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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Materials Science: Superconductivity Heats Up

The hunt for better superconductors received new impetus when A. J. Heeger and A. F. Garito at the University of Pennsylvania, Philadelphia, announced the observation of metallic properties in an organic charge-transfer salt known as (TTF)(TCNQ). In addition, in some crystals, when the conductivity was measured as a function of temperature, a giant peak in the conductivity was found at about 58°K and the Pennsylvania scientists speculated that this peak might represent a superconducting fluctuation —a precursor phenomenon observed in superconductors at temperatures just above the superconducting transition temperature. Although the technological impact of a superconductor near 60°K would be nothing short of revolutionary (the temperature record at that time was 21°K, and was observed in a niobium-aluminum-germanium compound), superconductivity itself has not been observed. In fact, a metal-insulator transition occurs at temperatures below that of the maximum conductivity. Moreover, the only scientists outside of the Pennsylvania group who have been able to reproduce these results (at the Bell Laboratories, Murray Hill, New Jersey) have shown that the giant conductivity peak is a spurious effect—at least in the Bell Laboratories crystals—that is due to a special current flow path in the samples. Although most of the experts on superconductivity are skeptical about its existence in (TTF)(TCNQ), a great deal of work is continuing, and interest in the other properties of this material is far from dead.

Less debatable was the report in September of a superconducting transition temperature of 22.3°K by John R. Gavaler of the Westinghouse Research Laboratories, Pittsburgh, Pennsylvania, in a niobium-germanium compound (Nb_3Ge), and shortly thereafter the report of 23.2°K by Louis R. Testardi and co-workers of Bell Laboratories. Besides ending a drought of several years in efforts to increase the transition temperature of superconductors, the niobium-germanium compound also broke the so-called hydrogen barrier (liquid hydrogen boils at 20.4°K), so that superconducting devices no longer would have to rely on the more expensive and less abundant liquid helium (4.2°K) as a refrigerant. Moreover, the use of a technique whereby superconductors are produced by sputtering onto heated substrates promises other new superconducting materials not yet obtainable. Methods of producing the niobium-germanium superconductor in commercially usable forms have yet to be developed.

Progress in the development of niobium-tin (Nb_3Sn) multifilamentary superconducting wires (to replace niobium-titanium alloy wires or older and less reliable niobium-tin composite structures in magnets and electric motors), along with the award to two of the three recipients of the 1973 Nobel Prize in physics for research on aspects of superconductivity, rounds out what must be a satisfying year for superconductivity researchers.

Interest in amorphous forms of normally crystalline materials has been steadily increasing, the most dramatic (and controversial) development occurring when electronic switching devices made from glassy chalcogenide semiconductors were announced some years back. This year glassy metals became prominent as a result of two developments. Workers at IBM's Thomas J. Watson Research Center, Yorktown Heights, New York, produced amorphous gadolinium-cobalt magnetic bubble domain films by a sputtering process. Amorphous metal alloys have the potential for being made into devices with higher bubble densities, easier fabrication, and lower cost than devices made from crystalline films. Also scientists at the Allied Chemical Corporation, Morristown, New Jersey, produced iron and iron-nickel glassy metallic alloys with high strengths and high ductility. The high-strength alloys can now be produced in wire or ribbon form in commercial quantities, previously a problem.

Progress in metallographic instruments enables the materials scientist to "see" details of the structure of materials on a finer and finer scale. For example, using high quality, commercially available electron microscopes and (sometimes) certain "home-made" modifications, scientists can achieve a resolution of 2 to 3 angstroms. A recent application of this resolution is that of S. Iijima and others at Arizona State University, Tempe. Looking at 100-angstrom thick niobium oxide particles (formed by grinding) in transmission electron microscopy, the Arizona workers observed contrast due to individual oxygen interstitial complexes (which consisted of two displaced niobium atoms and two oxygen interstitials). Apart from studies with field ion microscopes, this is as close as anyone has come to directly "seeing" individual atoms in a solid.

Also benefiting from improvements in experimental and theoretical techniques is the old and established field of surface physics and chemistry. As one observer put it, "We are no longer just counting bonds." For example, in the field of catalysis, increasingly sophisticated studies of surfaces are proving to have important technological applications. Surface properties also strongly influence processes like corrosion, which is an important economic problem for the materials-manufacturing industries.

This has been the year of the energy crisis and of shortages of just about anything you can name. The effects of these new conditions are just beginning to be felt and will increase as time progresses. For example, emphasis on conserving fuel has caused a search for more efficient motors. One way to increase engine efficiency is to operate the engine at higher temperatures; but for higher temperature operation, structural materials that can withstand high temperatures are required. One class of materials considered for high temperature applications is the covalently bonded ceramics, such as metal nitrides, borides, and carbides. Although these ceramic materials have been studied for many years, recent results in several laboratories suggest they may be more useful than once thought.

Winning metals from their ores is the basic process on which all subsequent uses of the metal depend. In this era of scarce and expensive resources, observers expect increased attention to be given to making extractive metallurgical processes more efficient. For example, the production of aluminum from bauxite ores requires a notoriously large amount of electricity. This year at least two new processes were announced (by Alcoa in the United States and the Applied Aluminium Research Corporation in Great Britain) that would greatly reduce the amount of electrical power consumed (by 30 percent in Alcoa's process). Also eliminated is the problem of having to deal with fluoride emissions that result from the aluminum production process currently in use.—Arthur L. Robinson