Summer 1981

Oak Ridge National Laboratory

review

The COVER: Donna Woodard grows a culture of mouse x human hybrid cells containing both human and mouse genes that were introduced into the cells by cell fusion. See "Genes and Cancer," p. 36.

Oak Ridge National Laboratory

review

VOLUME 14 NUMBER 3 **SUMMER 198**

DEPARTMENTS

Editor
BARBARA LYON

Staff Writer
CAROLYN KRAUSE

Consulting Editor
ALEX ZUCKER

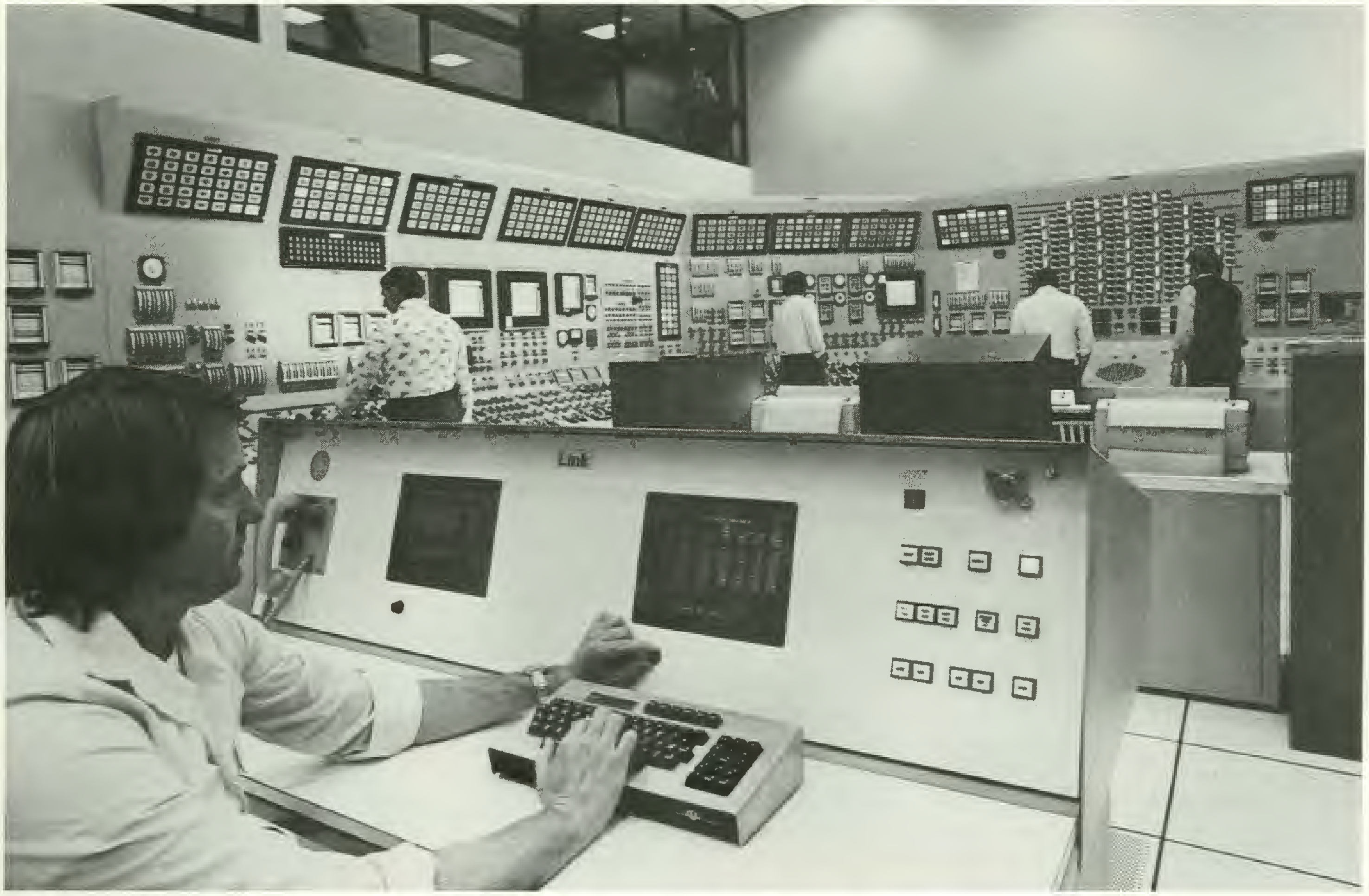
Art Director
BILL CLARK

Publication Staff: Technical Editing/Lydia Corrill; Typography/Betty Littleton; Make-up/Ginger Turpin; ORNL Photography and Reproduction Departments.

The *Review* is published quarterly and distributed to employees and others associated with the Oak Ridge National Laboratory. The editorial office is in Building 4500-North, Oak Ridge National Laboratory. P.O. Box X, Oak Ridge, Tennessee 37830. Telephone: Internal 4-7183; commercial (615) 574-7183; FTS 624-7183.

ISSN 0048-1262

OAK RIDGE NATIONAL LABORATORY
OPERATED BY UNION CARBIDE CORPORATION · FOR THE DEPARTMENT OF ENERGY



The Browns Ferry simulator is a computer-run, full-scale mock-up of the actual Browns Ferry control panels. In the foreground, a training center staff member programs and monitors the simulator as the trainees learn procedures for start-ups, shutdowns, and accidents. (Photo credit of Tennessee Valley Authority)

The Human Factor of Reactor Safety

A control room operator at a pressurized-water reactor looks up as an alarm sounds and rushes to the control panel. As he reaches up to silence the bell, he calls to the senior operator sitting at the control room desk, "It's the ice-condenser door again." He quickly checks the instrument panel for measurements of containment pressure and radiation, coolant temperature, steam-generator pressure, and pressurizer level and pressure. He scans the control board for any indication of leakage of primary coolant, which is needed to prevent the reactor from overheating and releasing radioactivity.

The ice condenser in this plant is a design feature intended to help reduce containment pressure in the event of a malfunction such as loss of primary coolant. Seeing no further indication of problems, the reactor operator returns to the control room desk. This time he does not walk behind the central control panel to check the containment humidity reading; had he done so, he would have observed a rising humidity—a clearer sign of a potential coolant leak than the readings on the other instruments. Instead, the operator reacts much like his colleagues who have heard the ice-condenser door alarm when there was no apparent cause and have come to consider it a "cry-wolf" alarm which deserves attention but is not likely to signal a real accident.

About ten minutes later, the control panel erupts in a display of alarms and flashing lights indicating a reactor scram—a sudden shutdown with automatic activation of the emergency core-cooling system. The operators quickly identify the cause—a small loss of primary coolant. Then they verify that the automatic safety systems are operating and take the manual action required to safely shut down the plant.

This imaginary scenario, although somewhat contrived and melodramatic, illustrates a few typical problems in an area of real concern—the ability of nuclear power plant operators to identify emergencies quickly and respond accurately and efficiently to them. As this example clearly shows, factors affecting reactor operators' responses in an emergency may include the existence of indicators that do not give specific information on what is going wrong (ice-condenser door alarm) and the poor placement of indicators that can identify the specific problem (humidity meter).

For the most part, necessary actions immediately following severe emergencies are automated. The operator, however, plays a critical supervisory role in ensuring correct and continued operation of automated systems. He also often controls plant systems manually as the accident runs its course. In many cases, the operator is given the option, within proper supervisory restrictions, to override automatic systems. In less severe accidents or "abnormal incidents," the operator can take manual action to resolve the problem without shutting down or at least can bring the reactor to a controlled shutdown over a period of time, which works less of a hardship on the plant than does a scram.

The Human Factor

Before the reactor accident at Three Mile Island in March 1979 (which was caused by a combination of mechanical and human errors, including the overriding of an automatic safety system by an operator), a few specialists in human factors had been called upon by the Electric Power Research Institute and the U.S. Nuclear Regulatory Commission to examine control rooms in nuclear power plants and evaluate them from the standpoint of human engineering. They concluded that there is indeed room for improvement in the design of control rooms to aid the operator in performance of the job, particularly during the highly stressful minutes following an emergency.

The TMI event and subsequent reviews revealed that a great need exists to apply human factors principles to the design and operation of nuclear power plants and that a considerable amount of research and longer-term studies will be required. Personnel selection, training and education, procedures systems, control board design, diagnostic information systems, management structure, staff motivation—these and other aspects of the total system of interaction between human and machine need to be examined more formally and rigorously. Thus, the NRC has initiated sizable programs dealing with human factors in both its licensing and research offices and plans to carry out a major portion of the research effort at ORNL.

One critical need is data on operator performance. In 1978, ORNL became involved in starting work in this area through the Safety-Related Operator Actions Program headed by Paul Haas of the Engineering Physics Division. At that time, an EPD project of building a national data analysis center for breeder reactor reliability was under way. That program concentrated on data on equipment failures, but as the EPD staff began to examine records of incidents at DOE breeder reactor sites, the importance of the human factor became apparent. After expressing an interest to the NRC in operator performance on light-water reactors, Haas and his former co-worker Terry Bott were asked to collect and assess data on operator performance during emergencies as part of an effort to develop an industry design standard to determine whether key safety-related actions should be automated or handled by operators.

Experiments on Simulators

As a result of that study a program of controlled experiments

"...there is indeed room for improvement in the design of control rooms to aid the operator in performance of the job..."

was proposed in which performance data would be collected on operators responding to simulated abnormal incidents or emergencies on a full-scope nuclear power plant simulator. This program, begun in March 1980, is currently being carried out by General Physics Corporation, an ORNL subcontractor, under Haas's direction. In cooperation with the Tennessee Valley Authority and other participating utilities, General Physics gathers information on operator performance on simulators at the TVA Training Center in Soddy-Daisy, Tennessee.

The simulators are virtually exact replicas of the reactor control rooms at TVA's pressurized-water reactors (Sequoyah) and boiling-water reactors (Browns Ferry). Computer hardware and software simulate both normal and abnormal reactor behavior. The simulator permits collection in a short time of more extensive data than would be accumulated in years of operating experience. Software developed previously by General Physics for EPRI produces precise, automatic recording of operator actions.

One problem, of course, is the difference in environment between a controlled simulator exercise and the real-world operation of a nuclear power plant. To quantify this difference and thereby "calibrate" the simulator data, the initial part of the program has been to collect field data—information from records of accidents that have occurred in operating plants—on the same type of events used in the simulator exercises. The field data collection is being performed under contract by Memphis State University's Center for Nuclear Studies, which has experienced commercial nuclear plant operators on hand to assist in the evaluation of recorded data and interviews with operators. The selected event scenarios range from relatively minor events, such as an instrument failure, to rather serious but not catastrophic accidents, such as a small loss-of-coolant accident.

If a calibration can be obtained, data from more extensive simulator experiments can be extrapolated with some confidence to predict performance under actual emergencies. The data can be used to help develop the desired criteria for manual vs automatic action and will be useful to a number of NRC and industry efforts in the areas of operational safety, human factors, and risk assessment.

What Shapes Performance

Through continued collection and evaluation of experimental data, it should be possible to identify and perhaps quantify "performance shaping factors" that have a significant impact on the operator's ability to respond effectively. These performance shaping factors might include, for example, psychological stress, procedures, and adequacy of control board design, especially diagnostic displays. Recommendations for changes to improve performance could be made to reflect this information.

Problems identified earlier by human factors analysts, such as the "cry-wolf" alarm illustrated by the ice-condenser door example and the poor placement of instruments such as the containment humidity meter, have already been observed in the simulator experiments. Problems with procedures, such as references to instruments and valves in manuals that are inconsistent with labels on the control panel, have also been observed, as have diagnostic information displays that are not specific enough to permit prompt identification of failed equipment.

After the field-simulator calibration study is completed this fall, plans call for continued simulator experiments to add to the statistical data base and to investigate key performance shaping factors. For example, one set of controlled exercises might investigate the difference in performance of operators using new (post-TMI) symptom-based procedures vs old event-based procedures. Other experiments might examine the effects of operator training or the impact of modifications to control panel design. Continued collection and careful assessment of information on operator performance should contribute greatly to a data base that has heretofore not existed. By observing people in action and recording their behavior under stressful conditions—a program unlike most conducted at ORNL—program participants hope to gather useful data that will ultimately improve the safety of nuclear power plants. ornl

readers' comments

To the editor:

Does that glucose sugar referred to on page 45 of the Winter 1981 issue of the *Review* ["Biomass into Energy: What Are the Environmental Effects?"] ferment to ethanol alcohol? Does that fermentation perhaps produce a small amount of acetone ketone as a by-product?

W. M. Woods
114 Tabor Road
Oak Ridge, TN 37830

Jim Schreyer, who provided information to the *Review* on fermenting biomass to fuel alcohol, replies:

To answer Mr. Woods's first question, as stated in the article, glucose is converted directly to enthanol by fermentation. The second question requires a more detailed answer. In unsanitary conditions, contamination with undesirable microorganisms during fermentation can reduce the yield of ethanol and produce toxic substances as by-products. However, this would not reduce the value of the product for use as liquid fuel—the purpose of our process. Under sanitary conditions, yeast converts glucose sugar into ethanol and carbon dioxide by an anaerobic process. Small quantities of fusel oil, succinic acid, and glycerol are also obtained. Yeast designed for distillers' use is available commercially. This product has been found to work well for sugar beets, sugarcane, molasses, or converted starchy grains. The ethanol production for beverage consumption uses only top-quality farm products. For use as liquid fuel, below-grade grains, crop culls, and agricultural wastes can be used for the production because all by-products are combustible.

To the editor:

We read the interesting paper, "Golden Days—or Brass?" by Herb Inhaber in the Winter 1981 *ORNL Review* and offer the following comments:

1. The main point of the article is to debunk the "rosy haze that has settled over the period of the last two or three decades—it was a time of cheap and abundant energy." The article later points out that the "golden days were the late sixties and early seventies, when energy prices were at their lowest level of the three decades." Inhaber is correct in his assertion about when prices were lowest; but *whose* myth is he debunking? Who claims that prices were lower in the 1950s than they were in the late 1960s?

2. The article's discussion of trends in residential energy prices ignores three important issues. First, although prices may be no higher now than they were 15 to 20 years ago, the *direction of change* (i.e., the first derivative) is different. Real (corrected for inflation) energy prices are now increasing, whereas they were decreasing until about 1970. Because of this, people's *expectations* for the future are different. Finally, our *capital stocks* (automobiles, homes, heating, equipment, appliances) are economically inefficient at today's fuel prices and are becoming increasingly so as prices rise further.

3. As an example of the points noted in #2, consider changes in residential electricity use. Between 1950 and 1970, average household consumption increased from about 1900 to 7000 kWh (an average annual growth rate of almost 7%). Between 1970 and 1979, on the other hand, consumption increased at less than 3% per year (to 8800 kWh). In discussing energy costs, one must consider *consumption* as well as *prices*. Indeed, if one normalizes by household income, the relevant comparison is expenditures (consumption × price) and changes in shares of income spent on different fuels. While Inhaber's ratio of price to income shows a *decline* for electricity between 1965 and 1978, the share of income spent on electricity increased from 1.6% in 1965 to 2.0% in 1978, a 25% *increase*. The difference arises when one considers consumption as well as prices. The increase in consumption is due to a variety of factors—more electricity-using equipment in homes, larger appliances, and shifts from gas and oil equipment to electric equipment. For example, only 2% of the nation's homes were electrically heated in 1960; in 1977, about 15% of the homes were electrically heated.

4. Inhaber normalizes prices by *family income* without offering any basis for doing so. Economists generally normalize retail prices by the Consumer Price Index. Also, use of family income is misleading

because it excludes households that are not families. In 1978, for example, about one-fourth of the nation's households were not "primary families," as defined by the Bureau of the Census.

5. The article provides data only through 1978. However, monthly press releases from the Bureau of Labor Statistics and the Department of Energy's *Monthly Energy Review* provide more recent information that could have been used in lieu of the question mark and the assumptions made in the article. This is important because of the dramatic increases in fuel prices during 1979 and 1980. For example, the real price of gasoline (adjusted for inflation using the BLS CPI) increased by 22% between 1978 and 1979 and by almost 50% between 1978 and 1980. Publishing an article on energy prices that ignores the existing data on these dramatic price increases during the previous two years is puzzling.

Eric Hirst
Jackalie L. Blue
Energy Divsion

Inhaber replies:

1. Whose myth? The energy literature is replete with references to the "cheap energy" days of a decade or two ago. To choose one at random, Bud Keyes, president of Bailey Controls Company, recently referred to "... 1946 through 1973 (what you might call the golden age of free energy...)" (*Energy Daily*, April 9, 1981). Far more examples could be supplied; lack of space precludes listing them here. To satisfy myself on this score, after I had done the research for the article, I informally polled a number of my colleagues (not Hirst or Blue) on what were the days of "cheap" energy, however they defined it. With few exceptions, they said it was before 1973. I then concluded that the myth was indeed widespread.

2. It is incorrect to say that the article "ignored" people's expectations on energy prices. On page 15, column 3, I said, "People come to believe that the trends (of falling relative prices)... are laws of nature, rather than economic coincidences." It is true that the article is not primarily about psychology, but it never pretended to be.

3. The direction of change of relative energy prices was not ignored; it is clearly shown in the only graph in the article. Most of the text is concerned with how these prices varied over time.

4. What is meant by "efficiency" or "inefficiency" of capital stocks is a matter of debate among economists. Clearly this is a question for another article and could not be treated in any detail in mine.

5. I did not "ignore" the question of why the average family's total energy costs are higher now than they were in the 1950s. On page 15, column 3, I noted that "our bills are greater mostly because we have more appliances and drive more." This statement was also part of a prominent tag line at the top of the page. However, the article was not primarily concerned with total bills, but with marginal ones, that is, how much it costs a family, in terms of their income, to buy one more gallon of gasoline or kilowatt-hour of electricity. This, I submit, is more important in terms of energy policy than the total energy bill each family pays.

6. It is true that economists often use the Consumer Price Index to "normalize" energy prices. However, Hirst and Blue supply no basis for normalizing by the CPI other than that some economists do it. A reasonable basis for normalizing by family income was supplied on page 12, column 3. It was explained there that families generally do not make economic decisions on the basis of the latest CPI, but rather on how much money they have available.

7. The point about households and families is a technical one. The reason family income was used, rather than income of families and "unrelated individuals," as the Census Bureau puts it, is that data on family income were available back to 1950, whereas the latter set of data was not. If Hirst and Blue have a data source other than the *Statistical Abstract of the United States*, I would be pleased to see it. In any case, for recent years there is an almost-perfect correlation between average family income and that for families and unrelated individuals. Because my conclusions dealt with ratios, not absolute values, using the income of families and unrelated individuals (even if it had been available for all the years I considered) would have changed nothing.

8. Recent data were not overlooked in writing the article. As noted there, the relative price combines two sets of data: energy prices and family income. Hirst and Blue mention recent energy prices, but seem to miss the point that both sets of data are required to calculate relative price. Unfortunately, data on family incomes are not published as quickly as that on energy prices. One cannot calculate a ratio if only the value for the numerator is available.

T. J. Blasing cores a pine tree on the Oak Ridge Reservation. Then he examines the core sample, counts the rings, and determines that the tree is about 25 years old. At far right is a mounted tree-ring core sample from a Norris, Tennessee, white oak that dates back to 1637.

Reconstructing Past Climate

By CAROLYN KRAUSE

In late December 1980, ORNL dendrologist Dan Duvick spotted a white oak tree on a bluff near Des Moines, Iowa, that immediately interested him. Because it looked like a very old tree, he used the tree-coring tool he was carrying to bore two holes into the center of the thick trunk and extract the wood cores from opposite sides of the tree. Upon inspection of the tree rings in the cores, he became quite excited. A subsequent ring count revealed that this tree dates back to 1573, making it 407 years old.

