1973: Research Progress on a Broad Front

Despite political and economic turmoil, the year was productive of a number of new ideas, unexpected discoveries, and quietly spectacular developments in research both basic and applied. The debate over solutions to the energy crisis dominated the news but yielded little in the way of substantive progress in energy research. In other areas, however, the story was different. This week the Research News section is devoted to a sampling of highlights and trends in research during the past year.

Earth and Planetary Science

That the solar system is heliocentric and not geocentric was first proposed by the Polish astronomer Nicolaus Copernicus on the basis of telescope observations. Now, 500 years after his birth, exploration of the solar system has advanced to the point where seven major planetary probes —three U.S. spacecraft and four U.S.S.R. spacecraft—were en route in 1973 toward targets ranging from Jupiter to Mercury. This was also a year in which Skylab astronauts gathered a multitude of new data about the sun and in which analyses of data from earlier explorations began to produce a clearer picture of the moon and of Mars. On the earth, scientists made considerable progress in understanding the ozone layer that shields living things from ultraviolet radiation, the large eddies that constitute the ocean's subsurface "weather," premonitory phenomena that may give warning of earthquakes, and a variety of other atmospheric, oceanic, and solid earth phenomena.

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Biomedical Science

Immunology would have to rank high among the topics that dominated biomedical news in 1973. In particular, investigations into the genetic control of immune responses have received much attention.

The capacity to respond to certain antigens, including some viruses that cause cancer in mice, is determined by genes, called Ir or immune response genes that lie within the same chromosomal region as the genes for the histocompatibility (transplantation) antigens. Now, evidence from a number of laboratories has indicated that the products of the Ir genes may themselves be histocompatibility antigens and that they serve as recognition sites on certain cells of the immune system.

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Chemistry and Biochemistry

Unsuccessful new scientific theories generally die quietly, but that rule met with a major exception in 1973. The highly controversial polywater theory, which postulated the existence of a unique new high-molecular-weight form of water, was interred this year with nearly as much publicity as accompanied the first description of the theory some 7 years earlier. Its much heralded demise was but one of the highlights of a year that also marked the identification of the viruses that cause both forms of hepatitis, the taming of a rather unpleasant vaccine, the development of a major new form of an old drug, the unraveling of the structure of an antibody, and the development of a new type of pesticide.

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Physics and Astronomy

When the new discoveries for 1973 are analyzed, none of them have changed a scientist's view of the world—yet. The new experiments and observations are neither free of ambiguity nor easy to understand. Rather than reporting the discovery of a new particle with certain clear characteristics, physicists have found evidence for a subtle effect called "neutral currents." Rather than introducing the public to a new star in a growing cast of luminaries, astronomers reported finding two quasars apparently beyond the limit of last year's universe, radio signals that may carry new information about cosmology, and gamma rays that were never expected but come streaming toward the earth at least four times a year. Scientists may be forced to think about the dynamics of stars, cosmology, the properties of supercold matter, and the unification of the four fundamental forces of nature in new ways in order to understand the discoveries of 1973. Then again, they may not. Either way, much has been learned that is new.

The distances of objects far away from our galaxy, the Milky Way, are measured by the "red shift" of light that comes from them. The most distant galaxies ever discovered have red shifts of about 0.4, but quasars are found with larger red shifts. Only a year ago, the largest quasar red shift known was 2.88, and some astronomers were speculating that very few quasars with red shifts greater than 3 would be found. The red shift limit of 3 was likened to an indication of the limit of the universe or—because it takes more than 10×10^9 years for light from such distant objects to reach us—to a horizon in time. Last year the hypothetical limit was exceeded, as two quasars were found

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Materials Science

The year 1973 was an exciting one in the superconductivity research community—beginning with the announcement that superconducting fluctuations may have been observed at temperatures near 60°K in an organic compound, and ending with awarding of the 1973 Nobel Prize in physics to researchers in superconductivity. Amorphous metallic alloys began to receive some of the attention long reserved to amorphous semiconductors this year. High resolution electron microscopy techniques came closer to visualizing individual atoms in crystals than previously, and surface science continued to become more sophisticated. The ubiquitous energy crisis began to make its presence felt in materials technology, with renewed emphasis being placed on high-temperature materials for, among other things, more efficient engines, on finding less expensive materials to use in place of more expensive ones, and on improving the efficiency of extractive metallurgical techniques.

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Earth and Planetary Science: The Copernican Quincentenary

Easily the highlight of the planetary missions was the success of Pioneer 10, against considerable odds, in surviving the asteroid belt and the intense radiation fields around Jupiter to return first-hand data on that starlike planet and its satellites. Preliminary analysis of the data indicates that Jupiter has an unusual magnetic field and that the innermost of its Galilean satellites, Io, has an atmosphere. Pioneer 11, under way to Jupiter and possibly Saturn; Mariner 10, on course for Mercury by way of Venus; and four huge Russian spacecraft bound for Mars account for the remaining missions. The Russian spacecraft are believed to be comparable to the Viking probes now being prepared in this country and two of them, U.S. scientists speculate, may attempt to land instruments on the planet.

