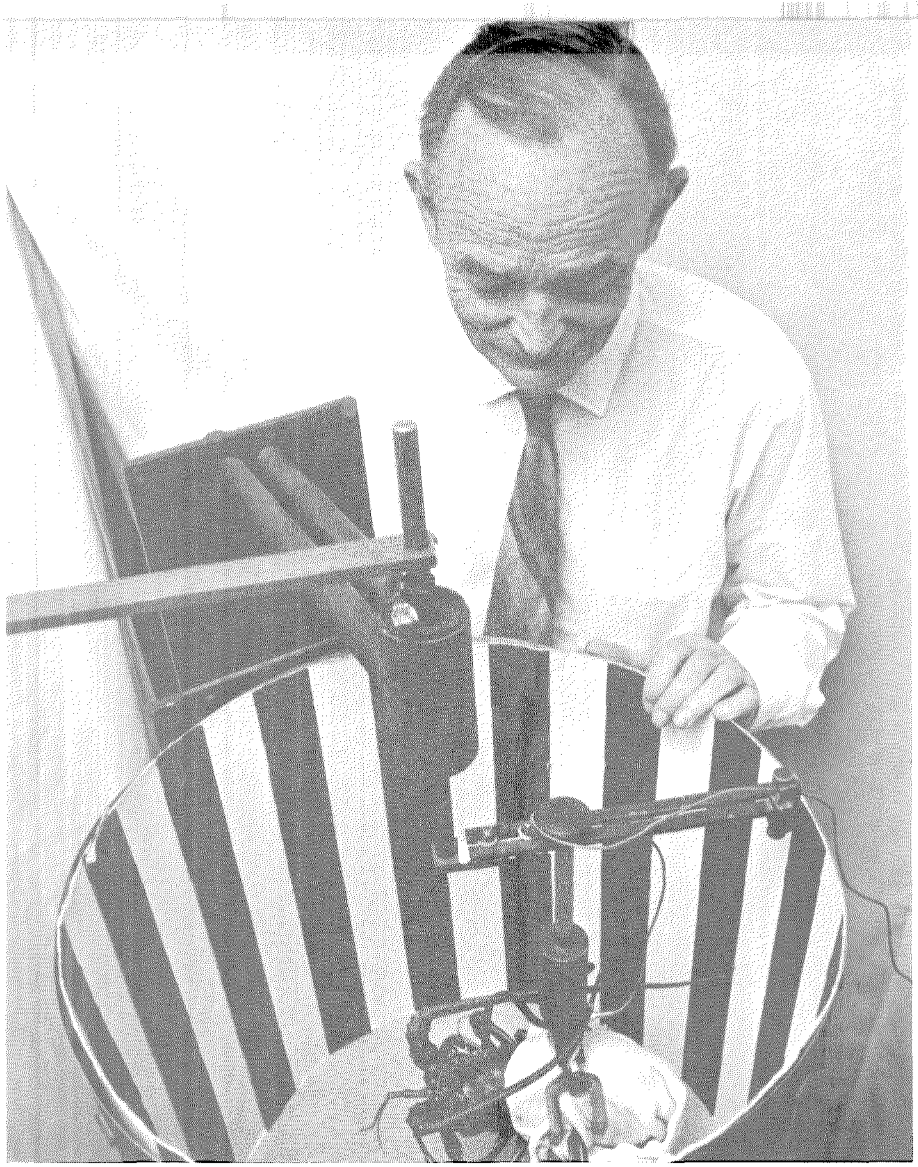
Research Notes



Any resemblance the striped cylinder has to a tide pool is intentional; the crab at the bottom is supposed to feel at home for studies C. A. G. Wiersma is making on how memory works.

Clever Crustaceans

Crabs, crayfish, and lobsters may not have the mnemonic abilities attributed to elephants, but they can remember some things accurately for as long as eight minutes.

What's more, a crab's memory enables it to detect changes in the position of its body relative to the visual background with far greater precision than a man can. In fact, it can remember its surroundings so well that it will recognize a shift of only one-sixtieth of an inch in the position of background objects—even though it didn't see the shift being made.

As with humans, one crustacean's memory may be better than another's, and—as is also true with humans—memory seems to become more hazy with advancing age. In a bright member of the clan, however, accurate memory forms within a half-second, builds for 20 seconds, and lasts for about 8 minutes.