Because trees are sensitive to moisture, their annual ring widths are excellent indicators of yearly variations in rainfall. Thus, Duvick and T. J. Blasing, both of ORNL's Environmental Sciences Division, have been studying tree rings from forests in the East and Midwest to help them estimate the annual precipitation received by these forests for the past 300 to 400 years. After using the harmless procedure for extracting tree-ring cores from as many as 50 trees per forest stand, they noted in which years the tree rings were narrow, indicating drought, or wide, indicating abundant precipitation. They have gathered this information from white oak trees in Tennessee, Kentucky, Arkansas, Illinois, Missouri, and Iowa, and from other tree species in other regions.

Estimates of annual precipitation in Iowa, made from white oak chronologies at three sites in the state, indicate that extensive, severe droughts comparable to those in the 1930s have occurred there six times over the past 300 years. Studies of the old tree found by Duvick are expected to add to the understanding of drought patterns in Iowa over the past 400 years.

Blasing, a climatologist who leads the tree-ring bioclimatology project, has been particularly interested in drought cycles in the eastern half of the United States. He has already discovered an intriguing, unexplained detail from tree-ring data: A particularly severe drought began in Iowa in 1816, the same year that New England experienced snow in August, presumably a result of the delayed effects of the Mount Tambora volcano eruption the year before in Indonesia.

Blasing, Duvick, and Darrell West (a forest ecologist in the

Environmental Sciences Division) have shown, with statistical confidence in excess of 99%, that ring widths of white oak, shortleaf pine, and other species contain information about year-to-year variations in climate at several sites in the Midwest and Southeast, including sites in eastern Tennessee. These findings, along with those of other groups working in other regions, demonstrate that reliable information about past climatic variations can be obtained from tree rings in the relatively humid regions of the eastern United States, as well as in the more arid western states.

What Blasing, Duvick, and West learn about climatic variations in the East and Midwest will help fit together the pieces of the puzzle on climate in the United States in the last 300 to 400 years. Part of that puzzle is being assembled for the West. Work at the University of Arizona Laboratory of Tree Ring Research has related drought patterns in the West to sunspot activity. By studying tree rings and expansion and contraction of deserts, Arizona researchers have discovered that drought has occurred in the West every 22 years for the past several hundred years, a pattern that seems to tie in with the 11-year sunspot cycle. Whether this drought pattern holds true for the East will be studied by Blasing and his fellow climatologists who are examining this part of the country.

Search for Ancient Pollen

In the fall of 1976, before the ORNL tree-ring studies began, University of Minnesota graduate student Hazel Delcourt was doing some detective work of her own to determine the influence of climate on vegetation in the Southeast in the past 16,000 years. To gather data for her doctoral dissertation, Delcourt waded through a Middle Tennessee shrub swamp named Anderson Pond in search of ancient pollen. She used a 1-m-long coring tube to probe as deep as 10 m into the sediment. At nearby Mingo Pond she collected more sediment. Using radiocarbon dating, she found that the most ancient Anderson Pond sediment was 25,000 years old and the oldest Mingo Pond sediment dated back 14,000 years.

By determining the age of the sediment, Delcourt knew the age of

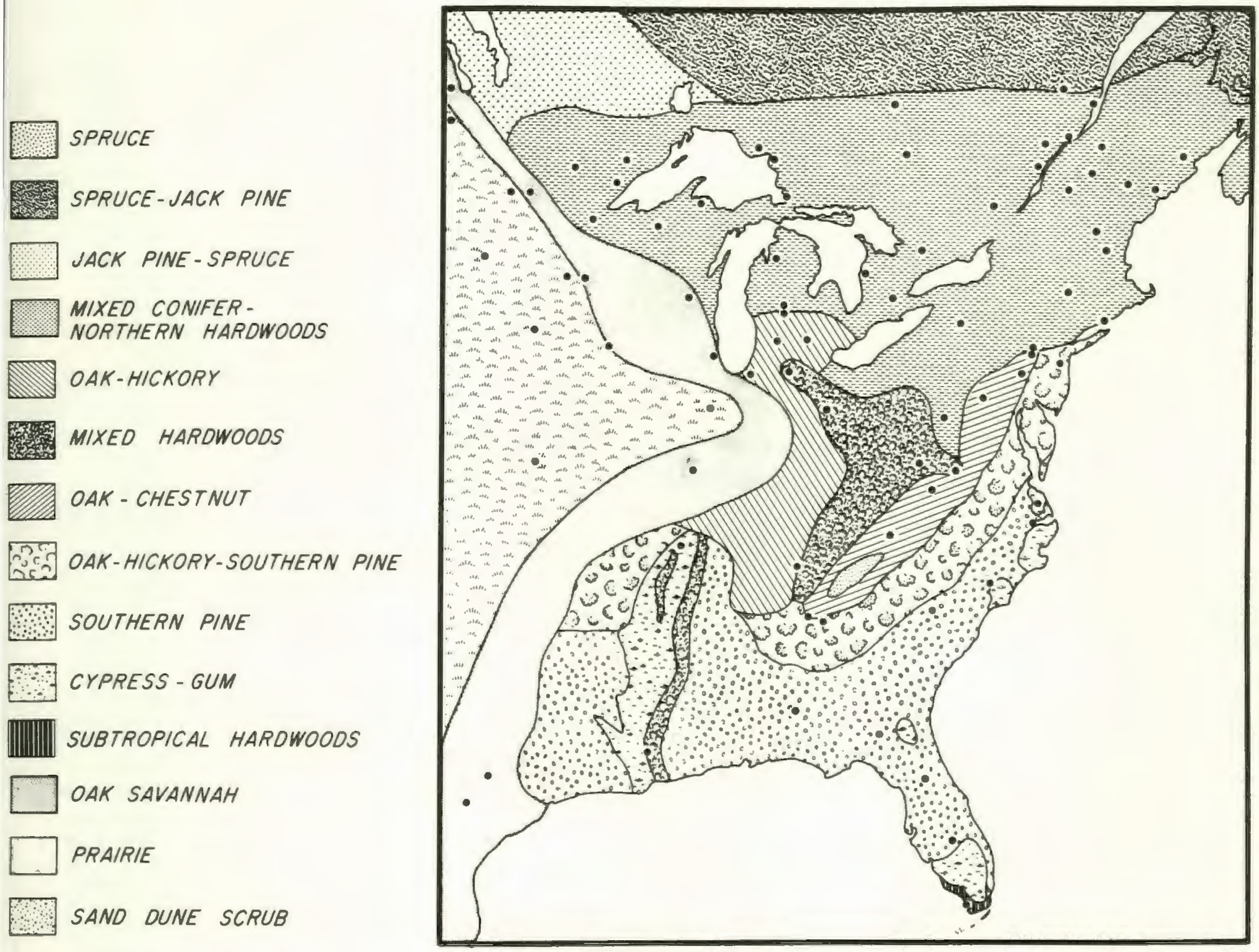
Al Solomon, left, and Hazel Delcourt aboard a raft on Cahaba Pond in Alabama dig up samples of sediment containing ancient grains of oak pollen using the 1-m-long sediment corer held by Solomon. By comparing the microscopic features of this pollen with pollen on the modern landscape, they are attempting to reconstruct the climate of thousands of years ago.

As the ice sheet retreated 18,000 years ago in the eastern half of North America (map at left), jack pine and spruce flourished in the region extending to Tennessee's southern border. This indicated a cool climate typical of that in Minnesota and Wisconsin today. Subsequently, the climate warmed up, and 5000 years ago, it was warmer than it is today. As a result, the vegetation changed, as shown on the map at right. Spruce forests were replaced by prairie grass in the Midwest, jack pine and spruce forests in the Southeast were supplanted by oak and hickory trees, and oak and hickory forests in the Deep South gave way to southern pine forests.

the pollen grains contained in the sediment. Pollen—a microspore in a seed plant—is a chemically resistant, dustlike particle with the physical appearance characteristic of the plant species from which it comes. After removing the fossil pollen grains from sediment samples by chemical methods that dissolve away both the organic material and the minerals, Delcourt studied the composition of the pollen under the optical microscope and then tried to match the ancient pollen assemblages with pollen produced by modern vegetation.

Delcourt found a match between pollen dated at 16,000 years old and pollen present today in Minnesota, indicating that the Tennessee climate 16,000 years ago was about the same as the climate in Minnesota today. She observed that the pollen dated at 13,500 years old matched that present in Wisconsin. Her conclusion was that the forests typical of Minnesota and Wisconsin today may have been prevalent in Tennessee 13,000 to 14,000 years ago.

In 1979 Delcourt published her dissertation on vegetational changes in Tennessee over the last 25,000 years in response to climatic changes—particularly alterations in ranges of temperature and precipitation. Subsequently, she was hired as a paleoecologist by ORNL's Environmental Sciences Division. Since then she has been studying samples of pollen from Cahaba Pond in Alabama. She also has studied chronologic trends in the ability of eastern forests to absorb atmospheric carbon dioxide.



Carbon Dioxide Question

The problem of global carbon dioxide has plunged ORNL researchers into studies of tree rings and pollen. Because of the world's fast-growing need for energy, fossil fuel combustion is expected to escalate significantly. A by-product of this combustion is carbon dioxide, which absorbs infrared radiation (heat) emitted by the earth. The earth absorbs sunlight and re-radiates it in the infrared range at a longer wavelength that is intercepted by carbon dioxide. As the atmospheric carbon dioxide concentration increases, more heat is retained in the atmosphere, and the earth's surface temperature rises. The result of this so-called greenhouse effect is expected to be a warmer climate.

How much warmer? Considerable debate continues on this question. Computer models set up to tackle this question have calculated that, if the concentration of atmospheric carbon dioxide were doubled, the global temperature would rise 2 to 3 degrees. That much change is enough to seriously affect the earth's inhabitants. Some scientists say that a warming of this amount could melt the polar ice caps, which would raise the ocean level and possibly cause flooding of coastal plains. Other scientists suggest that only subtle changes in regional climate and vegetation may occur. For example, Blasing predicts that American farmers in the western corn belt might have to switch from growing corn to raising wheat if the climate becomes warmer and drier. Alternatively, farmers who wish to continue raising corn may have to use more energy and water for irrigation.

Much uncertainty remains about the effects of a global temperature rise and whether a doubling of atmospheric carbon dioxide concentration would raise the temperature 2 to 3 degrees. Says Blasing: "I agree that there will be a temperature rise with increased fossil fuel combustion, but the computer models could be off by a factor of two, either way. Instead of a projected 2.5 degree increase, for example, we may experience only a 1.2 degree increase. Alternatively, it could get 5 degrees warmer. These models are not any more precise than that. The big problem is that climate is global. We need to fill in the pieces to determine relationships between global climate and regional weather."

Other factors besides carbon dioxide are involved in climatic change. Volcanic eruptions may tend to counteract a carbon dioxide-induced warming. Volcanoes can inject heavy loads of particulates into the stratosphere, where they may remain for years (unlike industrial dust, which is usually confined to the troposphere and is eventually washed out by rain). These volcanic particles can backscatter the sun's rays into space. Many scientists believe this effect may be strong enough to have a detectable cooling effect on the climate. Thus, a challenge to climatologists today is to determine to what extent volcanic activity may offset the warming effect of increased atmospheric carbon dioxide.

In most places, climatic records have been kept for less than 100 years, and sufficient volcanic eruptions in the last century large enough to permit an assessment of effects of volcanic dust on climate have not occurred. Analysis of tree rings can provide otherwise unavailable information about climate over a greater span of time so that the effects of volcanic eruptions in past centuries can be assessed.

A 7200-year-old pollen sample from Anderson Pond is shown in these scanning electron photomicrographs. Three oak pollen grains (inset in Fig. 1) are shown with organic and inorganic debris at 400× magnification. Figure 2A inset (2000×) and 2B (10,000×) show a fossil pollen grain most similar to modern pollen from black oak. Figure 3A (2000×) and 3B (10,000×) contain a fossil pollen grain typical of modern white oak and dwarf chinquapin oak. The pollen in Fig. 4A (2000×) and 4B (10,000×) matches pollen from shumard red oak and from pin oak.

Because pollen data reflect climatic conditions averaged over a century or more, they are not as suitable as tree-ring data are for analyzing effects of individual volcanic eruptions or other "short-term" effects. However, because the pollen record extends back in time for many thousands of years and covers periods of more extreme departures from the present climate than have occurred in the last several centuries, pollen studies can address another aspect of the carbon dioxide–climate problem.

Analog from the Past

Using pollen to reconstruct past climate over a long time scale, the ORNL researchers have focused special interest on the altithermal period 5000 to 8000 years ago. Based on changes in vegetation and other evidence, climatologists think that global temperature during this period was 1 to 2 degrees higher than the mean temperature today. Thus, this period may be the best analog to the climate we might expect should increased fossil fuel combustion result in a significant concentration of atmospheric carbon dioxide. If scientists can reconstruct precisely the vegetation changes before, during, and after this anomalous period, they may be able to predict with greater certainty the effects of carbon dioxide-induced climatic changes on forests and agriculture.

The pollen studies of Hazel Delcourt and her husband Paul Delcourt, assistant professor of geology and ecology at the University of Tennessee, have helped to pinpoint vegetational and climatic changes in the Southeast in the past 20,000 years. The Delcourts have summarized these data in a series of maps depicting changes in configuration of ice sheets, shorelines, and vegetation types across eastern North America. Here are some of their findings:

18,000 years ago. With the advance of the ice sheet during the glacial period, boreal forests of spruce, fir, and jack pine (now typical forests north of the Great Lakes) extended south and were the dominant forest species in Tennessee. The mean temperature at this latitude was 15 degrees lower than that of today. Oak Ridge 18,000 years ago would have been more appropriately called Spruce Ridge or Pine Ridge.

14,000 years ago. As the ice sheet retreated during the interglacial period, pine forests declined and oak forests began to flourish in Tennessee. The climate warmed to the point where jack pine and spruce could barely survive in much of Tennessee and oak could easily compete with these conifers, some of which still persist at high elevations in the Great Smoky Mountains. Between 12,000 and 8000 years ago, the climate warmed up, making the weather of the Southeast similar to that of the north central states today. The cool, moist conditions favored growth of oaks and mesic hardwoods such as beech, sugar maple, basswood, buckeye, and chestnut. The climate gradually became warmer and drier, more like today's weather in the Southeast.

8000 to 5000 years ago. With increased warmth and dryness, *"ORNL is an international center for computer modeling of forest ecosystems."*

the global temperature climbed to 1 to 2 degrees higher than it is now. As a result, a pronounced shift occurred from mesic hardwoods such as beech and maple to oak, ash, and hickory trees. (Some mesic species still persist in cool, moist ravines of Tennessee and in Great Smoky Mountain coves.) Hickory forests expanded with increased warmth. The causes of this warming are unknown, but some scientists have speculated that shifts in the earth's orbit and tilt with respect to the sun may be responsible for gradual climatic change.

2000 years ago. Hickory declined and chestnut forests increased, indicating that the climate cooled again and became wetter.

Oak Pollen and SEM

When Hazel Delcourt examines fossil pollen under an optical microscope, she can distinguish among pollen grains characteristic of oak, hickory, and as many as 50 other tree types. However, the 40 species of oak in eastern North America cannot be differentiated by this means. This makes characterization of the climate for the critical period of 5000 to 8000 years ago difficult for two reasons: (1) 80% of the pollen found from that period is undifferentiated oak and (2) oak as a genus has a widely varying tolerance to climate (i.e., oaks are indigenous to Canada as well as Florida).

"Several species of oak are northern in range," says Delcourt. "Others occur only along the Gulf Coastal Plain. Many species of oak are widespread in the East; a few flourish on floodplains while others thrive on ridge crests. The species present indicate both temperature and availability of moisture. If we could determine which species of oaks prevailed and which species were absent in eastern forests 5000 to 8000 years ago, we would be able to refine our interpretations of climatic conditions during that time period. That would be a breakthrough."

Fortunately, Allen Solomon of the Environmental Sciences Division has made some progress in distinguishing among fossil pollen of oak species by using scanning electron microscopy. He has made some revealing micrographs of pollen, including one of ragweed pollen that appeared on the cover of the November 1980 issue of *Bioscience.*

By studying the variations of surface sculpture on modern pollen grains from different species of oaks and comparing the surface details with features of fossil pollen, Solomon has been able to differentiate among ancient black oak, red oak, and white oak pollen grains. But he still has a long way to go before he can distinguish among all 40 species of ancient oaks.

Modeling Forests

Changes that occur in forests over thousands of years can be mimicked quickly by computer modeling programs. Ten years ago, Dan Botkin, then of Yale University, developed the first forest succession model for 13 tree species in the Northeast. In 1973, West and Hank Shugart of the Environmental Sciences Division, assisted by Lynn Tharp, on loan from the Computer Sciences Division, modified the Yale model and expanded it to include 33 species of the Southeast. They called the model FORET. ORNL now has seven forest succession models (including two developed in Australia) and is an international center for computer modeling of forest ecosystems.

FORET keeps count of the birth, growth, and death of each individual tree in a simulated forest stand. It can take into account various factors that affect the growth of trees, such as climate, soil type, competition for sunlight with other trees, logging, diseases such as chestnut blight, fire and hurricane frequency, and chronic air pollution.

Solomon is employing FORET to refine interpretations of the effects of climatic changes on eastern U.S. forests in the past 20,000 years. To validate the model's predictions on which trees were most likely to be growing in different periods of time, based on assumptions about climate, Solomon turned to the Anderson Pond pollen record. He found that the pollen record raises many questions that FORET might be able to answer. For example, the pollen record does not tell which factors produced forests dominated by certain species at different times or whether any

"...forests reflect the climate and, to some extent influence it too."

specific forests were dense or open. It records primarily wind-pollinated species, with little record of insect-pollinated species such as tulip poplars, which may locally compose 40 to 50% of the modern Tennessee forest. From the pollen, it is also difficult to assess the relative contributions of climate and species migration to the changing composition of forests.

Some of these questions can be answered by putting assumptions in the model, running it, and seeing if the answers make sense in light of present knowledge of forest ecosystems. For example, Solomon may simulate an ancient forest in which half the trees are insect-pollinated, although he has no direct evidence for the existence of these trees. Initially, he simulated a forest of 5000 to 8000 years ago that was dominated by oak. Not knowing which species actually grew there, he made an oak species that possessed characteristics of all possible oak species. This oak "for all seasons" did not grow in the forest at all, though pollen evidence showed at least 60% of all trees were oaks. So, he took the opposite tack and entered every oak species for which data were available. The model produced a reasonable match for forests described by the pollen; four oak species showed dominance—red, white, black, and chestnut oak.

Verification of FORET's predictions about ancient forest composition awaits SEM identification of undifferentiated fossil pollen. Says Solomon: "The presence or absence of certain oak species in the pollen record tells us which oak species should be put into the computer model. Then we can experiment with the climatic conditions needed to produce a match with the pollen record."

