brains. Although the rats might have acquired it from their food, Snyder thought its presence might be more than accidental. He noted that the Tokyo team had found D-serine in brain areas rich in NMDA receptors, and that other workers had shown that the amino acid stimulates the receptor in slices of brain tissue.

To follow up on his hunch, Snyder put his then–graduate student, Michael Schell, to work making antibodies to D-serine to use for mapping its brain distribution more precisely. Applied to brain slices, the antibodies homed in on the D-serine, showing that it is indeed closely juxtaposed to NMDA receptors. The researchers also discovered, to their surprise, that the cells housing D-serine are not neurons but "supporting" cells called astrocytes, and that glutamate could spur D-serine's release from those astrocytes. From those findings, reported in 1995, the researchers surmised that when a neuron dumps glutamate into a synapse, the transmitter not only sticks to the NMDA receptor but simultaneously triggers the release of its coactivator, D-serine, from an adjacent astrocyte.

The evidence for this offbeat theory was still circumstantial, however, so Snyder set out to find proof. To nail D-serine's origin to the brain, Snyder's postdoc, Herman Wolosker, went after the enzyme that makes it, serine racemase. He first purified the enzyme from rat brain, a tour de force completed earlier this year. And now, Wolosker, Snyder, and Seth Blackshaw have cloned the gene for serine racemase and shown that it is active in the same astrocytes that harbor D-serine, making D-serine's role in the brain hard to dispute. "The paper is extremely tight," says neuroscientist Gavril Pasternak of the Memorial Sloan-Kettering Cancer Center in New York City. "It all fits together nicely."

In as yet unpublished work, Snyder and his colleagues, Jean-Pierre Mothet and the University of Chicago's Angele Parent, added a final buttress to the case by showing that the brain's D-serine really does act on the NMDA receptor. They applied D–amino acid oxidase, an enzyme that degrades D-serine, to rat brain slices and cell cultures. As predicted, the enzyme drastically reduced NMDA receptor transmission.

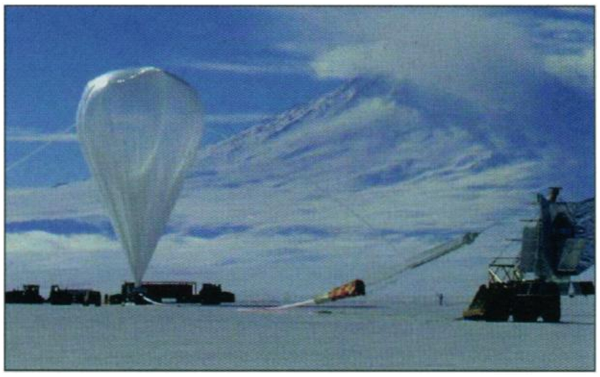
Still to be determined, however, is exactly what role D-serine plays in the brain. For example, neuroscientists will want to know whether it will totally supplant glycine as glutamate's coactivator of the NMDA receptor, and if not, how the two share the job. But by uncovering this surprising new neuronal regulator, Snyder's team has pointed scientists toward original ways of tinkering with and exploring the mind.

–INGRID WICKELGREN

COSMOLOGY

Balloon Flight Brings Cosmic Glow Into Focus

Seven years ago, the Cosmic Background Explorer (COBE) satellite thrilled cosmologists by revealing subtle temperature ripples in the faint microwave glow that pervades the universe. The ripples were the first glimpse of imprints left on the young universe during its birth in the big bang. But COBE could only view great chunks of the sky at once, so the fine details of the ripples remained elusive. Now, a telescope carried aloft by a balloon has scrutinized the microwave glow much more closely—giving cosmologists who have seen the early results another thrill.



Going up for a look. The balloon-borne BOOMERANG cosmic microwave probe, riding the gondola at right, is readied for launch near Antarctica's Mount Erebus on 29 December 1998.

The data come from BOOMERANG, a joint U.S. and Italian mission that flew over Antarctica for more than 10 days in December 1998 and January 1999. BOOMERANG's 1.3-meter telescope—soaring 36 kilometers high, above the atmosphere's moisture—zeroed in on fluctuations some 35 times smaller than COBE did. A preliminary display of the resulting temperature map sent ripples through an audience of astrophysicists at a recent meeting.* "It was a moment like seeing the COBE data for the first time," says astrophysicist Craig Hogan of the University of Washington, Seattle. "It's the most beautiful map of the sky I've ever seen."

BOOMERANG researchers are closely guarding their analysis until it is complete, which could take many months. But cosmologist Andrew Lange of the California Institute of Technology (Caltech) in Pasadena, the U.S. team leader, says the final results will expose the intricacies of the sky's temperature variations as never before. "We have moved into a new epoch," Lange says. "These are the first maps in which you can actually look and point in great detail at which parts of the sky are hot and which parts are cold." Lange and cosmologist Paolo de Bernardis of the University of Rome, La Sapiènza, who leads the Italian component of the team, think the tiny temperature bumps will help cosmologists pin down the proportions of matter and energy in the newborn universe.

The radiation measured by BOOMERANG and a myriad of other current and planned cosmic microwave probes is a cosmic fossil, dating from when temperatures in the young universe were so high that light and matter seethed together in an interacting soup. Small gravitational disturbances inside this plasma tried to draw the matter into clumps, but radiation pressure from the energetic photons fought back. The tug-of-war drove a series of acoustic oscillations within the fluid, much as drawing a bow across a violin's strings causes the instrument's wood to resonate at many different frequencies. Then, when the cosmos reached an age of about 300,000 years and cooled enough for energy to stream through the matter unimpeded, the photons escaped. They form the faint microwave background we see today, imprinted with the remnants of those primordial oscillations.