Meanwhile integration of the results of earlier missions to Mars and the moon has continued. The view that Mars has been subjected to the same intense bombardment as the moon in its early history and hence that much of the cratered martian surface is older than early reports indicated appears to be gaining wide support. Many investigators also believe there must be a considerable amount of water, as yet undiscovered, on the planet. There is as yet little agreement, however, on the nature of the mysterious martian channels, on the origin of the complex patterns near the poles, or on the tectonic character of Mars, except that these features have no direct earthly counterparts. More is known about the internal structure of the moon—that it has a thick crust, a rigid mantle, and possibly a partially molten core—and of its history, although the origin of the moon's magnetic field remains a puzzle. What is increasingly clear is that both the moon and Mars are strikingly different from the earth; when these differences are fully understood they may hold the key to the origin of the solar system.

A whole new era of investigation of solar physics is under way with Skylab, where studies with x-ray and ultraviolet spectrometers and a coronagraph are inundating scientists with data. Although detailed analysis is still to come, Skylab astronauts and scientists have found that the sun's corona is much more dynamic than expected, and they have observed a whole new range of solar atmospheric phenomena. Also, flares, solar prominences, and other transient phenomena seem to be more common and more diverse than expected. Comparison with terrestrial observations is showing that what appear from the ground to be minor phenomena are often major events in the sun's upper atmosphere—thus calibrating many years of data from ground-based observations.

Solar flares are known to disrupt the earth's ionisphere, but scientists have long rejected the idea that the sun has any influence on the weather of the lower atmosphere. Now, however, just such an influence has been documented by a group headed by J. M. Wilcox at Stanford. They showed that an index of bad weather was statistically related to changes in the sun's magnetic field lines that are carried past the earth by the solar wind. During winter, the probability of bad weather was lowest just after the boundary between two sectors of the magnetic field passed the earth; the effect is large enough to account for 30 percent of the variability of the weather index at all levels of the lower atmosphere. No physical mechanism for the effect has yet been established, but meteorologists are beginning to get used to the idea that solar-terrestrial interactions must be considered a contributor to atmospheric phenomena.

The debate over supersonic transports several years ago raised a number of questions about the effect of large numbers of such planes on the ozone layer—an effect that, according to H. S. Johnston of the University of California at Berkeley, might significantly increase the amount of ultraviolet radiation reaching the earth's surface. One result has been an upsurge in investigations of the photochemistry of the stratosphere that within the last year have begun to produce results. Laboratory studies have established the reaction rates of the principal chemical species. Models that take into account mixing within the stratosphere have been developed. Perhaps most important, balloon and aircraft measurements of in situ concentrations of nitrogen oxide, nitrogen dioxide, ozone, and similar species have begun. Some investigators, using data for one species to calibrate their models, have been able to predict the ozone concentrations in the normal atmosphere and are now studying perturbed conditions. So far, Johnston's initial conclusions have not been proved incorrect.

Other areas of active research include tropical meteorology and climate. New and more sophisticated attempts are being made to represent the effects of cumulus clouds—the heat engines of the tropical atmosphere—in numerical models. Efforts to model another type of tropical phenomenon, the hurricane, have given hope that forecasts of these destructive storms can be improved. On a longer time scale, models of climatic processes are beginning to appear. Both in the scientific community and in the government there is growing interest in the physical basis of climate and in the prospects for predicting climatic variations (such as the drought that led to massive Russian purchases of U.S. wheat).

Compared to the atmosphere, little is known about the oceans. In an extraordinarily successful Mid-Ocean Dynamic Experiment (MODE), however, an international team of physical oceanographers obtained the first detailed data on the eddy motions of the deep ocean. Eddies, which correspond roughly to the weather systems of the atmosphere, are believed to play an important role in the general circulation of the oceans. Preliminary results from MODE indicate that these eddies are about 200 kilometers across, have mean motions in deep water of about 3 to 5 centimeters a second, and have a lifetime of about 2 months. The researchers were able to observe one eddy as it intensified, moved across a heavily instrumented section of the Atlantic Ocean between Bermuda and Miami, and gradually died, and they identified three or four additional eddies in neighboring parts of the ocean.

Infrared photography has been used in oceanographic research before, but never very widely. Now a high resolution radiometer on the NOAA-2 (National Oceanic and Atmospheric Administration) satellite appears to be gaining new acceptance for this technique. The instrument can distinguish sea-surface temperature differences of 1°C over large areas. Oceanographers believe remote sensing of surface thermal patterns will help in studies of currents, upwelling regions, and sea ice.

Research in the solid earth sciences continues to be dominated by the plate tectonic model, which describes the earth's crust as composed of a small number of essentially rigid plates. A wide range of geological and geophysical investigations were directed toward filling in the details of the model, testing its implications, and, increasingly, inquiring into the driving forces within the mantle which cause

plate motion. This effort was given new impetus by a National Academy of Science report proposing a detailed plan for U.S. participation in a worldwide research effort—the Geodynamics Project—designed to exploit the new concepts to their fullest.