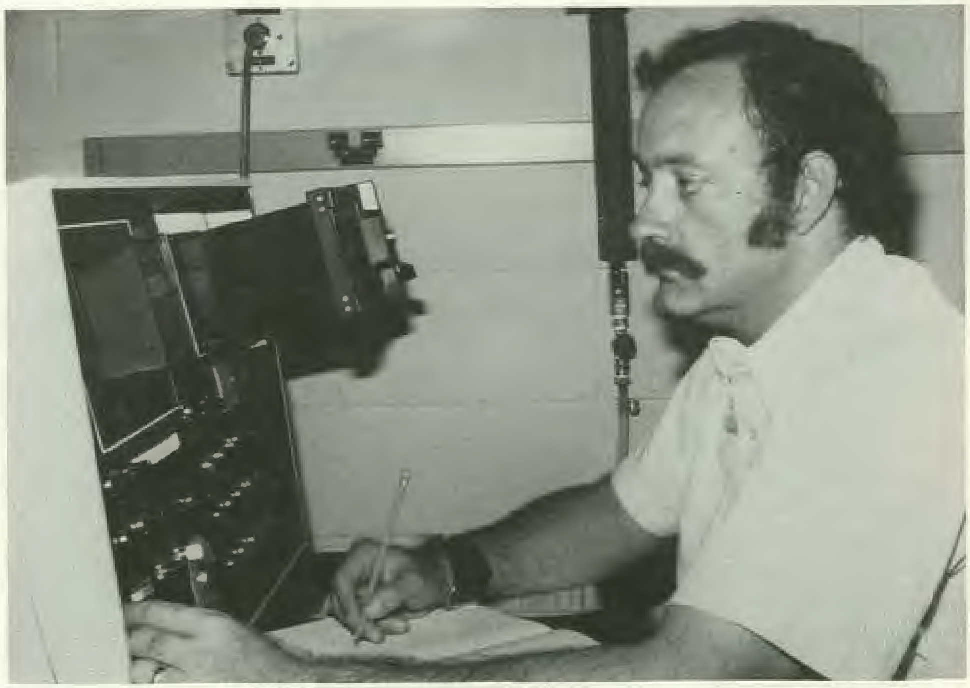
Solomon has used FORET to test theories that explain why some trees shift in importance in the pollen record of the last 10,000 years in the eastern United States. One popular theory is that saplings and seeds of most plant species were present, but that a species assumed importance in the forest only when the climate allowed seed growth. Another theory, proposed in 1973 by Margaret Davis, Tom Webb, and others at the University of Michigan, attributes most changes in the pollen record of the northeastern United States to delayed migration of tree species that flourished south of the ice sheet. They hypothesized that plant species that dispersed northward earliest after the glacial ice receded (about 12,000 years ago) became established and grew successfully because they lacked competition from the more slowly migrating species. When the slower migrants arrived, they in turn became dominant, appearing in the pollen record as they would through effects of climate change alone. How were the seeds dispersed? Scientists have proposed that wind, storms, rivers, migrating birds, and seed-eating animals may be responsible for seed migration.

Solomon and his colleagues ran the FORET simulation model to test whether variance in the pollen record in the Southeast is caused primarily by delayed migration rather than by climate. "We simulated a constant climate and entered tree species only when they appeared in the 16,000-year pollen record," says Solomon. "Then we ran a simulation in which all 65 simulated species were available, but climate change alone controlled the variance we saw in the pollen record. We found that climatic changes accounted for most of the variance in the pollen record from Middle Tennessee, with only a small amount due to delayed migration during the first 4000 years of the simulation. In the past 12,000 years, we found that climate was solely responsible for the variance in the pollen record. So our model appears to support the prevalent assumption that, at least in the southeastern United States, tree species generally available did not assume importance until the climate was favorable."

Preliminary results from computer simulations also indicate that the biomass (carbon storage capacity) of forests in the Southeast has increased in the last several thousand years over what it was 5000 to 8000 years ago when the climate was abnormally warm.

Carbon Storage Trends

Strong evidence exists that climate influences the composition of forests. Indications also exist that forests may have an impact on climate. That is because forests



Al Solomon at the scanning electron microscope.

absorb carbon dioxide, which results in less fluctuation of global temperature. Growing forests constitute a net sink for carbon dioxide. On the other hand, if forests are logged for building and paper products or are cleared for agriculture, housing, and commercial developments, much of the unused residue probably will be burned. Because carbon dioxide is a byproduct of wood combustion, deforested land could become a net source of carbon dioxide, possibly contributing to the warming of the global climate.

One question that ORNL has sought to answer is whether the forests of the Southeast constitute a net sink or a net source of carbon dioxide. Using data from U.S. agricultural census statistics and forest survey records, Hazel Delcourt and Frank Harris (former head of the Terrestrial Ecology Section of the Environmental Sciences Division and now with the National Science Foundation) studied this question and published their results in the October 17, 1980, issue of *Science*. They found that forests of the Southeast have been a carbon dioxide sink since 1950, largely because of the U.S. Forest Service's success in intensive management of forests to increase productivity for the building and paper product industries.

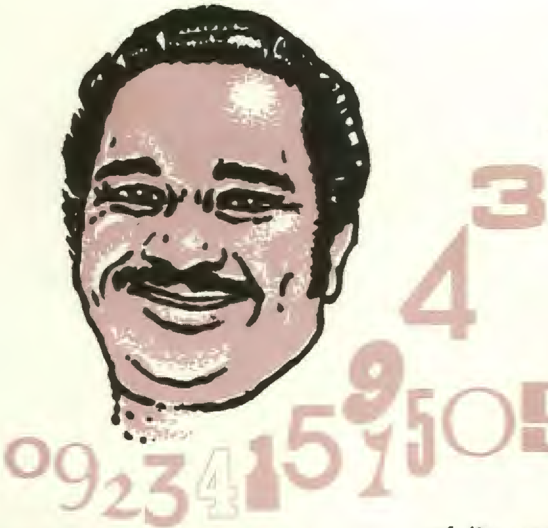
They also found that, from 1750 to 1950, this region underwent a continuing loss of carbon and was a net source of carbon dioxide. Before colonial settlement began in 1750, 91.6% of the land was forest; by 1880 less than 35% of the Southeast remained in virgin forest. This was because the forests were cleared for settlements, roads, and conversion to farmland. Settlers cleared the forests by burning them and also added to the atmospheric carbon dioxide concentrations by burning wood to heat their homes.

Delcourt and Harris determined carbon storage trends in the Southeast by assigning biomass values to virgin forest, secondary forest, and cropland and multiplying these values by the land area occupied by each type of vegetation.

What is the outlook for southeastern forests and the carbon dioxide problem? Says Delcourt: "It is estimated that 20 to 60% of the carbon dioxide released through fossil fuel burning could be taken up by present growth of the world's temperate forests, of which southeastern U.S. forests make up 15%. These forests are a substantial carbon sink. If timber harvesting and farming increase, we need to evaluate what effect this could have on carbon dioxide uptake."

"For example, the bottomlands in the Southeast are now being logged and converted to soybean fields. It is estimated that by 1990 there will be few bottomland forests left in the Southeast. This might be a problem because decreasing the forested area in the Southeast by 10% would change the region from a net sink to a net source of carbon dioxide. As a source, southeastern U.S. forests could contribute 3 to 5% of the total atmospheric carbon dioxide. Thus, if we want to maintain the Southeast as a carbon sink, we should consider compensating for the loss of bottomland forests by encouraging forest growth in other areas."

Delcourt and Solomon plan to extend the biomass mapping from the past 230 years back through thousands of years by using the information obtained from computer modeling and the pollen record. Solomon, Delcourt, and Blasing will then try to establish a relationship between carbon fluctuations and climatic changes over long periods of time. In reconstructing past climate, it is important to know about the composition of forests because forests reflect the climate and, to some extent, influence it too. ornl



take a number

By V. R. R. Uppuluri

Illusive Conclusions

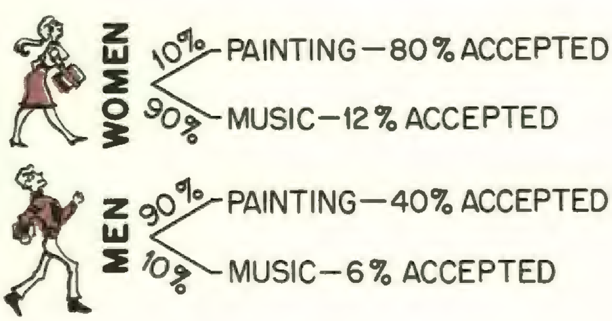
At times, information given on the components of a system may not reflect the true state of the system. The following example by Ruma Falk and Maya Bar-Hillel relates to the admission of men and women to a college. The admission rates of two departments of the arts school suggested that females were favored in both departments, although in the arts school as a whole, the admission rate of males was higher than that of females.

More specifically, suppose a certain arts school has only two departments: painting and music. Past records show that the Painting Department admits about 80% of its female applicants vs 40% of its male applicants, whereas the Music Department, which has stricter requirements, admits about 12% of its female applicants vs about 6% of its male applicants. Thus, prima facie, it looks as if the admissions are very much in favor of women.

Additional statistical information shows that women are more interested in music: 90% of the female applicants to the arts school enroll for music and 10% for painting. For men the opposite is true: 90% of the male applicants enroll for painting and only 10% for music.

Thus, the unconditional probability that a male may enroll in the arts school is 37% [(0.4)(0.9) + (0.06)(0.1) = 0.366], and the unconditional probability that a female will enroll in the arts school is 19% [(0.8)(0.1) + (0.12)(0.9) = 0.188], exactly the reverse of the situation within the departments.

Thus, even simple questions such as "Who has a better chance of admission, male or female?" can have different answers in different contexts.



Numbers Divisible by 9

Take any three-digit number and consider all the numbers obtained by permuting the digits. For example, take 123 and obtain 132, 231, 213, 312, and 321. The difference between any two of these numbers is divisible by 9; for example, 321 − 123 = 198 = 9 × 22.

Similarly, take any four-digit number, such as 5671, and a number obtained by permuting its digits, such as 7516, and consider the difference: 5671 − 7516 = −1845. Note that this difference, though negative, is divisible by 9; all differences will be divisible by 9.

This result is true for all numbers with any number of digits.

Although Dick McCulloch is the titular author of the accompanying article, he wants it known that Kathy Wyble has helped him write it. Kathy, on the other hand, points out that Dick has omitted to say that it was he who was the instigator of the entire system he describes here; he located the hardware, acquired it, identified the Computer Sciences Division personnel most appropriate to be involved, and contributed to all the decisions, software, direction, and management that have helped to get this massive effort into operation. Dick holds degrees in mathematics and physics from Birmingham Southern College and the University of Tennessee. He has been with the Nuclear Division since 1960: ten years at Oak Ridge Gaseous Diffusion Plant and ten years with the Laboratory's Computer Sciences Division. At present, he is in the Nuclear Division's Management Information Systems Department. He and Kathy work out a problem here in her office in 4500S.

Putting it on the Line

Electronic Help for ORNL Authors and Editors

By R. D. McCULLOCH

As an author, do you have difficulty in producing high-quality technical reports that are timely and are produced at low cost? Do you get tired of reading the same material time and time again because each time the document is revised it must be retyped, complete with new errors? If you would like to make just one more minor revision, do you fear the wrath of the typist?

As a technical typist, do you have trouble formatting complex tabular material and multilevel equations? Do you wish that the author would write what he wants on the first draft? Would you like to get rid of your scissors and glue pot? Do you hate to see that 200-page periodic report come up for another revision? Would you like the capability of checking all words in the report against a comprehensive dictionary to find misspelled words and typographical errors?

As a programmer, do you still use punched cards for your programs? If so, can you ever find the current deck? How about the version before that? Do you have trouble with JCL (job control language, to the newcomers)? Do you have problems producing an acceptable listing of your programs to use as camera-ready copy for your Laboratory reports? Have you ever been asked by a regulatory agency to replicate a computer run of an important program that you made two years ago using slightly different input data?

As a researcher, have you wished that you could produce good-quality visual aids for that important meeting that was just scheduled for tomorrow morning? Have you despaired of reaching your colleague on the telephone and wished that electronic mail was here? Would you like to be able to access various computer systems with the same terminal and hard-copy printer?

Have we got news for you!

There is an air of excitement about several Laboratory projects involving the preparation of technical documentation. Many long-anticipated events have either come to pass or are about to happen.

The Information Division's third-generation phototypesetter, an Autologic APS-micro5, has been delivered and is operational. This equipment completes the basic text-management system for the Technical Publications Department.

The precision graphics microfilm recorder, the FR-80, which is operated by the Computer Sciences Division, has been upgraded to a COMP-80. The FR-80 became a COMP-80 when a graphic arts font capability was added. Ultimately, the COMP-80 will have fonts much like those available on the APS-micro5. The COMP-80 can produce microfilm in a variety of formats: 35mm-aperture format in black and white, sprocketed 16mm and 35mm in black and white and in color, and microfiche in 42× and 48× reductions.

The computer graphics software DISSPLA has been enhanced by adding a front-end processor, MAPPER, which allows the creation of graphic arts material on the computer by users who are not computer programmers. MAPPER, originally written at Los Alamos National Laboratory, has been revised extensively by including ORNL graphic arts style as defaults in the system. This was accomplished in a cooperative effort by Morris Slabbekorn of the ORNL Graphic Arts Department, Bruce Johnston of TPD, and Keith Penny and Betsy Clark and staff in the Graphics Coordination Group of CSD. A second front end processor, TELLAGRAF, was acquired to allow users to obtain business graphics—again without a knowledge of programming languages. A post-processor that will allow the APS-micro5 phototypesetter to record any DISSPLA graphics was also acquired. Merging of text and computer graphics is scheduled to begin this fall.

A computer system called VERSACOMP has been acquired by Frank Hammerling's file management systems group of the Computer Applications Department to take computer resident files and format them for output on the APS-micro5 or the COMP-80. This software will run in the batch mode on the IBM 3033 system, and all data base publishing tasks should benefit from it. Special monospaced fonts have been acquired for the APS-micro5 so that computer print lists can be produced without the broken or misaligned characters often associated with line printers.

Three minicomputers with UNIX operating systems have been installed for technical document preparation. These systems will be connected by high-speed communications links and software for file transfer and message transfer among the machines. A fourth minicomputer runs UNIX as a sub-operating system and will be linked to the other three.

Since UNIX is such an important part of these happenings, let's look at it in detail. UNIX, a trademark of Bell Laboratories, is a general-purpose, multi-user, time-sharing, minicomputer operating system. Computer scientists familiar with UNIX associate this "word" with programming software tools that assist programmers in software development. Technical editors tend to think of UNIX as a system that aids in the preparation of documents containing multilevel equations and complex tabular material. Individuals concerned with automating office functions tend to think of the UNIX communication facilities and the possibility of using UNIX to accomplish word processing tasks. UNIX provides all these features and more. Four UNIX systems have been installed in the Oak Ridge area, three at ORNL and one at DOE's Technical Information Center. Other systems are in the acquisition stage or are being planned for installation at the X-10, K-25, and Y-12 sites, both in unclassified and classified areas. The systems installed and those planned for installation are for purposes specified by the various functional groups and as such are closely held. Excess capacity on some of the systems will be made available to interested users on a cost-recovery basis. (If you are interested, contact A. A. Brooks at 4-5304.)

Two Bell Laboratories staff members, Ken Thompson and Dennis Richie, developed UNIX in the early 1970s as a time-sharing operating system for Digital Equipment Corporation PDP-11 minicomputers and compatible equipment. The operating system is written in a programming language called "C." Programs were written so that programmers could use terminals to create and modify programs. File management software that did not require JCL was written for the computer system so that files could be easily accessed and manipulated. Communications software was developed so that program modules could be moved from the minicomputer system for execution of the program in the large batch-processing computers.

Thompson and Richie developed interesting applications programs to do specific tasks. They wrote formatting programs to accept text and commands that would produce complex technical document pages on a phototypesetter.

After the enthusiastic acceptance of this software by Bell's staff members, word of UNIX's simplicity and ease of use spread to the computer community. Other users wanted access to the software. Bell Labs decided to make

T. R. Walker, Information Division; Ray Hinds, Computer Sciences Division; and Jim Mason, Information Division, are all involved with helping the Laboratory tool up to use the new electronic editing and typesetting technology. Here they watch Information Division's James Smith (far right) work with the newly purchased APSmicro5 typesetter in Walker's composition department.

unsupported copies of the software available to universities for a small fee. That is to say, the software development was cut off at a specified time and the systems transferred as they were, although at Bell Labs they continue to be changed and updated. Federal agencies and contractors, as well as firms in the private sector, can obtain the software, again unsupported, from Western Electric, Bell's manufacturing and marketing arm, for a per-copy license fee. The cost to federal agencies is about $7200, and the cost to private firms is $20,000.

UNIX now runs on hundreds of university systems. As a result, there is a very active UNIX users group and extensive sharing of the software developed for the UNIX system. Many federal agencies and private firms have elected to pay the licensing fee to obtain the unsupported UNIX. This has led to the creation of a host of software and hardware vendor products for UNIX-based systems with support. These vendors also must pay royalties to Western Electric for this privilege. One of the vendors is Interactive Systems Corporation of Santa Monica, California. This software house greatly modified the Bell UNIX system, especially the editor and the formatter for photocomposition devices, and marketed the resulting product as a supported system. This software is packaged in different ways and is called either IS/1 UNIX or IS/1 Workbench.

We decided to buy UNIX systems from ISC to avoid the local systems maintenance that would have resulted had we bought the software from Western Electric. The programming support that would have been used in maintenance will be used for applications to enhance system capabilities for users. Other research facilities, financial institutions, universities, and large corporations in North America and in Europe have also elected to obtain UNIX from ISC. Some of these organizations are National Center for Atmospheric Research, Jet Propulsion Laboratory, Los Alamos National Laboratory, Chemical Abstracts, World Bank, Wells Fargo Bank, California Institute of Technology, General Motors, Hughes Aircraft, and Siemens.

Minicomputer Systems

ORNL has acquired three minicomputer systems to support IS/1 UNIX software. They are a PDP-11/60, acquired by CSD for testing and evaluating various aspects of the IS/1 UNIX system; a PDP VAX 11/780 in the Information Division's Information Center Complex to support data entry activities, data base management, and

text editing; and a PDP-11/70 in the Information Division to support TPD in technical document preparation. A PDP-11/70 for text management has been acquired by TIC. Kathy Wyble, manager of the Text Management Systems Group, is responsible for all the UNIX systems now in Oak Ridge, with prospects of managing four additional systems coming in this year. Organizations should not have indispensable people, but indispensable has to be the word for what Kathy has been to the IS/1 UNIX systems effort. Only her systems skills and an inordinate number of hours worked on weekends and evenings have made possible the present working system. Becky Bolling and other members of Kathy's group provide user training and consultation for the text-management systems. These staff members offer problem determination and other assistance to all users from 8:00 AM to 4:30 PM.

Their group will also develop additional software tools. Ted Ohtani, on special assignment from the ORNL Central Research Library, and Jim Mason, TPD staff member, ensure that these software systems provide the proper tools for preparing technical documentation.

Users of terminals interfaced to these PDP-11 systems through the UCC-ND network are greeted with a message when they activate their terminals:

UCCND NETWORK CONTROL
WHICH SYSTEM?

By responding with the integers 1, 2, 3, or 4, the user can be connected to the PDP-10 system, the IBM 3033 system, the PDP-11/60 IS/1 UNIX system, or the Information Division's PDP-11/70 IS/1 UNIX system. Duane Winkler, the PDP-10 systems manager, has provided technical advice on the PDP-11 systems and has made the communications facilities associated with the PDP-10 system accessible to PDP-11 users.

IS/1 UNIX Software

Let us look at the software components that are available in the IS/1 UNIX Workbench package. Some of the available features include:

The Source Code Control System. The SCCS contains subsystems designed for the control and manipulation of documents. Documents may be technical manuals or reports, legal contracts, administrative reports, program source codes, etc. For files undergoing maintenance, the system provides an audit trail of revisions. Any past version of the file can be regenerated with the execution of a single command. Different versions of a document may be compared: the system marks the differences between the versions, shows who made the changes, and indicates when and why they were made.

INed, a cursor-based CRT editor. INed, which is easy to learn and use, may be regarded as a two-dimensional viewing and editing window into a file. As many as eight active windows may be displayed on the screen at one time, each with a different file or with segments of the same file. Blocks of material may be taken from one window and moved to the document displayed in another window. Most editing operations can be accomplished by pressing one or more function keys.

INword. INword is a word processing system tailored to the office environment. In conjunction with INed, the functions avilable on most word processing systems are available.

INmail, an electronic mail system. This system can be used to create, send, answer, and file messages, letters, and documents. Messages may be routed to any other user's mailbox within one computer or, with network capability, to any user on the network.

