only to cope with disease and disability, but to improve the quality of life altogether—and perhaps even to survive as a species. □

Books . . . continued from page 3

represented in this volume, it is impossible to identify any single unifying viewpoint. Nonetheless, all of the essays do seem to address certain basic questions. One of them concerns identifying the problems future generations will have to face. Can we predict with accuracy the nature and extent of future world problems? Brown and his colleagues are pleased with their past performance. On the whole, Brown tells us, their "batting average" has been pretty good. Twenty years ago, for example, they predicted that there would be close to five billion people inhabiting the earth by the year 2000. As things stand in the seventies, the world population is currently over four billion and still rising. They also predicted that petroleum production in the contiguous United States would peak in 1970, and this too proved to be correct.

At the same time, there were notable failures. In addition to neglecting environmental problems and not foreseeing the vulnerability of industrial societies to boycotts of essential materials and services, Brown and his associates, like others in the fifties, overestimated the demand for PhD's in engineering and science. Moreover, while they predicted the depletion of petrofuel resources in the United States, they were overly optimistic about the future of nuclear energy as a replacement. They did not anticipate the rising concern for public safety in the seventies.

What this seems to suggest is that both changes in conditions per se and in social goals and values can complicate the task of prediction. Viewed retrospectively, the supply and demand of nuclear energy depended upon changing perceptions about the value of a safe environment, as well as upon the costs of development and the availability of resources. Apparently our success in predicting future problems hinges in part upon our ability to say what the goals and values of future generations will be, and that is a very difficult task.

Can one identify future world problems with a high degree of accuracy? Most social scientists think not. The future is characterized by too much uncertainty to project accurately 100, 90, or even 80 years ahead. On the other hand, thinking about future world problems might still be a valuable exercise per se if it forces us to consider the long-range implications of the choices we make now, or if it brings us to think about the obligations we owe to future generations.

A second concern uniting these studies is whether we have the technology to solve anticipated problems. I detect an important progression in attitude on this question from the first to the third book. In *The Next Hundred Years* the authors were extremely optimistic about the prospects of discovering new technology and applying it to solve the world's problems. Commenting, for example, on the issue of food shortages, they said in 1957, "If we can produce sufficient quantities of energy and expend it properly in the production of food and materials, we can meet the demands we foresee for the future. All we need do is add sufficient energy to the system, and we can obtain whatever materials we desire."

Twenty years later, that optimism had dimmed somewhat. As James Bonner points out, despite the Green Revolution in agriculture, the food situation in the third world has deteriorated: 65 percent of the third world receives 250 calories less than is required for optimum nutrition. Moreover, during the last eight years, the food *deficit* has grown at a rate of about 1 percent per year in the developing countries despite a 10 percent increase in the tilled acreage of the world and a higher production per acre due to more irrigation, more fertilizer, high-yielding strains of crops, disease-resistant plants, and the saturating use of pesticides.

Why haven't technological advances solved the food crisis? Bonner cites several factors. One is that while food production in the underdeveloped countries increased by 1.5 percent per year, population increased by 2.4 percent. World problems tend to be interrelated; you can't solve one without addressing the others. Another constraining variable is that the technology of higher food production has inherent limits; as Bonner explains: "The Green Revolution can only work in places that are good for agriculture, with good climates, good water supplies, good soils. It is not yet suitable or applicable to tropical soils, which, when denuded of their hardwood canopy, quickly become eroded and sterile." Thirdly, and perhaps more importantly, there are social and political constraints: the obsession of developing-nation politicians with impressive projects to the neglect of agriculture, corruption, extreme maldistribution of income, and cultural prejudices that favor inefficient meat over vegetarian diets.

One cannot help but notice the progressively political orientation of these studies. In 1967, the contributors to *The Next Ninety Years* still had faith in technology, but they were more conscious than they had been 10 years earlier of the political and social dimensions of world problems. "Science and technology," they told us then, "have given us the power to create a world in which virtually all people can lead free and abundant lives . . . yet, somehow, we can't seem to organize ourselves to use that power effectively to solve mankind's basic problems." Political factors figure even more prominently in *The Next Eighty Years*. With a few exceptions, the contributors to the third volume touch upon political and behavioral as well as technological problems.

This leads us to the third question; namely, can we effectively implement the technology we have, in order to solve world problems? There are two reasons to be guarded in our optimism about these matters. First, decisions about which goals to attack inevitably involve disagreements over priorities, and these priority conflicts can stand in the way of solving problems like poverty and starvation. The contributors to *The Next Eighty Years* offer several examples.

Thayer Scudder writes of the biases in African states in favor of the urban-industrial sector. Agricultural prices are often kept artificially low for the benefit of urban consumers, and showcase projects like dam construction are designed primarily to provide hydroelectric power for the city and industries with little regard for the impact on local rural communities. An obsession with military power is another common competing priority.