These are some of the interesting facts being turned up by Cornelis A. G. Wiersma, professor of biology, and psychologist Richard L. Hirsh, a research fellow in biology, in their current studies at Caltech on how memory works.

Crustaceans make excellent research subjects for these studies because their memories are conveniently accessible to "wire tapping." Their eyes are located on external stalks, which carry the optic nerve circuitry, so Wiersma has developed a technique for monitoring the minute electrical impulses from their memory mechanism. A minute metal electrode is inserted into one eye stalk in such a way that it touches one of two specific motor nerve fibers. (Finding these precise fibers among the available bundle of them is a fine art.) The fibers connect the memory mechanism to the muscles that move the eye. One fiber moves the eye to the left; the other moves it to the right. When the eye moves in the negative sense for the fiber investigated, the normal discharge rate (about 10 per second) of the fiber is lowered. The difference between the frequency of the impulses from the memory mechanism between a positive and negative change in background measures the memory. The electrical signals of these impulses, about one-thousandth of a volt in strength, are recorded on tape, displayed on an oscilloscope screen, and fed into a loudspeaker. Thus, they can be both seen and heard as often as wanted.

To find out how memory controls eye movements, Wiersma and Hirsh house their subjects in a miniature version of their ocean homes—a cylinder lined with two-inch-wide black and white stripes. The pattern of the cylinder is similar to that of an ocean tide pool. The crab is placed in a fixed position near the bottom of the container, and a light is switched on for one minute so that it can get its bearings. The light is then switched off, and the striped cylinder walls are turned, say, one inch. When the light is switched on again, the crab moves its eyes to take in the shift, indicating that it remembers the former position of the striped walls. It not only knows that the cylinder has been turned, but it also knows how much.

This reaction probably means that in its native habitat the crab's position in relation to his background is very important to him.

After they learn as much as they can about the qualities of the memory, Wiersma and Hirsh may go looking for the site of the memory storage—which may be somewhere in the crustacean's brain, or in the motor cell itself. If that search is successful, then they can look for what happens in the individual neuron to create memory.

The research is supported by the National Science Foundation and the U.S. Public Health Service.

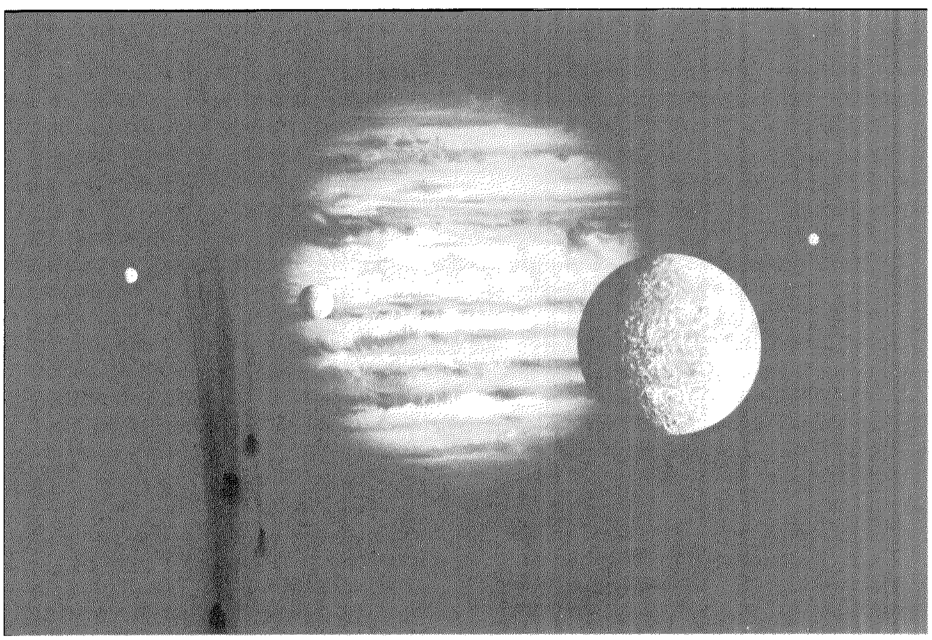
Pioneer 11—An Ace in the Hole

With Pioneer 10 about three-quarters of the way along on its 21-month journey to the planet Jupiter, a twin spacecraft—Pioneer 11—streaked away from Earth on April 5 on a similar voyage. The first probe will reach its destination sometime in December of this year. Pioneer 11 will reach Jupiter early in 1975.