INcomp. INcomp provides sophisticated formatting capabilities for production of multilevel mathematical equations and complex tabular material in conjunction with a variety of output devices. The command language to describe multilevel equations and complex tables requires only the characters found on typewriter and terminal keyboards.

Computer Sciences Division's Becky Bolling is one of the troubleshooters for users of the new UNIX editing terminals. You could say she wrote the book.

INremote. This feature makes possible remote job entry between the PDP-11 system and the IBM system.

INnet, the communication software. This software allows PDP-11 hosts and VAX 11/780 hosts to be nodes in a network. The network will allow users of different hosts to connect to other hosts, receive mail from remote hosts, and to access files on other hosts. The software will allow communication with compatible alien networks, including TELEX and Telenet.

Input Devices Supported

A wide spectrum of terminal equipment interfaces to the IS/1 UNIX system. The INtext terminals (Perkin-Elmer terminals with microcode from ISC) are tailored to work with the INtext editor. Many of the editing functions normally done on the central processing unit are done on the terminal, allowing the PDP-11 to support twice as many users as a comparable system with dumb terminals. INed can be adapted to run with most terminals having direct cursor-positioning capability.

The myriad TTY ASCII devices that do not have cursor-positioning capability, whether they are video-display or hard-copy terminals, can be used with the INtext system means of a line editor. In fact, the correspondence-quality printers can input to the system.

Word processing equipment with the appropriate communications features may also be used to transmit text to IS/1 UNIX (the special formatting commands used internally by the word processing machines will not be understood by IS/1 UNIX). Systems that have been tested are the CPT 8000 and the Lanier No Problem, both having TTY ASCII asynchronous communications. Documentation has been prepared by Charles Reeves (at Y-12) and Kathy Wyble on how to set up the CPT to receive computer communications.

The Selectric typewriter found in almost all offices can be used with TPD's optical character reader to provide initial keystroke capture to IS/1 UNIX. An OCR font must be used on the typewriter to make the characters readable by the device. Remember, the command languages required to produce equations and tables use only the characters that are found on a Selectric ball. T. R. Walker, of TPD, can provide information concerning the OCR (4-6963).

The text-management system also has access to computer files via magnetic tape or from computer systems within the UCC-ND computer network. One of the processors in the network, the Information Division's PDP-11/70, has a remote job entry link to the IBM 3033 system at ORNL. An RJE station is a device that allows punched cards to be read into a computer system.

Three correspondence-quality serial printers interface to the INtext systems. They are the Diablo, NEC Spinwriter, and Qume. Several high-speed printers may be supported, including the IBM OS/6 6640 jet ink printer, the IBM 6670 laser printer. The Versatec 1200, a 200-dot-per-inch electrostatic

The new electronic editors can produce highly sophisticated formulas and even some graphs directly on line from the keyboard.

A straightforward syntax allows easy equation input. For example, the following equation

$$J_0(z)=\frac{1}{\pi}\int_0^{\pi}\cos(z\sin\theta)\,d\theta$$

was produced using the following set of commands:

```
.EQ C     (C for centered equation)
J sub 0 (z) = 1 over pi int sub 0 sup pi cos ( z sin theta ) d theta
.EN       (end of equation)
```

this equation:

$$Pr\{\vec{i}_D\} = \sum_{m=2,4,\ldots,\lfloor D\rfloor_e} (i_m-1)N^{D-m}\int_0^1 \prod_{k=0}^{D-1} T^{P_k(m)}(u,k)\;du \qquad (5.6)$$

was produced from

```
.EQ (5.6)
Pr "{" i vec sub D "}" ~ =
sum from {m=2,4,...., left floor D right floor sub e}
(i sub m -1) N sup D-m
int sub 0 sup 1 ~
prod from k=0 to D-1 T sup {P sub k (m)} (u,k)~du
.EN
```

It is also possible to produce simple tables without much effort.

Mediterranean Fruit Flies	
Year	Number intercepted
1965	45
1966	218
1967	2420
1968	9070
1969	4218
1970	20300

can be produced by using either of the following input files:

```
.TS
allbox, tab (|);
c s
c c
n n.
Mediteranean Fruit Flies
Year|Number intercepted
1965|45
1966|218
1967|2420
1968|9070
1969|4218
1970|20300
.TE
```

or

```
.TS
allbox, tab(!,10);
c s
c c
n n.
Mediteranean Fruit Flies
Years     Number intercepted
1965          45
1966         218
1967        2420
1968        9070
1969        4218
1970       20300
.TE
```

printer/plotter, is also supported. The Versatec driven in the graphics mode allows generation of multiple fonts in different type sizes and can be used as a proof-copy device for documents to be phototypeset.

Phototypesetters that can be supported include the Wang C/A/T/4 and C/A/T/8, the Mergenthaler Linotron 202, and the Autologic APS-micro5. Interface programs can be written to drive new printer products. In the near future we will see enter the market printing devices with a variety of recording techniques, including ink jets, fiber optics, and laser xerography, having a capability of multiple font production in multiple point sizes. These devices will produce copy of correspondence quality. As these devices become available, they will be interfaced to the IS/1 UNIX systems.

Conclusion

Years of hard work have gone into gathering the hardware components and computer software for this system. Planning a total system was perhaps the easiest part. Gaining funding for equipment and places to put it and identifying people to manage the system were difficult. It seemed at times that acquisition of the third-generation phototypesetter would not be possible. Ellen Williams, formerly with ORNL in the Information Division, deserves much credit for gaining Joint Committee on Printing approval for acquisition of the phototypesetter.

The efforts to produce systems to aid in the production of technical documentation have been successful due largely to two people: Al Brooks, manager of Computing Applications, and Dan Robbins, director of the Information Division. Al acquired the first minicomputer system as a test and development vehicle. He gave management support, direction, and encouragement to the small group that set out to build a system. Dan gained Laboratory support to acquire the necessary hardware components—a large minicomputer, printers, terminals, and the phototypesetter that are essential parts of the total system. Largely through the efforts of these two people, we have a collection of tools that will allow all of us to share our knowledge with others in a more timely manner. We also have a modular minicomputer network that allows us to investigate the possibilities of electronic communications and other aspects of office automation. ornl

BOOKS

Innovation and U.S. Research: Problems and Recommendations, *W. Novis Smith and Charles F. Larson, eds., American Chemical Society, Washington, D.C., 1980. 260 pp. $26.75. Reviewed by W. S. Lyon, Analytical Chemistry Division.*

Abou Ben Adhem, encountering one evening an angel making out performance ratings, asked to be listed as one who loved his fellow man. Most researchers at ORNL, finding themselves in a similar situation, would probably request a rating of creative or innovative. For ORNL itself, Laboratory management would almost certainly opt for these two descriptors because the function of institutions such as national laboratories is innovation; new ideas translated into new processes, procedures, or philosophies are the sine qua non of this or any other research organization. But U.S. innovation, like the old gray mare, ain't what she used to be; our creativity seems to be slowing down. What can we do about it?

Innovation and U.S. Research: Problems and Recommendations is based on an American Chemical Society Symposium held in 1979 to address the problem. Twenty-six papers cover every aspect of innovation and range from personal reminiscences of innovation to discussions of what the proper role of the federal government should be. Listen, for example, to Jacob Rabinow of the National Bureau of Standards and holder of 215 patents as he discusses "The Individual in Government Research and Innovation": "In the good old days the question of justification would not have arisen. If you wanted to do something interesting, you just did it because the boss was a technical man, the accountants were not yet in charge, and you could do whatever you liked within reason." Here is Senator Orrin G. Hatch discussing "The Bureaucratization of American Science": "Almost without exception, when government takes over a function from the private sector, there is waste, fraud, and inherent discrimination. That the federal government has given itself the responsibility to support science and technology to this extent is the problem. Valuable capital for research and development is lost and priorities are set which do not really reflect the needs or capabilities of the American scientific enterprise. When 50% R&D funding is appropriated and awarded by government, we will see declining results." And, finally, in the more reasoned "Appropriate Role of Government in Innovation," J. Herbert Holloman of MIT says: "Anybody who reads the history of the economic development in this country would understand that many of the developments were encouraged by some sort of government policy and interference." Three strong and very different views on innovation. Most of us who remember Clinton Laboratories can probably empathize with Rabinow; those who voted for Reagan will find some mutuality of interest with Hatch; but all of us who believe in ORNL must agree with Holloman.

Some ancient shibboleths about innovators are struck down by Joseph Steger of Rensselaer Polytech in *The Individual in Research Innovation: Eleven Hypotheses About Innovators.* Peer evaluations in three different laboratories negated the beliefs that innovators are weird, risk taking, better educated, more adaptive, etc. Steger found but two factors that seem common to creative people: early and avid reading and a home environment that viewed the universe as knowable and science rather than religion as authoritative. Innovative individuals "center their lives on their work," says Steger.

There are, of course, more facets to the diamond of innovation than those mentioned above. The private sector, investment decisions and economic considerations, patent policy, rewards and incentives, and that innovative jewel of the Pacific, Japan, all come under discussion. The authors are knowledgeable, recognized authorities who, unlike many symposia participants, persuasively advance their beliefs.

Innovation and U.S. Research is an attempt to bring some creative thought to the serious problem of apparent decline of U.S. innovation. Organizing a symposium or reading its papers will not metamophose us into a nation of Einsteins and Edisons, but recognizing the problem, especially as viewed from a variety of positions, is a first step toward solution.

As part of the problem and also, one hopes, part of the solution, ORNL staff members should be aware of current thinking on innovation and research. Who knows, the angel may come some day to write against our name. And if we cannot honestly call ourselves "innovative," we can, at least, after reading the book, confidently proclaim, "knowledgeable in the field."

Entropy, A New World View, *by Jeremy Rifkin with Ted Howard, Viking Press, New York, 1980. 305 pp. $11.95. Reviewed by Alvin M. Weinberg, Institute for Energy Analysis. This review has appeared in* Population and Development Review.

Neo-Malthusianism has acquired a new catchword: entropy. First introduced into economic thinking by Georgescu-Roegen in his remarkable book, *The Entropy Law and the Economic Process,* the edia is gradually catching on, if not so much among professional economists, then certainly among politically active environmentalists, antigrowthists, small-is-beautiful adherents, decentralists, solarists—in short, the new radicals who are convinced that the Malthusian catastrophe is here at last, and its name is Entropy.

Entropy is a measure of disorder, or randomness. According to the Second Law of Thermodynamics, the world is inevitably headed toward a state of maximum entropy —that is, ultimate disorder and randomness. This, in its social and economic dimension, is Georgescu-Roegen's Entropy Law. He, as do so many of his disciples, especially Jeremy Rifkin, sees the inexorable working of the Entropy Law as pervading *all* of human existence: physical, social, psychological, and religious. There is no escape from its workings. Our current social and economic disorganization is a manifestation of the Entropy Law. Only by a total change in our way of transforming energy and of organizing society can we survive despite the workings of the Entropy Law.

Entropy is a slippery concept. John Von Neumann, perhaps the foremost mathematician of the twentieth century, once advised Claude Shannon, founder of information theory, to designate the mathematical expression Shannon had devised to measure the amount of information in a message by the word "entropy." Von Neumann gave two reasons: "First, your formula is identical in structure with the entropy of statistical thermodynamics. And second, and more important, no one understands entropy. You will therefore always be at an advantage in an argument."

If entropy is all that difficult a concept, how come that it emerges as the unifying theme of modern Malthusianism? In truth, this modern Malthusianism, with its stress on entropy, is, to a degree, merely a more accurate reformulation of classical Malthusian doctrine. Malthus argued that man increases his numbers geometrically; his means of subsistence, arithmetically. Ultimately his demands exceed his means of subsistence. Many authors since Malthus have recognized that Malthus's views had a thermodynamic connotation. Because, in principle, energy can be transformed into all material goods (such as food, water, and fiber), the Malthusian dilemma has often been described as an energy dilemma: expanding humankind would eventually outrun its energy resource.

This is not quite accurate. Because energy can be neither created nor destroyed, we can't be running out of energy per se: it is only energy in a form (oil, gas, uranium, for example) that can be transformed into useful work. Such energy is described in thermodynamics, a bit inaccurately, as "free energy," a term introduced by Helmholtz. Free energy and entropy are closely related: the lower the entropy, the greater the free energy and therefore the more useful the resource. Thus, Malthus's energy dilemma is more accurately an entropy dilemma: what we lack—the lack that will eventually do us in—is enough energy at *low* entropy.

What is new in Georgescu-Roegen's reformulation of the familiar Malthus dilemma is his realization that the increase in entropy incurred in all human transactions creates difficulties of and by itself: pollution, too much carbon dioxide in the atmosphere, and, in a somewhat analogic sense, social disorganization, randomness, complexity, semantic confusion, anomie.

Almost all of us, neo-Malthusian pessimists and technological optimists, are convinced that Malthus's original doctrine, as indeed Georgescu-Roegen's, is correct *in principle*. The earth can sustain only so many people before the society will "collapse," as envisaged in the report, "Limits to Growth," to the Club of Rome. This collapse, according to the original doctrine, was to be manifested as a shortage of free energy (i.e., our nonrenewable fossil energy resources). The collapse has not occurred, and most would argue that its avoidance represents the supreme triumph of technology. How much longer can our technology stave off the Malthusian collapse?

Exponential population growth has to stop—but where? Is the 6 billion world population now projected for 2000 sustainable, essentially forever? Or must we eventually revert, as Rifkin claims, to a population of less than 1 billion? The issue becomes quantitative: do we have enough free energy to sustain a very large population over the long term?

Rifkin, and to a lesser degree Georgescu-Roegen, insist that once we use up our fossil reserves of free energy, we have no choice but to turn to the sun, an essentially inexhaustible source of free energy. A society based on the sun is, in Rifkin's view, a frugal society. There must be fewer people. These few will lead lives that are simple and are decentralized, both politically and technologically. Rifkin more than flirts with the Buddhist way: only a more contemplative, less frenzied life-style can be sustained by an energy source as diffuse as solar energy. Further, this way of life is uniquely moral because it alone conforms to Georgescu-Roegen's over-arching Entropy Law.

Georgescu-Roegen, in a 15-page Afterword, seems less certain than Rifkin that the solar society can sustain even as many people as Rifkin contemplates. After all, solar energy sources demand equipment made of silicon, aluminum, and plastic, and according to the Entropy Law, these too become dissipated and unavailable as they are transformed to fill human needs. For Georgescu-Roegen there is not only a free-energy (or entropy) dilemma, there is also a materials dilemma caused by the dissipation of useful minerals into ever more dilute states of higher entropy. In this sense, he adds a material as well as a social dimension to the original free-energy dilemma of Malthus.

I am a technological optimist, one for whom Rifkin has only contempt. I cannot allow to go unchallenged three of Rifkins's, or more accurately, Georgescu-Roegen's, primary theses. These are, first, that once the fossil fuels are used up (or abandoned because their use will cause unacceptable change in climate), man has no alternative but solar energy; second, that we are destined to experience shortages of mineral products, such as metals or concrete or plastics, much like those we experience with oil; and third, that no alternative to semantic chaos and social disorganization exists other than a return to a less technological, simpler, and decentralized social order. On the first two accounts, I believe Rifkin and Georgescu-Roegen are more likely to be wrong than right. On the third account, I see at least one technological alternative that hardly figures in either Georgescu-Roegen's or Rifkin's thinking.

As for energy, Rifkin's underlying assumption is the rejection of nuclear energy. This is so large an assumption, and so little justified, as to vitiate much of what Rifkin claims. The breeder reactor is an inexhaustible source of energy at low entropy. Whether fueled with residual uranium and thorium in granitic rocks or with the uranium dissolved in the sea, a breeder reactor system sufficient to provide most of the energy man will ever need can be sustained for *millions* of years. Ten thousand breeder reactors could provide enough energy to sustain a population of 6 billion people at an average energy demand per capita twice as high as the current average of 2 kWy/y per person.

Is such a large nuclear system credible? Rifkin, as do many others, dismisses the possibility; in so doing they discourage the society from even trying to develop such a system. I concede that the nuclear system poses difficulties, but to dismiss it when the alternative is a low-energy, Buddhist society in which time is sacrificed for decentralization and nonspecialization —this I cannot do. If nuclear energy is deficient, fix the deficiencies; don't reject it. To categorically give up on nuclear energy is a denial of human ingenuity that makes no sense to me. To encourage us to give up on nuclear energy without expending every effort to make it work is immoral.

As for Georgescu-Roegen's insistence that we shall also run out of mineral resources, I can only refer him, and Rifkin, to the paper Goeller and I presented at the 1978 Helsinki meeting of the International Union for the Scientific Study of Population on "The Age of Substitutability." Our main point was that 95% of the metals used by man are iron, aluminum, silicon, magnesium, and titanium. These are the most abundant metals in the earth's crust; we shall never run out of them, even if they are used at high concentrations. As for metals like copper or mercury, of which supply is not infinite, many possibilities for substitution exist; even if their price increases tenfold, the cost of an average pound of metal hardly doubles.

Thus, although Georgescu-Roegen is correct *in principle* in claiming that the world will eventually be overwhelmed by the inexorable Entropy Law whether or not we stabilize the population, the relevant question is when? In this generation? In 100 years? In 10,000 years? I see far too many technological possibilities to be overwhelmed by such pessimism, even though I agree that the world's population must stabilize.

Finally, neither Rifkin nor Georgescu-Roegen do justice to the extraordinary advances that are now occurring in the handling of information. For example, how the chip and the microprocessor will change our society is anyone's guess. Can these devices restore order to a society that is now too complex to be governed, or possibly too complex to retain a modicum of stability? I do not know. In any case, as a technological optimist, I believe it is at least plausible that the computer will turn out to be the solution to semantic chaos, rather than part of the problem.

Rifkin's style is arrogant: he *knows* that he, as Paul to Georgescu-Roegen's Diety, has a sacred mission, and he cannot let facts divert him. He must demonstrate that the whole modern society is rotten and that this rottenness is not something transient or isolated but is immanent and pervasive. It is all a working-out of the Entropy Law.

The chapter on medicine illustrates the poverty as well as the style of Rifkin's approach. Because, according to the Entropy Law, everything is getting worse, the health, and therefore the life expectancy of our entropic society, must be diminishing. To support the argument, Rifkin invokes authority. He does not verify his authorities' credentials—it is sufficient that an authority, any authority, support his thesis. Rifkin quotes studies that show (1) that modern medicine, especially antibiotics, has contributed negligibly or even adversely to human health; (2) that "Most diseases are environmentally induced" [p. 180]; and (3) that male life expectancy in the United States has begun to drop. Data, however, show otherwise: (1) although better sanitation was the primary step in the elimination of infectious disease, the knockout blow surely has been delivered by immunization and antibiotics; (2) Professor Higginson, the original proponent of the view that up to 90% of human cancer is caused by environmental agents that can be removed, has now recanted his earlier belief; and (3) the life expectancy of a male reaching the age of 65 in the United States has increased by 2 years in the past generation.

The pollution-induced catastrophe to human health envisioned by Rifkin and the entropists hasn't happened. But Rifkin is not alone in his error. Bureaucracies such as the Council on Environmental Quality and the Environmental Protection Agency in the United States and comparable bodies elsewhere are equally at fault. Unless the environment can be blamed for the alleged deterioration in public health, a prime raison d'etre for the existence of these bureaucracies is removed.

If these bureaucracies are weakened, what hope is there for the entropists to create a new society according to their vision of the future—a society whose ethical justification lies in its conformance with the Entropy Law? This society is the truly moral society since it alone conforms with God's, or better, Science's, supreme law of entropy.