Marcus Franda explains how the Indian government's obsession with maintaining a large army—the third largest in the world—diverts valuable resources from health care, agricultural development, and antipoverty programs. Given that none of the Indian political parties dares to advocate diminishing India's military capabilities, Franda despairs of reallocating much "of India's resources out of military-strategic and heavy industry kinds of things and into rural-oriented development matters."

The problem of conflicting priorities does not belong exclusively to developing nations. Other priorities may prevent industrialized nations from tackling the energy crisis or dealing with world poverty. A greater appreciation for the environmental costs of unrestrained development may restrain us from fully exploiting our energy resources. Moreover, as John Teem points out, "trade-offs that are politically desirable in developed countries may be viewed from quite a different perspective in the less-developed countries." Developing countries may not "want to pay the necessary costs for a clean environment, to the same extent that the developed countries do." Such post-industrial second thoughts may create real obstacles for developing countries in the future.

Even when a nation decides that it really ought to do more about poverty, circumstances can conspire to prevent it from carrying through on its resolve. As Maydon tells us, Mexico wanted very much to redirect its efforts into the industrial sector during the seventies but found that the need to slow down growth in order to correct a growing deficit in the balance of payments and the difficulty of redirecting funds from old to new priorities thwarted its intentions.

Thus, divisions in goals and priorities can make it hard for society to organize itself effectively in order to apply technology to the solution of pressing problems. Sometimes, however, institutions that mediate conflicts over goals can become obstacles themselves. The function of a polity is to provide a mechanism for making and enforcing public choices where there are conflicts over goals and values. One of the real dangers in developed countries is that their political and economic systems may ossify and become institutionally resistant to beneficial change and innovation. Michio Nagai hints at this prospect in Japan and suggests that, like Britain before it, Japan may lose its industrial preeminence to upstart competitors like South Korea.

Even when technological innovation offers the prospects of material improvement, there are strong incentives in developed economies to continue with the old technology. Studies have shown how it is often in the interest of both managers and workers to inhibit competition in the market, and to slow down the rate of technological innovation even when it is not in the long-range interests of the society as a whole. In addition, the role of vested interests in political parties and the desire of politicians not to rock the boat can bring the force of the government on the side against innovation and change. This has been the bitter experience in Great Britain during the last 25 years.

Thus, the key issue for the future in America may not be a particular set of problems per se but whether our political and economic institutions will be prepared to deal with new problems, whatever they turn out to be. Can we design our institutions so that people cooperate efficiently but without excessive coercion? Can we undermine the incentives that are resistant to change and innovation and prevent the ossification of political and economic institutions in countries like Britain, the United States, and Japan? These are the questions that emerge finally from these studies, and that require the urgent attention of scientists and social scientists alike.

Bruce E. Cain is an assistant professor of political science at Caltech.

DYNAMIC ECONOMICS

by Burton H. Klein

Harvard University Press $15.00

Reviewed by Edward A. Schroeder IV

Those of us who took Professor Burton Klein's course on the economics of technology at Caltech several years ago used to wonder if he would succeed in getting his many ideas collected together in written form. The book finally made it into print in 1977, as *Dynamic Economics.* The delay in publishing was probably just as well, since many of the references in the book are to work published in the last few years.

Several of this wide-ranging scholar's favorite subjects show up in this book: Thomas Kuhn on scientific revolutions (briefly), Thomas Jefferson's ideas on dynamic processes (frequently), and the history of the automobile and aircraft manufacturing industries (in detail). It is a pleasure to read an economist who can make use not only of various material from economics but also such diverse subjects as thermodynamics, Maslow's theories of personality, Feynman and Heisenberg on science, and various issues in engineering.

I believe that most economists have a far better grasp of the "static" than they do of the "dynamic." In fact, when many so-called dynamic models are really only embellished static models, it seems fair to say that economists have not yet agreed on how to approach dynamic questions, although we can agree on their importance. To his credit, Professor Klein has taken on difficult questions in his book; the answers to these questions will not come easily.

Professor Klein argues that the traditional economic concept of efficiency is a static one, and that a new dynamic concept of efficiency, which may well be in conflict with static efficiency, is needed in order to answer the real questions about an economic society. His dynamic definition of competition is quite different from the standard approach. His policy prescriptions for promoting private inventive behavior through public promotion of proper risk is certain to be controversial.

The book, of necessity, covers only a small part of what is required in order to develop a useful, workable theory of dynamic economics. However, I believe that Professor Klein's insights and wide range of interests have produced a book that will be of help to future investigators in this area.

Edward Schroeder, '70, is now teaching economics and management at California Lutheran College in Thousand Oaks.

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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.

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