2001 and beyond: A space odyssey

Two years ago, a national advisory panel began an elaborate, two-year project to identify space-science research objectives extending into the 21st century. The space shuttle Challenger had exploded only six months before, and much of the U.S. space program is still reeling from the blast. But the hefty, seven-volume report of the National Research Council's Space Science Board (SSB) was finally released this week, suggesting roadmaps for 30 years of tomorrows.

Nearly 100 scientists worked on the task, which looks as far into the future as the Space Age has come since Sputnik 1, the first artificial satellite, appeared in the sky in 1957. "The intent was to challenge the participants to expand their horizons and to garner as many stimulating ideas as possible for future enterprises in space science," says SSB Chairman Thomas M. Donahue of the University of Michigan in Ann Arbor.

The report is divided into six sections, each of which begins by projecting existing or planned activities in its field through 1995, and then looks ahead through about the year 2015.

Planetary and lunar exploration: Besides returning samples from Mars, Venus, the moon (as part of planning for a proposed permanent lunar base) and perhaps from some asteroids, the report recommends a variety of unmanned landing craft, surface-roving vehicles and networks of widely deployed surface instruments. One of many envisioned technological challenges involves developing a craft to land on Jupiter's volcanically active moon Io, where it would have to survive exposure to the intense Jovian radiation belts.

There would be probes to penetrate deep into the atmospheres of the giant planets Jupiter (the upcoming Galileo mission is to take a relatively shallow dive in 1995), Saturn, Uranus and Neptune, as well as of Saturn's moon Titan. Another suggested goal is to penetrate the icy crust of Jupiter's moon Europa, to see whether a liquid ocean lies beneath. One proposal calls for a craft that would orbit close to the plane of Saturn's rings, shifting its orbit slightly to allow slow encounters with ring particles to study their composition and observe what happens when the little chunks collide.

Expanding the search for planets around stars other than our sun, using earth-orbiting telescopes specifically dedicated to that purpose, also makes the list. Other items include human exploration of Mars and earth's moon, and perhaps of asteroids whose orbits carry them close to earth's.

Astronomy and astrophysics: Among the telescopes envisioned for the sky-watchers of tomorrow is a group of orbiting radiotelescopes, linked by laser beams into interferometers with baselines up to 100 times the diameter of the earth and capable of resolving sources as narrow as 10 one-millionths of an arc second. Optical and infrared observations might be conducted in space with a cluster of nine telescopes mounted on a tetrahedral array of struts, each longer than a football field. Besides ultraviolet telescopes and gamma-ray and cosmic-ray detectors, envisioned instruments include an X-ray imaging facility at least 200 times as sensitive as the best such devices yet flown in space.

Solar system and space physics: One proposed project, called the Solar Probe, would orbit "as close to the sun as possible and still survive to provide useful data near closest approach." This could be as close as four times the sun's radius, the report suggests, depending on the development of an adequate heatshield. Another envisioned mission is the Interstellar Probe, to venture beyond the heliopause — the "edge" of the sun's influence — to study the interstellar medium. A Solar Polar Orbiter would circle the sun at about earth's distance, but in an orbit that carried it over the sun's poles, enabling it to study the full range of solar latitudes.

Mission to planet earth: Addressing questions of global changes and habitability on earth, the SSB proposes a satellite-based observing system (provided in part by other countries) with five geostationary satellites, two to six polar-orbiting platforms and a complementary network of earth-based sensors, providing a regular infusion of data for theoretical modeling. "This accomplished, scientists could use the entire earth as a laboratory," the panel says.

The report contains a section on fundamental physics and chemistry. Proposed experiments include a radio beacon orbiting the planet Mercury to detect changes in the gravitational constant, another space-based facility to detect gravitational radiation and a test to study Einstein's general theory of relativity to an accuracy of 1 part in 1 quintillion (10^{18}). A major focus is science in a microgravity environment such as that of a space station. Rather than concentrating on specific missions, the panel urges NASA to increase its support for basic research in the field, giving microgravity studies "the highest possible priority."

— J. Eberhart

Estrogen receptors detected in bone cells

For years, scientists have known that osteoporosis, or bone loss, parallels decreasing estrogen levels in postmenopausal women. Suspecting that estrogen directly controls the growth of bone, they have looked for estrogen receptors within bone cells, but to no avail. Now, two research teams using highly sensitive detection methods have discovered small numbers of estrogen-binding sites that are probably receptors within the nuclei of bone cells.

By revealing the likely mechanism of how estrogen regulates bone growth, "the findings provide a rationale for treating menopausal women with estrogen to prevent bone loss," says Lawrence Riggs of the Mayo Clinic in Rochester, Minn., who led one of the studies. Bone researcher David Baylink, of the Veterans Memorial Hospital in Loma Linda, Calif., calls the reports "two of the most important discoveries in the field."

In past experiments on breast cancer and uterine cells, researchers have spotted several thousand estrogen receptors per cell. But with improved techniques, the two groups were able to detect even smaller amounts inside bone cells, they report in the July 1 SCIENCE.

Riggs' team added radioactively labeled estrogen to bone cells, then counted how many estrogen molecules bound to sites in the nuclei. Analyzing the cultured human bone cells, Riggs, Erik Eriksen and Thomas Spelsberg noted a mean of 1,615 estrogen-binding sites per cell.

In a second study, Barry Komm and Mark Haussler, working at the University of Arizona College of Medicine in Tucson, incubated lysed nuclei of sarcoma cells from rat and human bone with highly radioactive estrogen. They found approximately 200 estrogen-binding sites per cell nucleus. They also observed that estrogen enhanced the cells' production of the genetic messages coding for collagen, a major protein of bone.

Although Komm hesitates to call the nuclear binding sites "receptors" without first isolating the actual proteins that make up the binding sites themselves, he says the evidence argues that they are indeed receptors. Presumably, estrogen binds to and then changes the shape of its receptor, enabling it to fit into a special region of the nucleus and thereby on genes controlling bone growth.

Such results would explain why estrogen as a drug has been able to halt bone loss in postmenopausal women. But estrogen therapy may have unwanted effects, such as possibly stimulating the growth of certain breast cancers (SN: 5/14/88, p.314). Still, says Baylink, "no drug is more important in the prevention of osteoporosis than estrogen," and by learning how it acts, scientists may be able to create a form of estrogen that works only on the target receptors and with fewer ill effects.

— M. Hendricks