It is but a small step from preaching, as Rifkin does, the inevitability of such social evolution along paths dictated by thermodynamics, to coercive prodding or even violent hauling by the Entropic Revolutionaries. They, like revolutionaries at all times, are prepared to coerce society into saving itself from its otherwise foreordained destruction. The resemblance to the Scientific Socialists is uncanny: Marx proved that capitalism's downfall was ordained by general and immutable scientific principles. Lenin, impatient with the pace at which history unfolded, introduced revolutionary socialism. Stalin demonstrated that social movements, ordained by the workings of grand scientific laws, too often are captured by human beings driven by lust for power. The result is a quantum increase in human suffering, justified always by the claim that the new social configuration conforms more closely to the Laws of Science —whether the dialectical materialism of Marx or the Second Law of thermodynamics as perceived by Jeremy Rifkin. Let the new entropists remember history before they reject so easily the more humane approach of the technological optimists for staving off the dilemmas of Malthus or of Georgescu-Roegen.

The following books list members of ORNL staff as principal authors or editors:

Health Effects Investigation of Oil Shale Development, edited by W. H. Griest, M. R. Guerin, and D. L. Coffin. Ann Arbor Science Publishers Inc., Ann Arbor (1981).

Environmental, Health, and Control Aspects of Coal Conversion—An Information Overview, Volumes 1 and 2, edited by H. M. Braunstein, E. D. Copenhaver, and H. A. Pfuderer. Ann Arbor Science Publishers Inc., Ann Arbor (1981).

Toward a Desirable Energy Future:

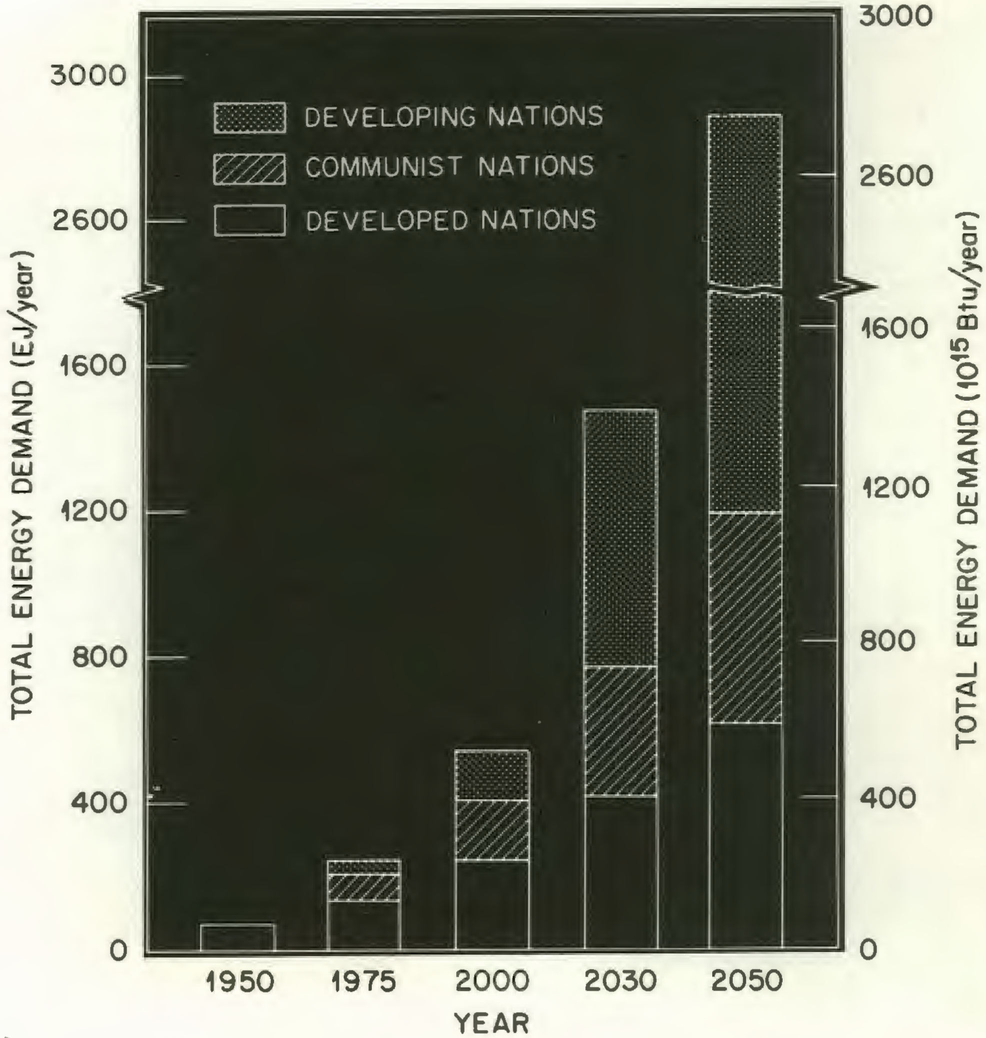
A Summary of Results from the ORNL National Energy Perspective Project

By TRUMAN ANDERSON

"The last thing this country needs is another energy study." That was the response from some of our ORNL colleagues when we started the ORNL National Energy Perspective project in the summer of 1979. We thought that they were wrong, but we were not completely confident that they were wrong. After all, the events of 1973-1974 that affected the oil market had spawned a multitude of energy studies by government, universities, and private groups. But even with these studies—some say because of them—there seemed to be no national consensus about our essential energy problems, the appropriate policies and programs to deal with these problems, or the role of energy research and development. This last point was particularly worrisome for an R&D institution such as ORNL.

Consequently, Herman Postma asked Bob Livingston, who was then director of Program Planning

Truman Anderson is director of the Program Planning and Analysis office having succeeded Bob Livingston this year when Livingston retired. Prior to his current position, he had been a member of the Engineering Technology Division and its predecessor, the Reactor Division, since he came to ORNL in 1958. The ORNL national energy perspective (ONEP) project began as a study in PP&A while Anderson was still a member of the Engineering Technology Division. The accompanying account is an abbreviated version of the final published ONEP report of the same name.



By the year 2030, the energy consumed by the developed countries will represent a much smaller fraction of the total world energy consumption than today.

and Analysis, to organize a study, the goal of which was to develop an independent perspective on energy that could provide a framework for later R&D planning. Other major participants in the study were Ted Besmann, Mitch Olszewski, Bud Perry, Colin West, and I. In addition, many ORNL staff members contributed by preparing overview papers on more than 20 topics.

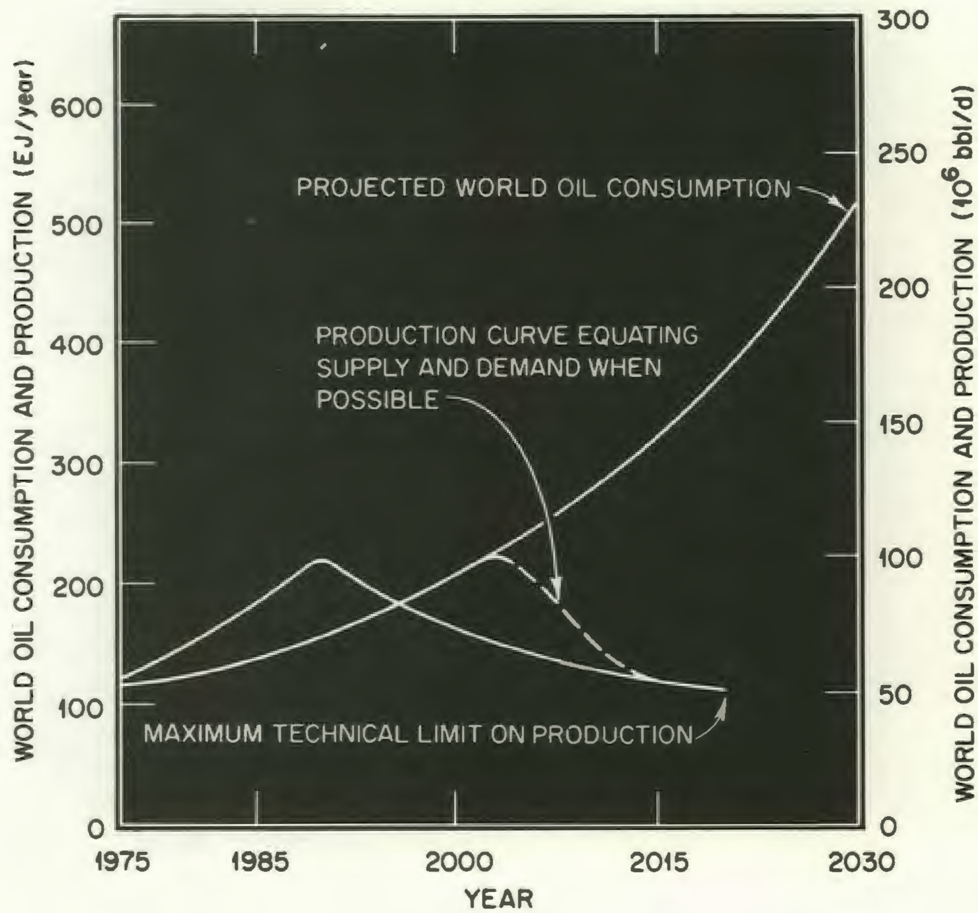
This broad participation does not, however, imply that our study represents a consensus from ORNL about energy. With regard to the whole subject, the Laboratory is a microcosm of society, and consequently no single viewpoint can represent the whole.

The World View

Historically, man's cultural developments have gone hand in hand with his ability to acquire and use energy. In today's world, economic well-being and energy use are closely correlated. This statistical fact is plainly evident in spite of some analysts' attempts to show that economic growth and energy can be decoupled. There are no wealthy countries that use little energy. Low energy use is associated with societies that are desperately poor.

From 1956 to 1976, world energy use almost tripled, and about three-fourths of this increase was provided by gas and oil. Contrary to the impression created by many energy spokesmen, almost all the increase in energy consumption —80%—took place outside the United States. The trend in energy use was a positive development in that many of the industrial nations were able to strengthen their economies, and, more important, most of the developing countries were able to survive without reductions in

Projected world oil consumption and production figures indicate that world oil shortages will begin before the end of the century.



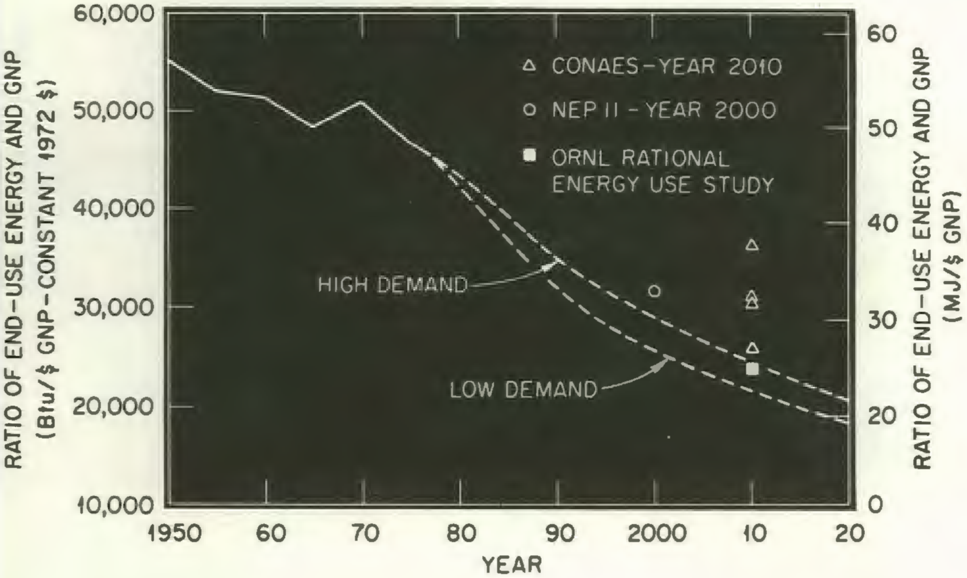
living standards, despite huge increases in their populations over the same period.

Some of these countries have even been able to make real gains in national and personal prosperity. The poorer countries and regions that have made real progress toward development in the past quarter of a century have done so with substantial increases in the amount of energy used. For instance, energy use increased by a factor of 14 in China, by a factor of 8 in Latin America, and by a factor of 11 in Southeast Asia. Most of the increases have been for serving basic human needs, not for leisure-class luxuries. For example, "the green revolution" that was achieved over the past 15 years resulted from the development of dwarf varieties of wheat and rice that could utilize the benefits of irrigation and fertilization. Without these energy-related inputs, the new varieties of grain would have been less productive than the domestic varieties they replaced.

A Look Forward

And what of the future? The world is currently on a population-doubling time of less than 40 years, and one phenomenon of population dynamics, the momentum of population growth, is of critical importance in understanding the future. An expanding population, a characteristic of developing countries, is heavily biased toward younger age groups and contains a high proportion of women who are or will be of childbearing age. As a result, even if fertility control programs are highly successful, world population will continue to increase for some time. If the birth rate for the world can be reduced to the replacement level by 2015—a fairly optimistic assumption—there may well be 9 billion people by the middle of the twenty-first century. Nine billion is about double today's population.

Adequate food for such a number, not to mention improved human living standards, requires efficient agriculture, crop storage, and food processing and distribution. These are all energy-intensive activities. Similarly, energy consumption will have to increase as industrial activity increases, no matter how efficient the industrial processes become. In short, if worldwide living standards are to improve, energy usage must grow much faster than population. Our study suggests that if the less developed parts of the world are to make significant progress, world energy production must increase by up to a factor of 6 in the next 50 years, even with strong emphasis on conservation. Conservation is vital, but any strategy that does not also emphasize energy supply is a blueprint for human disaster. However, even with emphasis on supply, do we have the needed energy resources? If we limit our perspective to traditional sources of gas and oil, the answer is no: The



The ONEP assumptions about achievable improvements in end-use energy efficiency result in a higher level of conservation than do those of most other studies.

world production capacity for both these fuels will very likely fall short of demand late in this century or early in the next. But, if we look to other resources, such as coal and nuclear energy, the answer is yes. The world has enough conventional energy resources amenable to *known* methods of extraction and use to last well beyond the middle of the next century. This does not include the unconventional resources, such as oil shales and heavy crudes, which are also extensive. And the options will almost surely be broadened by future developments in such areas as fusion, solar, and breeder reactor technologies.

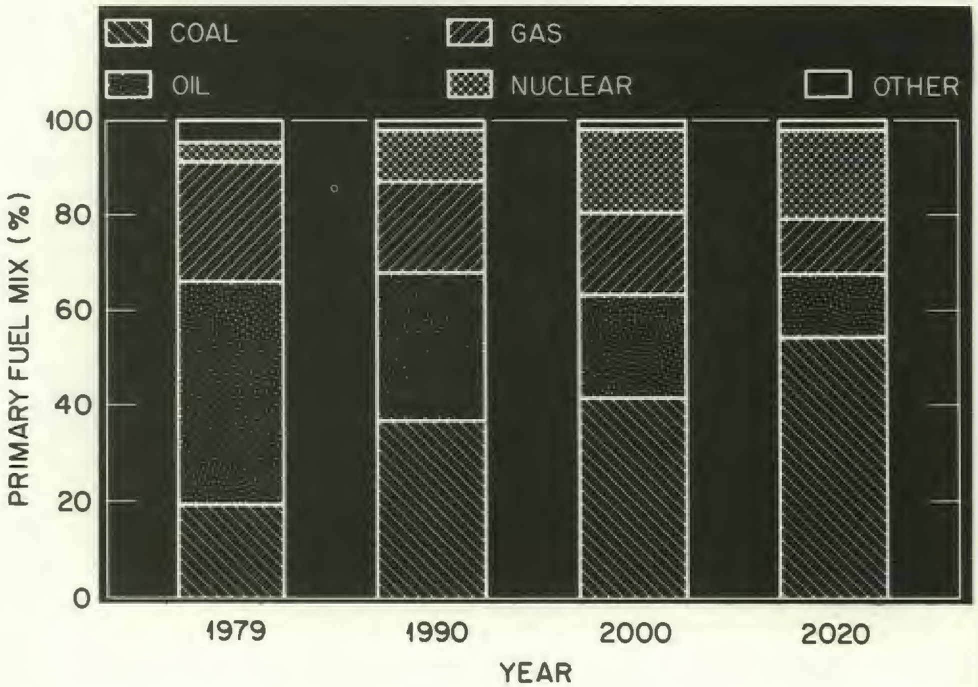
We are thus facing a future of greatly expanded world population, but also, hopefully, a correspondingly expanded world energy supply. Most of the increases in both population and energy demand will be in nations that are now classed as less developed. The needed energy cannot come from the same resource base that allowed the expansion of the last few decades: We must make a transition from our present situation, in which growth in demand has been met largely by natural oil and gas, to one in which we resort to more abundant resources to provide most of our energy.

Concerning CO_2

Even though the world has sufficient energy resources to supply increasingly large demands for many decades, some concern exists that exploiting these resources, and in particular the fossil resources, may lead to serious environmental impacts. One of the potential "showstoppers" is the effect of carbon dioxide on the global climate, a phenomenon about which much has been written. Estimated recoverable resources of fossil fuels, worldwide, appear to be more than enough to quadruple the present level of atmospheric CO_2, and it seems likely that such a level would bring about climatic and other changes that the world may well wish to avoid. Some accounts of the CO_2 issue suggest that disaster is imminent, but the facts do not support this view. It is very unlikely, for example, that the CO_2 concentra-world energy demand occurs. What will ultimately be an "acceptable" level of CO_2 is now unknown, though we know of no evidence that a level of 500 ppm or even more would be unacceptable. Even if the transition from fossil to nonfossil energy sources is gradual, we believe there is ample time (say, 20 years) to learn much more about the factors affecting the accumulation of CO_2 before imposing any limits on the use of fossil fuels. By no means should the CO_2 question be taken lightly. At present, however, it is more a matter for science than it is for energy policy. The possible seriousness of the phenomenon requires that it be the subject of intensive scientific research during the next two decades.

U.S. Perspective

Over the past eight years the American people have been subjected to dramatic changes in the reliability of their energy supply. Prices have skyrocketed; occasional long waiting lines for gas have sprung up; an avalanche of energy rhetoric has filled the media; new and varied energy-related social philosophies have been propounded; energy laws, regulation, and deregulation have become facts of life; and the establishment of new government energy organizations has been accompanied by



If oil imports are to be reduced to acceptable levels, demand trends show that coal and nuclear sources will become the predominant fuels through 2020.

perpetual reorganization. The confusion has led us to seek an answer to the explicit question: What *is* our energy crisis?

The United States faces a number of energy issues. The cost of energy service is higher than it should be because our capital stock is optimized for the energy prices of the 1960s, not the 1980s. The production, conversion, and use of energy have resulted in legitimate concerns about adverse impacts on our air, water, and land resources. These and other issues must and can be dealt with. Without denigrating these important issues, we conclude that our heavy reliance on imported oil is by far the most significant problem and should be the central near-term focus of U.S. energy policies and programs. Our dependence on foreign oil affects us adversely in three important ways:

- It is seriously damaging the U.S. economy. It contributes to our unfavorable balance of trade and weakens the U.S. dollar abroad; at home, it contributes to inflation and unemployment. The magnitude of the dollar drain is hard to appreciate, but an example may give some perspective: If land in the state of Tennessee were valued at $3000/acre, we traded the worth of the entire state for foreign oil in 1980.
- It reduces our ability and willingness to act as an independent nation in our own best interests, either in international affairs or in domestic affairs. This vulnerability is recognized by the members of OPEC and by the United States alike. The real message of 1973–1974 was the oil embargo, not the price increase.
- It threatens world peace and stability. Our dependence on unstable supplier countries for a vital resource could easily lead to armed conflict. Risks associated with energy facilities commonly analyzed in environmental impact statements pale into insignificance relative to the consequences of war.