While the missions of the two spacecraft are similar, Pioneer 10's performance as it flies by Jupiter at a distance of about 87,000 miles will determine the objectives for Pioneer 11. If the first probe, for instance, should encounter lethal radiation that destroys its sensitive electronic equipment, the second spacecraft will repeat the mission at a greater distance from Jupiter. But if the first vehicle succeeds—and the threat from Jupiter's powerful radiation belt does not materialize—the follow-up craft will be switched to one of several alternative missions. It could, for example, be steered into a different trajectory to look at a second swath of Jupiter's multicolored, cloud-covered surface. Another alternative would be to bring Pioneer 11 to within 27,000 miles of the planet. Still another possibility would permit the use of Jupiter's gravity to whip the spacecraft on to probe Saturn. If either or both of the Pioneers survive all the hazards of their primary missions, they will loop out of the solar system toward other stars in our galaxy—the first man-made objects to do so. Because they could conceivably be our first contact with an extraterrestrial life, each spacecraft carries a message plaque devised by Carl Sagan (director of Cornell University's Laboratory for Planetary Studies) while he was at Caltech as a visiting associate in planetary science (*E&S*, March-April 1972).

Like Pioneer 10, Pioneer 11 weighs over 550 pounds and is almost an exact duplicate except for the addition of a special magnetometer to measure strong fields in the vicinity of Jupiter. The 14 experiments aboard Pioneer 11 (and the 13 experiments on Pioneer 10) are designed to collect detailed information about Jupiter's internal structure, atmosphere, heat balance, radiation belts, and magnetic fields. In addition, scientists hope to learn more about some of Jupiter's 12 moons, the solar atmosphere, the interstellar gas, cosmic rays, and asteroids and meteoroids in the solar system. Several of the experiments aboard both spacecraft were designed by scientists at Caltech and the Jet Propulsion Laboratory (*E&S*, May 1972).

Perhaps the most intriguing of all the questions scientists hope to answer with the two Pioneer probes is why—and how—Jupiter radiates more energy than it receives from the sun. The answer to this question is central to determining whether life could exist in Jupiter's atmosphere, which is believed to consist of the same ingredients that produced life on Earth about 4 billion years ago. If, beneath its frigid cloud layer, Jupiter has regions that reach earthly "room" temperatures, the conditions are present for the growth of living organisms.



Looking like a striped beach ball, the planet Jupiter looms in space behind 4 of its 12 moons. Jupiter is the target for Pioneer 11's recently launched fly-by mission.

Superconducting Alloys

A new class of alloys that could have a significant effect on the way superconductivity is used to generate and transmit electrical power has been developed by Chang C. Tsuei, research associate in applied physics.

Superconductivity is a property of certain metals and alloys whereby they lose all their electrical resistance at very low temperatures, so that currents induced in them seem to flow indefinitely. At the same time the metals in this state become almost perfectly diamagnetic; that is, they exclude the lines of force of a magnetic field. A bar magnet dropped over a superconducting dish, for example, will hover above it, repelled by its own magnetic image. Entire new technologies are developing around superconductivity—from powerful new magnets for nuclear fusion reactors to new techniques for the transmission of very large amounts of electrical power. But much of this development has been blocked because the most promising superconducting materials are hard and brittle, making it difficult to mold them into wires, strips, and tubes for transmitting electricity. And the metals that can be shaped—most particularly copper, which is an excellent conductor at normal temperatures—are, unfortunately, not superconducting.

Tsuei has been able to eliminate most of these shortcomings by developing a hybrid alloy that combines copper with 5 percent niobium, a superconducting metal, and 1.5 percent tin. The metals are melted by conventional metallurgical methods into an ingot, rolled into wires, and heated at a moderate temperature for a few days. The niobium atoms form particles that are uniformly distributed in the copper-tin mixture and are elongated into long filaments after rolling. Reheated, the tin atoms diffuse out of the copper, move toward the niobium filaments, and form the superconducting niobium-tin compound. By this simple process, Tsuei, in effect, manufactures fine niobium-tin wires inside the copper. The result is a "copper" wire that has essentially the same properties as that of pure copper except that it is superconducting.

The new alloys are the result of ten years of basic research by Tsuei on the electrical and magnetic properties of metal alloys. The U.S. Atomic Energy Commission, which supports his research, has applied for a patent on the entire class of alloys. This new class of materials has been named SUPERCALT alloys (after the code name for Caltech's AEC project, CALT, for the study of the structure and properties of alloys). Tsuei is co-principal investigator with Pol Duwez, professor of materials science.