The big news, however, concerns the first real potential for earthquake prediction. The key to the conceptual model now being developed is dilatancy, a swelling observed in rocks stressed to their breaking point and hypothesized to occur in earthquake zones before rupture. The dilatancy phenomenon is believed to be the cause of a whole range of premonitory signals which, if they can be reliably interpreted, would provide a basis for prediction and warning.

—ALLEN L. HAMMOND

Biomedical Science: Immunology and Neurobiology to the Fore

Generation of an immune response requires interaction between the stimulating antigen and specific receptors on the membranes of cells of the immune system. Immunoglobulins can play this role in one type of immune cell, the B-cell. The T-cells of the immune system, however, do not carry detectable immunoglobulins and the question of the identity of the receptors on T-cells has intrigued immunologists. Since many investigators think that these receptors are the products of the Ir genes and are in fact histocompatibility antigens, two major lines of immunological research—that into transplantation and transplant rejection and that into the mechanisms of immune responses—seem to be converging.

Reports of the demise of molecular biology may have been premature, at least as judged by the amount of activity in that area. A number of new nucleic acid sequences have been reported, and Frederic Sanger and his colleagues at the Medical Research Council Laboratory of Molecular Biology, Cambridge, England, found a direct method for determining the sequence of DNA. Earlier methods were indirect since they required synthesis of either a complementary RNA chain (whose sequence could be directly determined) or a radioactive complementary DNA chain, and thus depended on the fidelity of the copying enzymes.

One of the more interesting RNA sequences reported is that of an RNA molecule (derived originally from the bacteriophage $Q\beta$), consisting of 218 nucleotides, that was determined by Sol Spiegelman and his colleagues at the Columbia University College of Physicians and Surgeons, New York City. Because the molecule replicates in vitro with the appropriate enzymes it can be used to study the molecular mechanism of evolution by determining what base changes occur when one kind of genetic expression mutates to another.

Because of their relatively small sizes—approximately 80 nucleotides—more is known about the structures of the transfer RNA's (tRNA's) than any other nucleic acids. Now, a team of investigators in Alexander Rich's laboratory at the Massachusetts Institute of Technology, Cambridge, has used x-ray diffraction techniques to determine the three-dimensional structure of yeast phenylalanine tRNA at a resolution of 4 angstroms. Although this is not sufficient to resolve the position of individual atoms, it does permit tracing of almost the entire polynucleotide chain. The base pairing within the tRNA is consistent with that of the cloverleaf model but the molecular is shaped like an L.

Rich's group also confirmed by x-ray crystallography, this time with a resolution of 0.8 angstrom which is more than adequate to resolve individual atoms), the Watson-Crick hypothesis for the double-helical structure of DNA. Rather than use DNA fibers, they performed their studies on single crystals of molecules corresponding to double-helical fragments.

The role of viruses in the etiology of cancer received its share of attention (and more, according to some) in 1973. Since the discovery of reverse transcriptase a few years ago, most of the attention has focused on the RNA viruses as candidates for causing human cancer. This year, however, marked a resurgence of interest in the DNA viruses, especially those of the herpes class. At the same time, interest in the RNA viruses remained high even though one candidate for a human cancer virus, called RD114, was eliminated from the competition when it proved to be of feline origin.

Neurobiology is often cited as molecular biology's successor as the center of the most challenging unsolved problems of biology. Understanding brain and nerve function requires, among other things, understanding how neurotransmitters interact with receptors on their target cells and thus transmit signals between neurons. Similar studies are being performed with drugs. For example, Solomon Snyder and Candace Pert at Johns Hopkins University School of Medicine, Baltimore, Maryland, demonstrated that opiates bind to specific receptors in rat and human brain. Their investigations should aid in unraveling the still unknown mechanism of opiate action. Moreover, the binding assay should facilitate design and testing of opiate analogs useful for alleviating pain and of antagonists useful for treating addiction to opiates such as heroin.

The function of the nervous system is also being investigated at a higher level of organization—that of the whole animal. A current approach to analyzing the factors that influence behavior fuses the disciplines of genetics, physiology, and biochemistry. For example, Seymour Benzer and his colleagues at the California Institute of Technology, Pasedena, are investigating fruit fly mutants that exhibit abnormal behavior. These researchers have traced in their mutants the physiological defects responsible for such altered behavior as inability to respond to light. Since they can "teach" fruitflies to perform simple tasks, such analysis may be applicable to more complex activities, including learning, if the investigators can develop mutants unable to learn.

Membranes are a recurrent theme in many of the most active research areas, and membrane research itself is an active area of investigation. Not only do membranes play an essential role in immune responses and the transmission of nerves impulses, but also in such critical functions as energy transformations in plant and animal cells. One of the concepts now stimulating much research is membrane fluidity—that the components of cell membranes can and do move, and that these movements may be correlated with the physiological state of the cell. For example, a number of investigators have observed differences in the mobility of membrane components in cancer cells as compared to normal cells.—JEAN L. MARX