Our conclusion that imported oil is the central U.S. energy problem may seem less than profound. As early as 1974, the Project Independence study accurately identified the near-term energy problem as one of vulnerability to disruptions in foreign oil imports, and many of the policy recommendations made then still seem reasonable today. Had they been carried out, our present position would be much less precarious. But some major energy studies following Project Independence seemed to miss the mark. For example, the Committee on Nuclear and Alternative Energy Systems, while recognizing U.S. vulnerability as a significant difficulty, failed to focus on the objective of limiting oil imports. Instead, all energy sources were treated equally; moderating demand growth, regardless of which resources were affected, seemed to be the essential response. Consequently, in every scenario, oil is expected to supply 10% of the primary energy input to produce purchased electricity in 2010. Further, oil imports as a percentage of total oil consumption remain at about 40% until 2010 in most scenarios, and in the high conservation case they actually increase to over 50% of consumption. The National Energy Plan II offers similar results. The NEP-II strategies project a *minimum* level of imports equal to 40% of total demand in the year 2000.

Can anything be done about oil imports? A view often heard is that all our solutions have serious problems and that we must, therefore, either do without or make the necessary accommodations to live with vulnerability. We believe this is incorrect. There are, in fact, many good options for solving the problem.

Anatomy of a Solution

Consideration of the purposes for which oil is used is important in determining how to reduce oil imports. Nearly 80% of our total oil use is accounted for by considering only six kinds of end-use devices: automobiles, 29%; space and water heaters, 16%; trucks, 14%; electric utility boilers, 9%; industrial process heaters, 6%; and industrial boilers, 5%. We examined three general ways in which oil imports could be reduced and yet maintain the services provided by these end-use devices. First, the energy efficiency of the devices or of the processes they support could be improved. Second, other energy forms of domestic origin could be substituted for present uses of oil. And, third, more oil or direct substitutes for oil could be produced from domestic resources. Thus, conservation, substitution, and production were subjected to detailed examination which included the following topics:

- Conservation
  - Efficiency improvements in automobiles and trucks
  - Conservation of oil and oil substitutes (gas and electricity) in buildings and industry
- Substitution
  - Coal for industrial boilers
  - Coal and nuclear for electricity production
  - Electricity and gas for space and water heating
- Production
  - Enhanced oil recovery
  - Heavy crudes
  - Oil from shale
  - Oil and gas from coal

From this list, we found several very attractive approaches to reducing oil imports; some examples follow.

Conservation will need to be an essential element of any strategy to reduce oil imports. By far the most important and direct approach to reducing oil imports through conservation is efficiency improvements in the transportation sector. For example, we estimate by extrapolation of current automotive technological advances that Americans can, by the turn of the century, drive about half again the distance they do today, using 30% less fuel.

Fuel substitution was found to be an extremely effective means of reducing oil imports. Because of historical conditions, including the relative prices of fuels and the priority placed on clean air in the 1970s, the United States now finds itself dependent on oil and natural gas in many applications that represent completely inappropriate and uneconomic uses of these fuels. It thus appears that fuel substitution—the use of abundant domestic energy resources in place of oil—represents one of the best near-term approaches to reducing oil imports. There are a number of good opportunities for fuel substitution in the electric utility, industrial, and residential-commercial sectors. However, the electric utility industry needs to be a key target because utilities are major consumers of oil and natural gas in base-load and intermediate-load power plants. Total gas and oil used for boiler fuel amount to about 6.6 EJ/y (3×10^6 bbl/d), divided about equally between oil and gas. Displacing gas in this sector is as good as displacing oil because the gas released could be used to displace oil now used in space and water heaters, industrial process heaters, and small industrial boilers. The total potential for oil import reduction in the utility industry amounts to about 40% of our imports. This reduction could be achieved, moreover, with substantial decrease in consumers' electricity bills. For example, replacing an oil-fired power plant (regardless of its age) with a new nuclear or coal plant would reduce the cost of electricity to consumers by roughly a factor of 2 over the next 30 years.

Concerning the production of oil and oil substitutes, we conclude that using *established* technologies to produce synthetic fuels from oil shales and coal is more economical than buying imported oil. Although we do not propose it as a strategy, we examined the feasibility of producing oil by indirect coal liquefaction at the 1978 level of imports (18 EJ/y, or 8×10^6 bbl/d). Our judgment is that this production capability could be achieved in the next 20 years if industry and the federal government make a major commitment to coal liquefaction. The total investment would amount to about \$450 billion (1980 dollars), a modest figure considering that our imported oil bill for the 20 years would be four times as great, based on current oil prices and import rate. Furthermore, the levelized product cost would be less than the levelized import price of oil. Other comparisons of cost are:

- less than 1% of U.S. GNP over the 20 years,
- less than 15% of the U.S. military budget, and
- an investment as a percentage of GNP similar to South Africa's oil-from-coal program.

In examining the various means by which the oil import problem can be addressed, one fact stands out: The United States has the resources to solve the problem. It is our willingness to accept the challenge that is in question.

Strategy

What energy future, then, should we plan for—and how do we get there? The production and use of energy is not a social goal in itself, but rather one of the many elements needed to accomplish social goals. Over the past decade, a degree of pessimism has developed within some segments of society about what can be accomplished in the future. According to this view, the future cannot be as good as the past. The same kind of thinking has affected several energy studies in which, for example, the future economic growth rate is assumed to be half the historic level. We reject this approach for two reasons. First, there is no technical or resource basis for the pessimism: The United States remains extremely well endowed in terms of material resources, technical and management know-how, and industrial capability. Second, and most important, energy planning based on limited expectations for the future has the elements of a self-fulfilling prophecy. Predictions at the outset that the future will be grim lead to the conclusion that the "need" for energy will be small; if that is the basis for energy planning, the future will indeed be grim. Our judgment is that the national focus should be, not on predicting the future, but on making it. Thus, we define a desirable future and determine what we as a nation should do to move toward that future.

What is a desirable future? The answer depends on the answerer, and we recognize that this simple question is at the heart of the debate surrounding energy. In contemplating a desirable future, many people might think of a pleasant home, a good job, a beautiful countryside, a bustling economy, a free and independent nation, clean air and abundant pure water, perhaps even a vacation at the beach or mountain resort, and all at affordable prices. Needless to say, the desirable future in our study is hardly defined in such romantic terms, but the more mundane definition used could well include these and much more. Specifically, our goals were:

- to reduce oil imports to 20% of total U.S. oil use by 2000 and to eliminate them eventually;
- to ensure that the U.S. energy system can support a per capita GNP annual growth rate of 2% (real)—a representative level of growth sustained over the past 70 years;
- to make possible the retention of existing life-styles, including continued use of personal transportation and dispersed patterns of living; and
- to achieve these goals while maintaining overall environmental quality within currently accepted standards.

These goals formed the foundation of our conclusions about an appropriate energy strategy. In broad outline, the strategy includes these basic elements:

- Implement an accelerated fuel substitution program focused on:
  - Electric utilities
  - Space and water heating
  - Industrial steam raising and process heating
- Encourage improvements in end-use efficiency with emphasis on improvements related to reducing oil use in:
  - Transportation
  - Space and water heating
  - Industry
- Accelerate energy production based on domestic resources, including:
  - Coal and nuclear power plant construction, with emphasis on nuclear
  - Oil and gas exploration, enhanced oil recovery, and development of unconventional gas
  - Movement toward establishing a major synfuels industry

It is strongly emphasized that this outline does not represent a "shopping list" from which one can pick and choose. The argument that conservation is better than, say, synfuels, is simply not relevant because no single activity will accomplish the stated goals. In the next two decades, major changes need to be made on both the supply and demand sides of energy. The fuel efficiency of our automobile fleet must approximately double, and the thermal integrity of our homes must be improved by over one-third. Oil and gas use for base-load and intermediate-load power generation must be phased out, which will require that certain utilities be rebuilt essentially from the ground up. Synfuel and shale oil industries capable of producing from 4.4 to 17.6 EJ/y (2×10^6 to 8×10^6 bbl/d) of gas and oil will need to be developed. The electric power generating capacity of the country will need to be increased by a factor of 2 to 3, and coal production will need to be increased by up to a factor of 3, even with near-maximum utilization of nuclear power. This list is not intended to be prescriptive; it illustrates the kinds of actions needed by the turn of the century if oil imports are to be brought under control and economic growth maintained. While the task is not trivial, our energy problems can be solved in a rather straightforward way. The job can be done with demonstrated technologies, acceptable environmental and social impacts, and a modest incremental investment relative to that required if we continue on the present path. Further, the prospects are good that the cost for energy service will be no higher, and probably will be lower, than the price the nation is paying today.

We believe that the proposed strategy to move away from dependence on imported oil represents a responsible approach by the United States in relation to the rest of the world. The situation as it now stands is that the United States and other developed countries are using oil for purposes that could better be supplied by coal and nuclear power. Only the developed world has the financial resources necessary to implement these capital-intensive alternatives; continued failure to do so will further increase the world price of oil and decrease its availability for the poorer countries. Thus, U.S. actions to solve its own energy crisis will result in an important benefit to countries that have no alternative to oil.

Beyond the year 2000, both the United States and the rest of the world will continue to move away from dependence on natural liquid and gaseous fuels. The services provided by these fuels will be accomplished by producing synthetic liquids and gases or by other means. In general, the supply of energy will move toward long-term and "inexhaustible" sources. Thus, even if the oil import problem is solved by the turn of the century, energy will continue to be a subject requiring attention. However, we cannot decide now on the amount and kind of energy supply and end-use technologies that are to be implemented in the distant future because we lack scientific information on potential future large-scale environmental and health effects. Nor do we need to make such decisions now. What is needed now, and what can be done now, is to formulate a vigorous long-range program of scientific research and technology development that will provide us with favorable options and that will allow us to make rational choices in the future.

In Summary

Based on our study of U.S. energy problems and alternatives, we are optimistic about the nation's energy future. The United States has the resources, the technology, and the ability to become essentially independent of foreign oil by the end of the century, and it is in the interest of both the nation and the entire world that we do so. The effort will require the commitment of substantial but not unreasonable technical and financial resources, and, most important of all, it will require an ability to make decisions and see them through. Ultimately, the United States, with its vast energy resources, will very likely become a major exporter of energy and energy technologies, and the world market will be large. In summary, the energy future of the United States need not be bleak; it can be whatever we choose to make it. ornl

"The U.S.... has the ability to become essentially independent of foreign oil by the end of the century..."

information meeting highlights

Engineering Physics, Jan. 26–27, 1981

Energy Model Evaluation

When an author publishes a book, there is a chance that the book will be subjected to independent evaluations in the form of published book reviews. Developers of computer models also may find their products undergoing public scrutiny and criticism. In fact, modelers in the field of energy and economics are having their computer models evaluated not just because of interest in their predictions but because a law requires it.

A recent federal law states that the Energy Information Administration of the Department of Energy must evaluate its energy-economic models and make them accessible to Congress and the public. The goal of EIA, which has approximately 70 models that have the capability of answering policymakers' questions, is to have all these models evaluated by 1986.

For the past two years, an interdisciplinary team of physicists, engineers, economists, mathematicians, information specialists, and computer programmers at ORNL have tried to help EIA in this venture. In performing energy model evaluation, the ORNL team is applying validation approaches used for many years in the physical sciences. This team's research is guided by the recently published report, *An Approach to Evaluation of Energy Economy Models,* by Chuck Weisbin and Bob Peelle of the Engineering Physics Division and Andy Loebl of the Energy Division.

According to Weisbin, "The ORNL goals for energy-economic model evaluation include an intellectually independent determination of the appropriateness (limitations and ranges of validity) of using energy-economy supply/demand projections to clarify specific issues and an assessment of useful improvements in model specifications and needs."

The ORNL team has completed an evaluation of LEAP, EIA's Long Term Energy Analysis Program, which makes energy forecasts for the period 1995 through 2020.

EIA gave the following conclusions in its annual report to Congress, based on the LEAP model's 1978 projections on the energy situation in 2020: (1) coal will be the dominant primary energy source, (2) the industrial sector will be the largest energy consumer, using 60% of the nation's energy (compared with 40% in 1977), (3) end-use consumption of gas and liquid fuels will decline from 83% in 1977 to 50% of all fuel used, and (4) oil imports will steadily decline, but liquid fuels will still be used at 1977 levels, thanks to rapidly increased production of shale oil and liquids from coal.

The LEAP model considers the various mixes of current and potential commercial energy technologies, including new ones such as breeder reactors and coal liquefaction. It takes into account economic inputs such as how taxes, return on equity, and other factors affect relative investment choices. LEAP output can assist policymakers in determining such issues as how much money should be invested in synthetic fuels production to reduce significantly the need for imported oil.

In a report completed in April, the ORNL validation team concluded that LEAP has a number of strengths. For example, it deals plausibly with resource depletion and new technology introduction in a single integrated computer program rather than a linked chain of codes. An engineering simulation model such as LEAP has a natural advantage in understandability. Because of its flexibility, LEAP is useful for studying the effects of various assumptions about resource and energy-conversion development.

The ORNL team also found weaknesses in LEAP-78. These included lack of satisfactory documentation and core storage and extensive computing time. LEAP-78 ignored effects of government regulation, and its fixed coefficient production made treatment of issues such as conservation and retrofitting difficult. LEAP-78 failed to account for important feedback linkages to the general economy from the energy sector. Its documentation did not allow most input parameter values to be traced to their sources. Its credibility was reduced by a lack of a well-documented data base and by lack of wide usage.

Sensitivities of all input data to specific results were obtained in the course of the LEAP-78 evaluation. The ORNL team folded the most important sensitivities with estimated data uncertainties to infer data-related uncertainties in results of interest to policymakers.

Some recommendations made by ORNL on how future LEAP models can be improved are:

1. Long-term annual analyses are unnecessary. Projections should be developed in two- to five-year cycles to permit higher quality results, better documentation, and more comprehensive evaluation.
2. Evaluated standardized energy- and economy-related data and software to process the data to particular forms used by alternative models should be developed simultaneously. Uncertainties in input data should be enumerated.
3. LEAP should become an "open" code—one that is well documented, widely used, transportable, closely studied by members of interested communities, and frequently modified by persons other than the originator.
4. Issues of concern, such as the cost of energy, should be related precisely to model output values to make LEAP more usable by policymakers.
5. Target accuracies for desired results need to be developed to provide a basis for

evaluating whether the model result and associated uncertainty can contribute to the resolution of a given issue.

Weisbin says that energy model evaluation is appropriately performed at national laboratories such as ORNL because the work is interdisciplinary, highly complex, under multiple DOE sponsorship, concerned with energy problems, and dependent on the availability of a sophisticated computing facility. Although it is far more complicated than writing a book review, model evaluation is important, says Weisbin, because it reveals which models have sufficient credibility to serve as decision-making tools.

Instrumentation and Controls, March 4, 1981

Radiation Detectors for the Navy

Radiation survey instruments that use Geiger-Muller tubes and ionization chambers (cutie-pies) to monitor radiation levels in the workplace have been in existence since the 1940s. For nearly this long, the U.S. Navy has been using ruggedized versions of these instruments to meet their special needs.

The Navy needs radiation survey instruments for its nuclear-powered aircraft carriers and submarines, for its submarines and tenders carrying nuclear missiles, and in the event of nuclear blasts in areas where Navy personnel are stationed. For today's Navy, radiation-measuring instruments should not only be rugged and sturdy enough to withstand battle conditions but should be easily readable and easily maintained by personnel who may have no more than a ninth grade education.

To meet these needs, a group of engineers led by Hugh Brashear of ORNL's Instrumentation and Controls Division has developed an instrument called a radiacmeter that is battle tough, easy to maintain, and simple to read. (Radiac is an acronym for radiation detection indication and computation.) The ORNL radiacmeter is an improvement over older instruments because of the incorporation of devices such as a microprocessor and a liquid crystal display much like that on modern digital watches.

In conventional radiation survey instruments using G-M tubes, the meter needle wobbles because its number of counts per second from a radioactive source varies statistically and because of the low efficiency of the detector tube. Also, to read the meter, the user has to select a range position that agrees with the radiation level that is being detected—0.1 to 1 mR/h or as high as 100 to 1000 mR/h.

The new ORNL radiacmeter eliminates the need for the moving-vane meter and the range-selector switch, two components particularly prone to failure. These Achilles heels are replaced by a microprocessor, which gives a steady, reliable needle reading derived from a statistical averaging of the counts, and by a liquid crystal display that permits automatic ranging—that is, it automatically switches from a 0 to 10 mR/h scale to a 0 to 100 or 1000 mR/h scale as the level of radiation escalates (at a hot spot, for example), just as swiftly as a time change is displayed on a digital watch.

However, unlike the digital watch, the display has a pointer and a scale so that it looks like a meter. The pointer and scale numbers, which are liquid crystal, display the correct decade for the value being measured by automatically adding or subtracting zeros in front of or behind the regular numbers. The result is an analog readout (as opposed to digital) as on a meter, but there are no moving parts. This display developed at ORNL, says Brashear, "was really the breakthrough that was needed to modernize these instruments and allow them to be operated with a simple 'on-off' switch that anyone can use."

Besides computing statistical averages and controlling the display, the microprocessor also selects the proper G-M tube (there are two tubes to cover five radiation ranges) and corrects for nonlinear response in each tube. A new value of measurement is presented to the operator once a second and the final value is displayed without lengthy delays, as is the case with the older equipment.

Brashear, Martin Bauer, Dick Todd, Bob Maples, and Bill Bryan of the I&C Division and Ed Kennedy (of the University of Tennessee) are developing a high-range radiacmeter. This radiacmeter will cover four ranges; the top range will be 1000 R/h. An ionization chamber is used in this radiac instead of a G-M tube. An electronometer (special amplifier to measure small currents) was developed to cover six decades of current measurement without any switching and still yield a linear rather than a logarithmic output. The electronometer is needed to make the high-range radiac automatic. This radiacmeter also has a liquid crystal display.

The drawbacks of the G-M tubes are their size, their high-voltage requirements, and their low count yield in low-level radiation fields. Low count yield and large statistical fluctuations make it difficult to obtain accurate readings. To compensate for this deficiency, a microprocessor is used in the latest generation ORNL radiacmeters. Even so, Brashear, Jerry Coleman, and Dick Fox hope to remedy the problem by replacing the Geiger counter with a brand new technology they are developing, namely, a cadmium-telluride gamma-ray detector. If they are successful, ORNL's next generation of radiacmeters will embody state-of-the-art radiation detection technology as well as modern electronics and display.

Peter Lalley looks through an inverted photomicroscope at human-mouse hybrid cells on a petri dish.

Metaphase chromosomes in Chinese hamster-mouse hybrid cells can be specially treated so that each chromosome has a unique banding pattern, making it possible to distinguish one chromosome from the others. The chromosomes are first treated with trypsin, an enzyme that removes some chromosomal proteins. Then the chromosomes are stained with Giemsa, which will stain some areas where protein has been removed as well as other areas where protein remains. The result is banded chromosomes. These hybrid cells have been used by Lalley to map the location of a gene that makes mouse cells resistant to invasion by a cancer virus.

Genes and Cancer

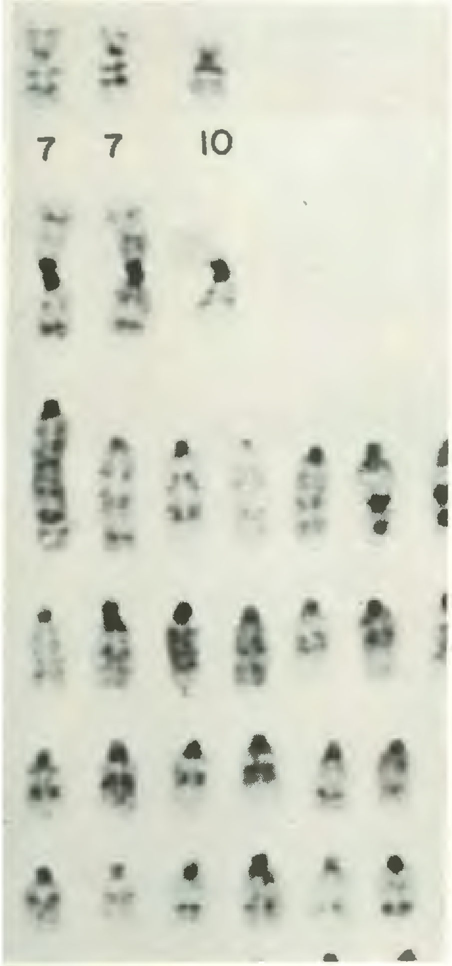
By CAROLYN KRAUSE

If there is a single answer to all forms of the complex disease state called cancer, it most likely lies in the genes. These units of heredity formed by the master molecule DNA can function when they are not supposed to or fail to work when they should. The result of genetic malfunction is sometimes unregulated, autonomous growth of cells—cancer. Thus, if ways could be found to induce genes gone awry to work as they should, some types of cancer might be brought under control.