Replication Site in DNA

Paul H. Johnson, a Caltech research fellow in biology, has discovered—and isolated—the site in a viral DNA molecule where replication starts. This achievement should make possible a better understanding of the mechanism of DNA multiplication—which is essential for understanding either normal or abnormal growth, such as occurs in cancer. It should help reveal how living things function at the most fundamental level.

In collaboration with Robert Sinsheimer, professor of biophysics and chairman of the division of biology, Johnson has been studying a virus known as Phi X 174. Its genetics are already well known through Sinsheimer's work. Phi X 174 is a small, comparatively simple virus whose ring-shaped DNA has only eight genes. The genes carry the blueprint for replication.

Johnson "cut" the virus's small DNA molecule into more than 20 specific fragments. The cleaving was accomplished by two enzymes, which are protein molecules that in this case degrade the DNA. The exact sites where the breaks occur cannot be controlled, although they take place at the same locations each time.

Using specific fragments of the DNA molecule, Johnson succeeded in reconstructing a viral physical-genetic map showing the location of Phi X's eight genes on the individual fragments and the starting place and order in which they are replicated.

It is important now to determine whether the initiation site for replication is between two genes or is actually inside and near the end of a single gene. If the latter is true, it means that a single gene can function in two ways. For instance, it can be involved in the intiation of replication, and it can also code for the manufacture of a protein.

When the replication sequence is turned on—perhaps by an enzyme that recognizes the chemical pattern at the replication site—the first step is for the single-stranded DNA ring to manufacture a complementary strand, a mirror image of itself. The resulting double-stranded DNA ring is then ready to serve as a template for the synthesis of RNA and ultimately for the manufacture of proteins that are needed to reproduce the DNA and build the mature virus.

Johnson hopes to determine the chemical pattern of the DNA—that is, the order in which its 5,500 bases are joined together. DNA contains four bases—adenine, cytosine, quanine, and thymine—and their sequence determines the genetic information in all organisms.

The research, which has been under way about two years, is supported by the American Cancer Society and the U.S. Public Health Service.

Flying Mountain

A two-mile-wide mountain of rock, believed to be the skeletal remains of a comet, is whirling past the earth some 25 million miles out in space. It was discovered by Charles Kowal, research assistant in astrophysics, using the 48-inch Schmidt telescope at Palomar Observatory. Called an Apollo-type asteroid, it is the fourteenth such object to be found in the solar system.

Kowal's find appeared as a streak of light on a photographic plate that he was scanning for supernovae in the course of his job. However, Apollo-type asteroids and lost comets fascinate him, and he has been looking for them in his spare time.

Typical asteroids orbit the sun in a well-defined area between the planets Mars and Jupiter. But these unusual asteroids (named after Apollo, the first of the group, which was originally sighted in 1932 and has only been seen again very recently) are believed by many scientists to be the remains of comets that have lost their streaming tails of dust and gas. These skeletal comets sweep near the sun and then whip far out beyond Mars in great elliptical orbits—each one on its own time schedule for return.

Apollo-type asteroids are among the most elusive objects in the solar system. The speed at which they pass the earth is so great that it has been hard to keep track of them long enough to determine a reliable orbit and predict where they will reappear. Many of them have been sighted only once. But interest in them is increasing, and with the use of the Schmidt telescope and advanced computational techniques, Kowal's newly discovered asteroid is not likely to get lost.

A second sighting of this asteroid was made by Eleanor F. Helin of the division of geological and planetary sciences, and a third was made in Switzerland by Paul Wild. These additional sightings were necessary to establish this asteroid's orbit. Preliminary estimates indicate that it should pass the earth every two years, and if it can be seen on two subsequent revolutions, Kowal will have the privilege of naming it. His choice for that is "Loretta," after his daughter.

Mrs. Helin is co-investigator with Eugene Shoemaker, professor of geology, in a search program for new Apollo-type asteroids—a project that will take about five nights a month for an indefinite period. One reason for setting up the project is that learning about the origin, evolution, and structure of such objects helps scientists understand more about the history and evolution of the solar system. Another somewhat more pragmatic reason is that it has been estimated that every few million years one of the Apollo asteroids collides with the earth. Even though the chances are slight, it would be useful to find out when another such collision might be expected. □