According to Frank Kenney of ORNL's Biology Division, "Cancer can be considered as a disease of gene expression, a consequence of the malfunction of existing genes. Cancer can occur by changes in the structure of genes by mutation brought about by irradiation or by chemical carcinogens or by changes in the fashion in which the expression of normal genes is regulated."

One way that cancer may arise is through a change in a gene that causes it to stop producing a key enzyme necessary for controlling the growth of cells. As the cell containing this defective gene divides, the defect passes on to subsequent cell generations. Lacking the control enzyme, the cells proliferate into a tumor that invades other body tissue if it is not stopped by the body's immune system or by surgery, radiation, or drug treatment. The same result could occur if the key gene remains normal in structure but its expression—the mechanisms governing whether or not it produces the key enzyme—is altered.

Because of spectacular advances in molecular biology in the 1970s, an understanding of the relationships between genes and cancer appears to be closer at hand. Says



This karyotype shows an artificial lineup of chromosomes from a human-mouse hybrid cell. The three chromosomes at the top (marked 7, 7, 10) are human, and the rest are mouse chromosomes. This hybrid cell was used for DNA repair studies.

Donna Woodard uses a sterilized aspirator to transfer mouse-human hybrid cells from a petri dish to a centrifuge tube. The cells are then centrifuged and resuspended in new media, which are placed on a petri dish.

Kenney: "The application of molecular genetics to the study of the causes of cancer is now the leading edge in cancer research. This is because several new techniques allow detailed molecular analysis of gene structure and function. This is a revolution in biology because what were thought to be nearly impossible tasks of understanding how genes work have now turned into almost routine analytical procedures."

Several ORNL biologists have taken quite different approaches to the cancer problem and have made some important discoveries that shed light on how genes can cause or prevent cancer. They reported their results at the Biology Division information meeting held in late 1980. They will also present their findings at an international symposium that they are organizing on "Molecular Mechanisms in Carcinogenesis," to be held in April 1982 in Gatlinburg. At this symposium, molecular biologists and cancer specialists from ORNL and all over the world will share their findings in this fascinating field.

Gene Mapping

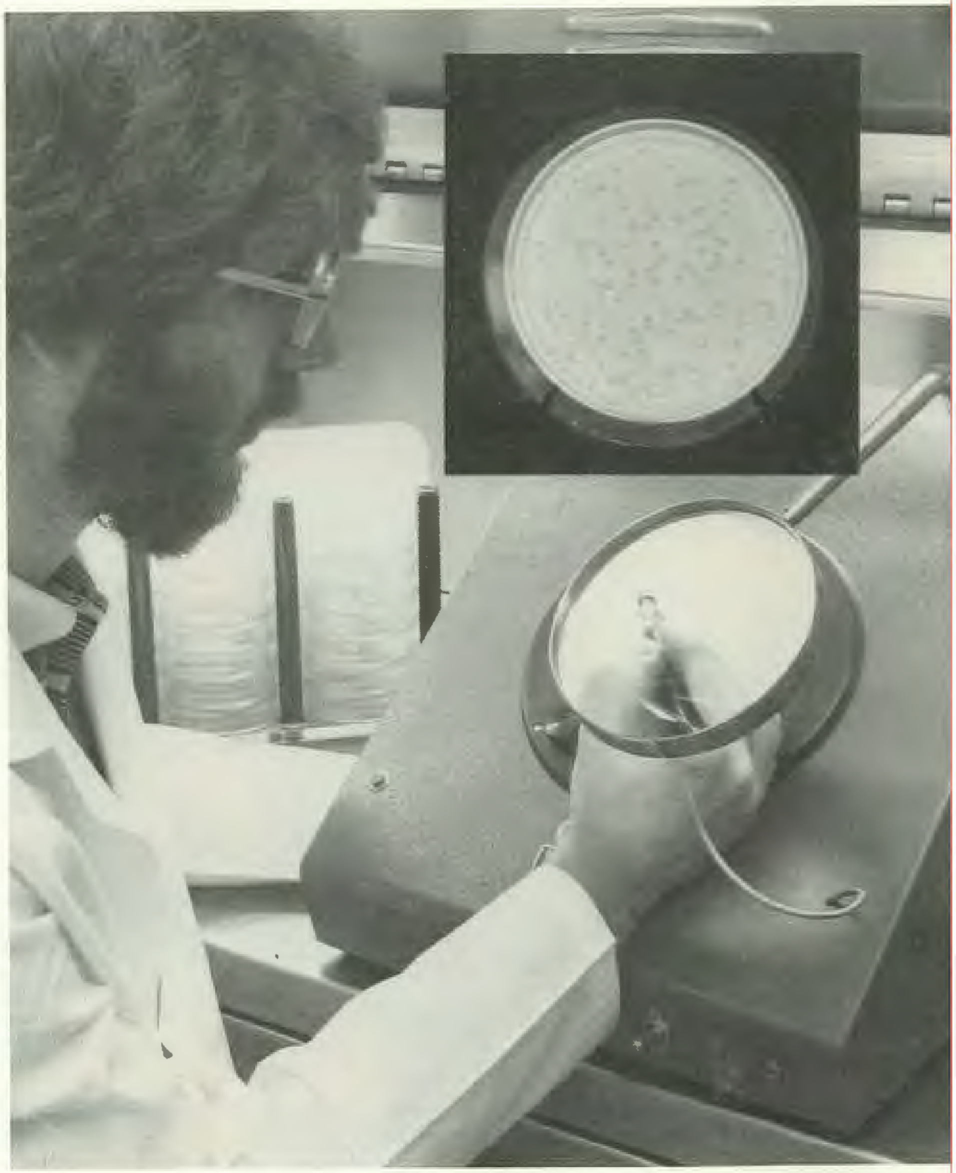
Peter Lalley, Jim Regan, and their colleagues in the Biology Division are attempting to map the location of some genes that may be involved in preventing cancer. They are determining which chromosomes—rodlike structures inside a cell's nucleus—may carry specific genes required for the repair of DNA damage. The mapping is done using somatic cells (body cells rather than reproductive cells such as eggs and sperm) from mice and humans. There are 40 chromosomes in a normal mouse cell and 46 chromosomes in a human cell. Lalley has been able to identify gene locations by fusing mouse and human cells in culture and isolating human-mouse hybrid cells.

Each hybrid cell contains both human and mouse chromosomes within a single nucleus. The unique characteristic that makes these cells useful for gene mapping studies is that human chromosomes, but not mouse chromosomes, are preferentially and randomly lost as the hybrid cells proliferate. Thus, independent hybrid clones which contain different numbers and combinations of human chromosomes can be isolated. These hybrid clones can be analyzed for the expression of specific human gene products by several procedures, including electrophoretic, immunologic, and recombinant-DNA techniques.

In addition, each specific chromosome in the hybrid cell can be identified through chromosome banding techniques. By correlating the expression of a specific gene product with the presence or absence of a specific chromosome in a series of hybrid clones, the chromosomal location of the gene that codes for this product can be determined.

For example, by electrophoresis, the researchers can determine which specific human enzymes are

Larry Boone counts bacteriophage plaques at a lightbox with a magnifying glass. The spots he sees on the petri dish (inset) represent clones of lambda phage viruses that have infected bacteria and commandeered them to reproduce the phage viruses, which burst out of the bacterial cells. The clones counted by Boone are carrying foreign genes inserted by recombinant DNA techniques.



produced by one set of hybrid cells but not another. They subsequently treat the cells using trypsin-Giemsa banding techniques so that the chromosomes are stained; each chromosome so treated shows a unique pattern of light and dark bands, allowing it to be distinguished from the other chromosomes in the cell. In their microscopic observations of the stained hybrid cells, Lalley and Regan look for a chromosome not common to both sets of hybrid cells. When found, that chromosome is deduced to be the site of the gene responsible for making the specific human enzyme detected (the marker).

By using cell hybridization techniques in conjunction with rapid, sensitive DNA repair assays, Lalley and Regan are trying to find the chromosomal locations of genes involved in DNA repair. They hope to achieve this by identifying which hybrid clones have retained the human DNA repair components and which clones have lost these components. Because the DNA repair process involves at least five enzymatic steps, the DNA repair mechanism in man is a complex, multigenic system.

Lalley and Regan have examined somatic cell hybrids for their ability to repair DNA damage caused by ultraviolet light. Using an assay pioneered by Regan and Richard Setlow (now at Brookhaven National Laboratory), they found that three particular chromosomes may be required for repair to occur. They are isolating these chromosomes and attempting to determine if the genes responsible for DNA repair are confined to one or two chromosomes or are distributed among all three chromosomes.

How does gene mapping relate to cancer research? Scientists are trying to determine which genes are responsible for DNA repair—which genes can reduce or eliminate mutations that might induce cancerous growth. To learn mor[e] about DNA repair, Lalley an[d] Regan have been studying huma[n] cells deficient in the capacity [t]o repair damage from UV radiatio[n]. These cells were isolated fro[m] individuals who suffer from [a] condition called xeroderma pi[g]mentosa (XP) in which the p[a]tients' ability to repair UV-induce[d] DNA damage is deficient and the[ir] susceptibility to skin cancer [is] higher than normal—a direct ass[o]ciation between the inability [t]o repair DNA damage and the deve[l]opment of cancer.

Revolutionary Techniques in Molecular Biology

The recombinant DNA, or gene splicing, technique is used by molecular biologists at ORNL and elsewhere to isolate specific genes and grow them in quantities sufficient for detailed chemical analysis and for production of biologically active proteins.

Pioneering experiments in DNA splicing were first carried out by Paul Berg and his colleagues at Stanford University in the early 1970s. Berg, who shared the 1980 Nobel Prize in chemistry for this achievement, conceived the idea of splicing or "ligating" a foreign gene into a virus and then infecting bacteria with the virus "vector" in such a way that the foreign gene (say, from an animal cell) is expressed, producing a protein which would be distinguishable from the bacterial proteins.

The technique has been subsequently improved by several developments, among them the discovery of restriction enzymes by Hamilton Smith of Johns Hopkins University and Werner Arber of Switzerland, who received the 1978 Nobel Prize in medicine and physiology for their discovery. These enzymes cut DNA at specific sites, generating a reproducible pattern of DNA fragment ends of known structure that can be readily ligated to another DNA molecule cut by the same restriction enzyme.

Research in a number of laboratories, notably those of Herbert Boyer of the University of California at San Francisco and Stanley Cohen of Stanford University, applied these concepts and techniques to the use of plasmids of *E. coli* and other bacteria as vectors. Plasmids, circular bits of genetic material, float freely outside the genetic core of the host bacterial cell and carry genes for antibiotic resistance. When one of these genes is cut by a restriction enzyme for insertion of a foreign gene, that resistance to antibiotics is lost, and the bacterial cell carrying the vector with the foreign gene of interest can be quickly detected by routine screening procedures.

Combining these discoveries, it is now possible to select a plasmid with the desired genetic characteristics, open up the plasmid ring with a specific restriction enzyme, and then splice into the opened DNA ring another piece of DNA, such as one that codes for a desired protein. The recombinant DNA molecule is then used to infect bacteria, which are thus induced to make the desired product of the transplanted genes. Such a product might be insulin, human growth hormone, or interferon (which has antiviral and possibly anticancer properties), all currently being produced commercially by these recombinant DNA techniques. Microorganisms other than bacteria and vectors other than plasmids are now widely used, as improvements in procedures are rapidly made.

In addition to producing desirable proteins, recombinant DNA techniques are important in research because they permit the production of genes in large quantities, providing enough material in pure form to analyze the details of gene structure and to deduce their functional characteristics. Here, another new development becomes paramount: Methods have been developed by Alan Maxam and Walter Gilbert of Harvard University and by Frederick Sanger in England for determining the sequence of DNA's basic structural units, or nucleotides. This sequence provides the genetic blueprint for assembling living organisms.

By undergoing four separate enzymatic reactions, a DNA chain can be cut or replicated to yield fragments ending specifically at one of the four possible radioactively labeled nucleotides. The radioactive fragments, separated into four lanes of electrophoretic gels, produce band patterns on x-ray film that can be easily read by an experienced worker to obtain the nucleotide sequences in the DNA chain. These DNA sequencing methods have had a profound impact on the molecular biologist's ability to explore the mystery of genetic machinery.

By fusing human xeroderma cells with mouse cells, the ORNL biologists have demonstrated that the mouse cells can correct the genetic defect in XP cells and that the hybrid cells can repair UV-induced damage normally. The researchers are now determining exactly which mouse chromosomes carry the genes capable of correcting the genetic defect in XP.

Lalley and Regan are also planning experiments on gene transfer in which they hope to isolate the three repair chromosomes from normal cells and transfer them into xeroderma cells to test whether these chromosomes can give the deficient cells the ability to repair DNA damage.

In another development, Lalley who has mapped 5 human genes and 14 mouse genes to date—has mapped the location of a gene known to be involved in virus-induced malignancy of mouse cells. Thus, Lalley and his colleagues have made some progress in locating genes that appear to play an important role in the development or prevention of cancer.

Tumor Promoters

"The development of cancer is thought of as a two-step process," says Kenney. "First, a cell is acted upon by a chemical carcinogen or some other assault. That cell then becomes 'initiated'—that is, it is potentially malignant. But that potential is not usually realized unless the cell is promoted. When a promoter acts on initiated cells, those cells become cancerous, according to theory."

Research done by Eliezer Huberman of the Biology Division has shown that this theory is not universally true. Working with two types of malignant mouse cells—leukemic bone marrow cells and skin cancer cells—Huberman showed that TPA, a laboratory chemical used as a tumor promoter in animal experiments, failed to make these initiated cells highly malignant. Instead, the cancerous cells acted upon by the tumor promoter returned to normalcy.

Huberman determined that the treated leukemic cells reverted to "normal" cells by studying the shape (morphology) of the cells under the microscope and by detecting the production of lysozyme, an enzyme produced by normal bone marrow cells but not by malignant ones. This enzyme, found in egg white and human tears and saliva, lyses (dissolves) bacterial cell walls, thereby killing the bacteria. Similarly, Huberman detected that the promoter-treated melanoma (skin) cells began producing melanin, a skin pigment. When these skin cells are malignant, they apparently suppress the gene that codes for the production of the enzyme that makes melanin. Huberman found that the production of melanin was restored when the cancerous skin cells were treated with the tumor promoter.

What Huberman's experimental results seem to be saying is this: Promoters influence the expression of genes. Promoters can cause a functioning gene to switch off or can induce a nonexpressed gene to turn on and begin functioning. Thus, a promoter may push an initiated cell to malignancy or push it back to normal.

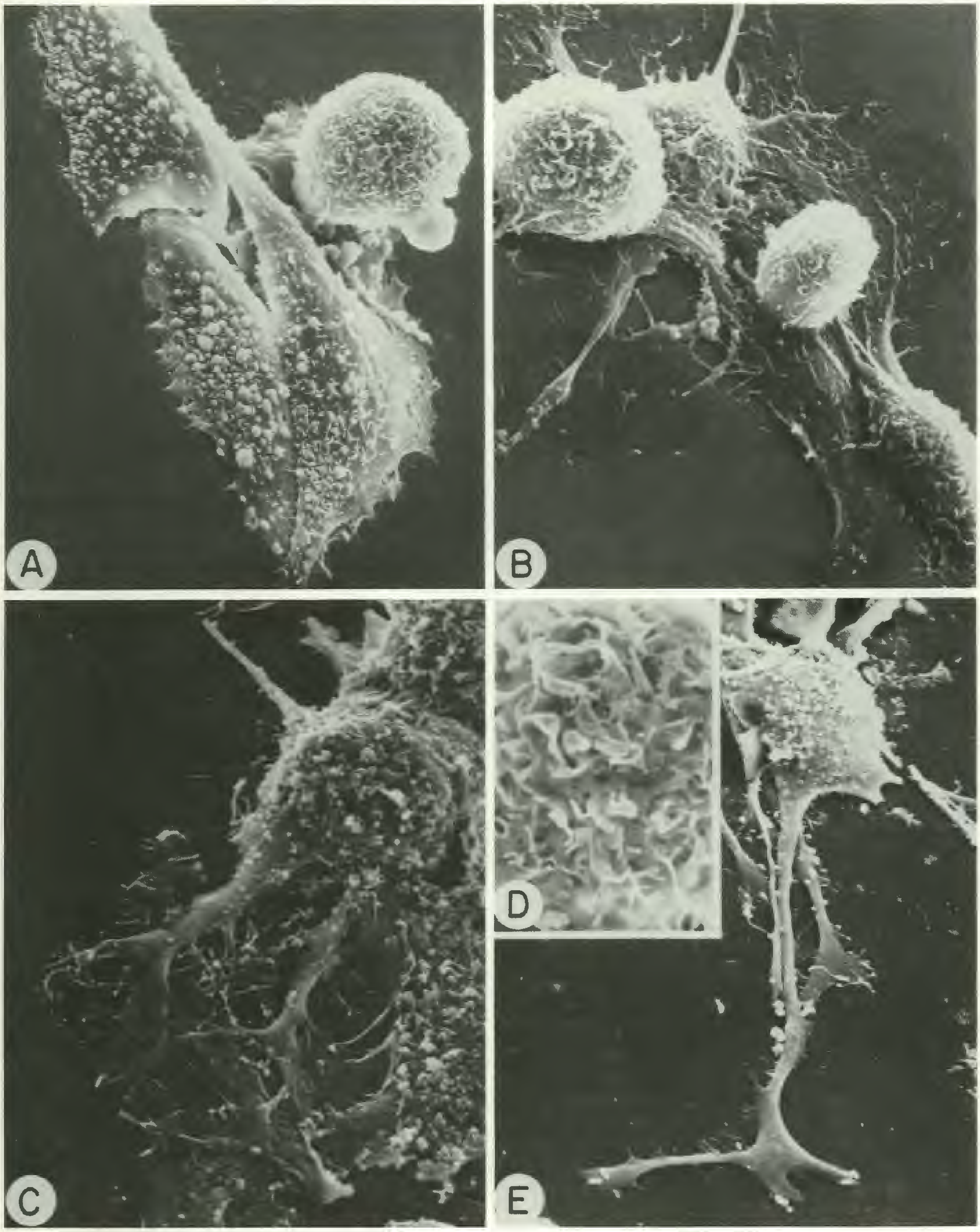
Viruses and Genes

In 1910 New York pathologist Peyton Rous showed that tumor cells from a chicken can be transmitted from one chicken to another by inoculation of a cell-free filtrate of the cancer tissue. The responsible factor in the filtrate was found to be a virus having RNA (ribonucleic acid) as its genetic material. These findings, since repeated in mice and a number of other animals, suggest that viruses carry genes that are active in producing cancer.

The same genes or same type of viruses might exist in humans and be involved in human malignancies. If this is so, cancer viruses in animals can serve as a "handle" by which researchers can determine which genes may be responsible for transforming a normal cell into a cancerous one. This working hypothesis has become very popular, especially after Nobel laureates Howard Temin and David Baltimore found a unique enzyme in these RNA tumor viruses, now called retroviruses because of the reverse flow of genetic information involved in their infectious and tumor-causing activity. Normally, a cellular gene expresses itself by making RNA from its DNA; the RNA in turn serves as a template for synthesis of a protein product. But an RNA-containing retrovirus makes DNA from RNA by the action of a unique enzyme (reverse transcriptase); the DNA copy is able to insert itself and become integrated into the DNA of the cell that the retrovirus infects, and in so doing may transform the cell to the malignant condition.

Wen Yang of the Biology Division, who is chairman of the Gatlinburg conference to be held next April, has led a team of researchers in studying how certain genes in mice can prevent

Scanning electron micrographs show morphologies of human melanoma cells under different conditions: (A) untreated control cell, (B) cell treated with tumor promoter for 4 h, (C) cell treated with tumor promoter for 8 h, (D) high-magnification view of ridges on the surface of an 8-h treated cell, (E) cell treated with tumor promoter for 24 h. Magnification is 2600× for A, B, and C; 5700× for D; and 1800× for E. Elie Huberman found that cancerous melanoma cells reverted to normal cells when treated with tumor promoter.


A
B
C
D
E

retroviruses from converting normal cells to cancerous ones. A physician and biochemist, Yang once treated a large number of liver cancer patients in Taiwan and felt helpless in his attempts to control the fatal disease. Now working in molecular biology research, he has a long-range goal of understanding the genetic basis of cancer formation and of developing tests to detect human susceptibility to cancer.

In the 1960s it was discovered that some genes present in the mouse can inhibit the retroviruses known to cause leukemia, cancer of the white blood cells. A particular one, called the Fv-1 gene, was well identified and mapped on chromosome 4 of the mouse. The Fv-1 gene is genetically dominant; this means that offspring are resistant even if one of the parents is susceptible to the viral leukemia.

In 1973 Yang started collaborating with ORNL cell biologist Ray Tennant, who had fused a susceptible cell with a resistant cell and found that the hybrid cell was resistant to the leukemia virus. They and Arthur Brown of the University of Tennessee found that the resistant cells contained a factor that they could extract. When the susceptible cells were treated with this factor, the cells became resistant to subsequent challenge by leukemia viruses. They further characterized the Fv-1 gene factor and published their findings in 1974.

Since then, Yang and his collaborators have been trying to pinpoint the precise biochemical step involved in the inhibition of leukemia viruses by the Fv-1 gene. They adapted a technique, known as DNA transfection, for particular use in leukemia viruses and mouse cells and applied it to study the Fv-1 gene action. From results of a series of DNA transfection experiments, they concluded that the resistance genes are not effective if genes of the leukemia virus are already in the final form of DNA (instead of in the form of RNA wrapped in an envelope). They also deduced that the Fv-1 gene partially blocks the formation of viral DNA (in linear or circular forms) in the resistant cells; the defective viral DNA therefore cannot be integrated into the cell genome in covalent linkage with cellular DNA.

Yang thinks that the Fv-1 gene products interfere with the proper reverse transcription of the viral genes, causing the linear viral DNA to be synthesized in smaller amounts or with impaired ends so that they cannot be linked to form a twisted ring structure. These results, contributing considerably to the understanding of host genetic control as well as detailed processes of retrovirus infection, have been published in four papers.

Transposon Concept

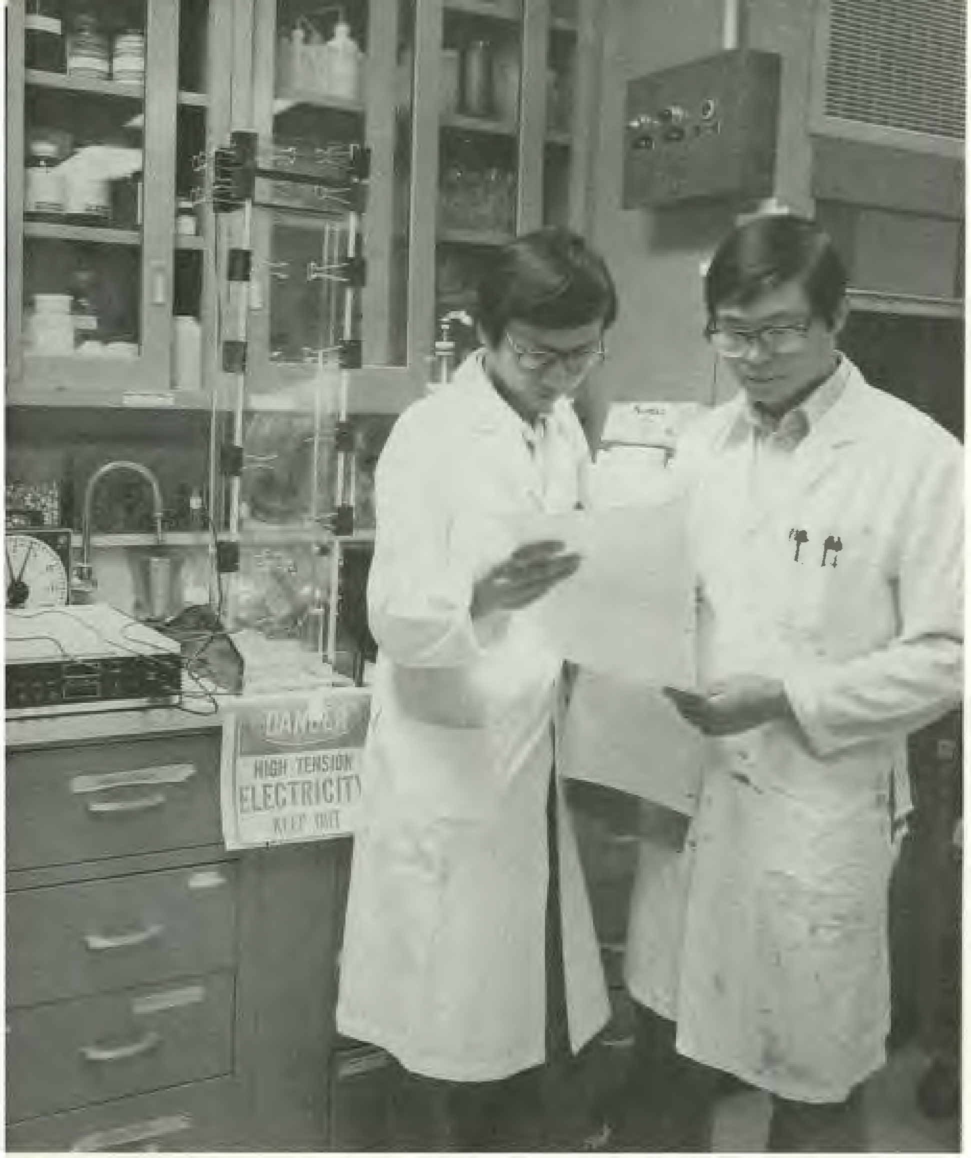
To investigate further the molecular defect, Yang's group has resorted to the use of recombinant DNA and sequencing techniques. A detailed restriction enzyme map of mouse leukemia viruses, obtained chiefly through the efforts of Chin-yi Ou and Jim Kiggans, not only determined where to cut for DNA splicing but also revealed an important feature of viral DNA structure, which has also been found in a few other laboratories.

The map shows that the DNA molecule formed from retrovirus RNA is approximately 10,000 base-pairs long and has an identical stretch of several hundred base-pairs at both ends. These ends are called large terminal repeats. This feature is characteristic of DNA molecules known to be capable of moving from one site to another in bacterial genetic material (called "transposons," or movable genes).

David Hwang and Ruey-Shyan Liou study x-ray film of a gel containing DNA fragments that have separated under the influence of an electric field because of differences in electric charges on various parts of the molecule (electrophoresis). Because the DNA was tagged with a radioisotope before being placed in the electrophoretic gel, the separated fragments are radioactive and produce characteristic band patterns on x-ray film, revealing the sequence of nucleotides in the DNA chain.

Larry Boone, a new member of the Biology Division team who has expertise in recombinant DNA work, was able to rapidly clone the several mouse leukemia virus genes in a bacterial virus. He and two postdoctoral fellows, Lap-chee Tsui and Ruey-Shyan Liou, transferred the cloned genes into a plasmid, enabling the production of the viral genes in large quantities. Employing the Maxam-Gilbert DNA sequencing technique, David Hwang elucidated a nucleotide sequence of 864 base-pairs, including those which constitute the large terminal repeat. From the nucleotide sequence, another characteristic feature of transposons stands out —namely, that at the ends of the 569 base-pair large terminal repeat itself are 13 base-pair sequences of inverted repeats (ABCDE at one end and EDCBA at the other end of the double strands of DNA, so to speak).

These results, Yang says, are similar to those found in other types of retroviruses at a few other laboratories at the National Cancer Institute, Massachusetts Institute of Technology, University of Wisconsin, and University of California. Molecular biologists are now speculating on how a retroviral gene having the unique sequences of large terminal repeats and inverted repeats in the DNA structure may join its ends together



in such a way that the joined ends can hit a cellular DNA site and snap its whole gene in. The precise mechanism of retroviral gene integration, however, remains to be explained.

The ORNL researchers think that their work on the Fv-1 genes is important in this respect: these control genes provide a natural defense for the cell to stop the movement of retroviral transposons and thus prevent the cell from becoming cancerous.

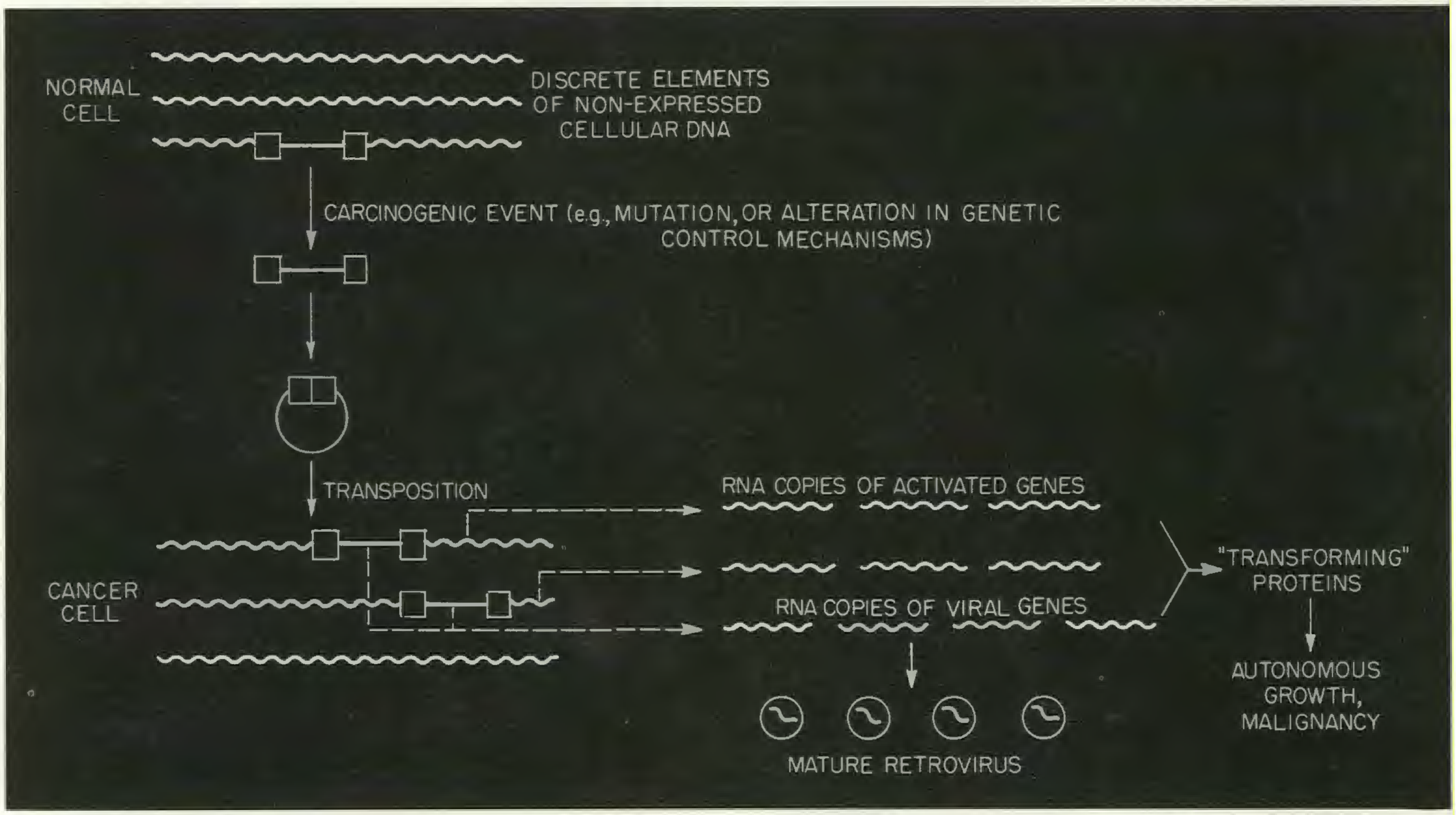
Although the movable gene element concept was originally proposed in the late 1940s by Barbara McClintock (Cold Spring Harbor Laboratory) from her genetic work with maize, the true significance of transposons did not become evident until recently, when such elements were directly demonstrated by molecular biologists. This concept lately has been applied to the phenomenon of cancer on the basis of recognition of the transposon structure of retroviral genes, together with findings that a high incidence of cancer is found in certain human genetic disorders associated with instability of chromosome structure.

Two Paradoxes

But how do retroviruses possessing nomadic gene potential cause cancer in animals? The answer is suggested by two paradoxical findings. First, the gene segment responsible for the cancer-causing property in animal retroviruses has been found to be almost ubiquitous—that is, it (or a close relative) is in normal cells as well as in cancer cells, in chicken cells as well as in fish, mouse, rat, and even human cells. Second, most retroviruses appear tame rather than vicious. In the mouse, genes of leukemia viruses are found in large numbers in cellular DNA and are passed from parent to offspring; yet many of these mice do not contract leukemia.

A reasonably clear picture that may explain these paradoxes is now beginning to emerge, according to Yang. He points to important observations made several years ago by Wallace Rowe and his colleagues at the National Institutes of Health. First, normal mouse cells, usually showing no signs of retroviruses, can be activated to produce these viruses by treatment with agents that perturb the usually stable DNA structure. Second, certain sets of retroviral genes are found in larger numbers in inbred mouse strains that have a higher incidence of spontaneous leukemia than in other strains.

When these results are considered in the light of the newer understanding of the transposon structure of retroviral genes, the message becomes clear: The integrated retroviral genes within the cell are well-behaved citizens in peacetime, but they are quick to move when society is in disorder (say, as a result of a gene perturbation caused by radiation or a chemical carcinogen). In the process of movement to other locations in the cell's DNA, the retroviral genes can lose the restraints placed on their expression in normal cells and can also alter the expression of neighboring genes by placing them within the sphere of influence of regulatory elements contained in the large terminal repeat (LTR) segment of the retroviral genes. The resulting disruption of normal patterns of gene expression can be



This schematic illustrates the current concept of the potential role of retrovirus genomes i the causation of cancer. In the normal cell, the viral genome (indicated by the two linked boxes) occupies a locus in the cellular DNA, where it is essentially silenced. A carcinogeni event releases the viral genome which, by virtue of its transposon structure, is able to circularize and insert into other sites in cellular DNA, where it is no longer silent. Instead, can be transcribed into RNA copies and can also promote the transcription of associated neighboring genes which are normally silent. Subsequent translation of these RNAs into specific proteins results in transformation of the cells to malignancy. In most animals, bu apparently not in humans, the viral RNAs can also be packaged into mature virus particle

particularly severe if the "kidnapped" normal genes carry out important roles in the normal functioning of the cell; altered expression of such genes could lead to the cell becoming malignant.

To explain the etiology of human cancers, scientists have proposed various theories and hypotheses, such as somatic mutation, blocked differentiation, and genetic transposition, which emphasize different biological mechanisms. This circumstance may reflect the fact that multiple factors are involved in the generation of several diseases called cancer.

ORNL biologists are, in fact, approaching these factors separately through their individual experimental models. Although not as apparent as a causative factor in other cancers as in the skin cancer of XP patients, the absence or presence of the DNA repair mechanism studied by Regan and Lalley is the early key step for man in coping with environmental carcinogens. While it is certainly not feasible to treat human cancers with the tumor promoter TPA, Huberman's work can ultimately help physicians find ways to control the disease process in cancer patients. An authentic human retrovirus has yet to be isolated, but Yang's working experiences in the mouse system are important for investigating the LTR-like regulatory gene elements and the gene transposition mechanism in man. After all, recent advances in molecular biology have unveiled many new mechanisms about how genes work in mammalian cells. Cancer researchers are now finding themselves in a better position than ever before to understand aspects of the most dreaded of diseases. ornl

☆ U.S. GOVERNMENT PRINTING OFFICE: 1981-740-062/195

awards and appointments

Wayne Rhoades has received the annual Award for Technical Excellence given by the Radiation Protection and Shielding Division of the American Nuclear Society.

Calvin White was named a member of the Materials Science Division Council of the American Society for Metals as well as program chairman of the ASM's Materials Science Technical Division.

Harry Yakel was appointed associate editor of the *Journal of Applied Crystallography*.

Keith F. Eckerman has received a four-year appointment to the International Commission on Radiological Protection Committee 2 on Secondary Limits.

Ray Blanco has been elected a fellow of the American Nuclear Society.

Everett Bloom is the 1981 recipient of the annual Young Members Engineering Achievement Award of the American Nuclear Society.

Ralph Dial has been elected national secretary-treasurer of the American Society of Certified Engineering Technicians.

Arthur J. Moorhead and Robert W. Reed, Jr., have been chosen to receive the American Welding Society's A. F. Davis Silver Medal for their paper, "Techniques for Joining Fuel Rod Simulators to Test Assemblies."

David Reichle has been named a member of the Air Quality Task Force of the Committee on Environmental Conservation of the National Petroleum Council.

Bob Hendricks was appointed a member of the Solid State Sciences Committee Advisory Panel of the National Research Council of the National Academy of Sciences.

Carl Koch received a Letter of Appreciation from the Council on Materials Science of the U.S. Department of Energy for his contributions to the panel report on needs for research on amorphous solids.

Gene Hise was one of ten engineers chosen to receive an Outstanding Achievement award by the National Society for Professional Engineers for his high-gradient magnetic separation method of cleaning coal.

Tsuneo Tamura is a member of the American Nuclear Society Executive Committee.

Joy Huffstetler has been elected president of the Southern Appalachian Chapter of the Special Libraries' Association.

Ralph James, a Ph.D. physicist from the California Institute of Technology, is a Wigner Scholar, working with Dick Wood in the Solid State Division.

Bill Foster was appointed to a five-year term as a member of the Subgroup on Radiography of the Boiler and Pressure Vessel Committee of the American Society of Mechanical Engineers.

Frances Sharples was selected as a recipient of one of six Environmental, Science, and Engineering Fellowships awarded by the American Association for the Advancement of Science.

Jerry Braunstein has been reelected to a two-year term on the executive committee of the Division of Physical Electrochemistry of the Electrochemistry Society.

Barbara Lyon was elected to a one-year term as president of the East Tennessee Chapter of the Society for Technical Communication, 1981-1982. **Donna Griffith** is second vice president of the chapter.

U.S. Postage
PAID
BULK RATE
Oak Ridge, Tenn.
Permit No. 3

OAK RIDGE NATIONAL LABORATORY *REVIEW*
P. O. BOX X: OAK RIDGE, TENNESSEE 37830

Hazel Delcourt excavates in a stream bed of the Nonconnah Creek, near Memphis. The organic layer (dark area) has revealed 20,000-year-old fruits and seeds of beech, yellow poplar, and other trees typical of deciduous forests, as well as those of northern white spruce. See article on page 6.