Cosmologists typically graph the oscillations as a function of power (differences in temperature) and angular scale (their apparent sizes on the sky). The resulting "power spectrum" resembles a roller coaster, with a high initial peak followed by ever-diminishing peaks, which mark the higher frequency overtones of the first oscillation peak. As it turns out, the details of those peaks—such as their relative heights and their precise angular scales—encode critical information about the nature of the cosmos.

For example, the first peak should fall at a scale of about 1 angular degree in a universe containing just the right density of matter and energy to make space geometrically flat, so that parallel light rays remain parallel forever. A flat universe is expected in a popular scenario of cosmic origins called inflation, which posits an extraordinarily fast expansion of space within a fraction of a second after the big bang. Other probes of the microwave background have suggested that the first peak meets this test, with varying degrees of confidence (*Science*, 17 September, p. 1831).

But "in order to really believe these results, we need to be able to see the higher peaks as well," says theorist Marc Kamionkowski

* Cosmic Genesis and Fundamental Physics, Sonoma State University, Rohnert Park, California, 28 to 30 October.

CREDIT: PHIL MAUSKOPF, UNIVERSITY OF MASSACHUSETTS, AMHERST/BOOMERANG TEAM of Caltech. Astrophysicists who saw BOOMERANG's temperature map believe that the data will pinpoint the first and second acoustic peaks and perhaps even outline the third. Their locations could make the flatness of space unmistakable, and they could also reveal how the makeup of the universe is divided between matter and a mysterious "vacuum energy" called the cosmological constant.

Other missions will provide a check on any conclusions. A balloon mission that flew over Texas in June, called MAXIMA, may also map the first and second acoustic peaks, says cosmologist George Smoot of Lawrence Berkeley National Laboratory in Berkeley, California, who led the original COBE analysis. And next fall, NASA will launch the long-awaited Microwave Anisotropy Probe to chart the background temperature fluctuations from orbit, with unprecedented precision.

For now, says astrophysicist Rocky Kolb of the Fermi National Accelerator Laboratory in Batavia, Illinois, BOOMERANG "certainly seems to show that we live in a flat universe." But he adds, "I'm a little worried about that, because it's the expected result. It's always easier to see what you expect."

–ROBERT IRION

IMMUNOLOGY

Memory T Cells Don't Need Practice

Once learned, some abilities, such as swimming or riding a bike, are never forgotten even after years without practice. Others, say running a marathon, need a regular brushing up. Immunologists have long debated which category our immunological memory falls into. Once immune cells learn to recognize a particular antigen, such as a viral protein, do they need constant reminders to stay on top of things, or are their memories permanent? Two reports in this week's issue of *Science* (pp. 1377 and 1381) now bolster the notion that immune cells never forget.

The immune cells in question are T cells, which spring into action to kill infected cells or orchestrate other immune responses when other cells "present" them with an appropriate antigen, together with a so-called MHC protein. The new work, which comes from two independent groups, led by Rafi Ahmed of Emory University in Atlanta and Susan Swain of the Trudeau Institute in Saranac Lake, New York, shows that memory T cells don't need to repeat this experience: They persist and maintain their ability to recognize their specific antigens, even when put into mice that have been genetically altered to eliminate the MHC proteins, which makes antigen presentation impossible.

SOME WAYS NAÏVE AND MEMORY T CELLS DIFFER

	Naïve T cells	Memory T cells
Number of antigen-specific cells	Low—less than 1 in 100,000	Up to several hundred-fold higher
Response to antigen	Slow—days	Fast—hours
Survive in MHC-free mice	No	Yes

For many immunologists, the findings cast a final verdict on the long-standing controversy. "These two papers nail it down pretty firmly that you don't need antigen or some orthodox signaling by classical MHC molecules" to maintain T cell memory, says Peter Beverley of the Edward Jenner Institute for Vaccine Research in Compton, U.K.

Not everyone is convinced, however. Benedita Rocha of the Necker Institute in Paris, whose own work suggests a need for constant "tickling" of memory T cells by MHC molecules, says the experiments on which the findings are based are very complicated and pose many pitfalls. At best, she maintains, "the results are not conclusive yet."

Ahmed and his colleagues worked with so-called killer T cells, which, when activated, attack and destroy certain abnormal cells, such as those infected by viruses. The team began by immunizing normal mice with the lymphocytic choriomeningitis virus (LCMV), a well-known mouse pathogen. After waiting several months until the antiviral T cell memory was established, the researchers purified the animals' killer T cells, including any anti-LCMV memory cells, and then transferred the cells into two mouse strains that had no T cells of their own. The strains were genetically identical, with a single exception. One also lacked the gene for a protein called β_2-microglobulin (β_2M), which helps transport the class I MHC proteins needed for antigen presentation to killer T cells to the cell surface.

As a result, T cells transplanted to these mice should get little or no stimulation by antigen-presenting cells. Yet when the researchers recovered virus-specific T cells from the recipient mice 10 months later, they found the same number of memory T cells regardless of whether β_2M was present.

Rocha sees a flaw in this experiment: She suggests that the MHC class I–positive T cells might have stimulated each other. Ahmed and his colleagues tried to guard against the possibility by testing memory T cells that themselves lacked β_2M, but Rocha maintains that "even these so-called MHC class I–negative T cells are not completely devoid of MHC." Immunologist Peter Doherty of St. Jude Children's Research Hos-

ScienceScope

Early Birds The White House has moved with record speed in nominating two scientists to serve on the 24-member National Science Board, which oversees the National Science Foundation (NSF). Historically, the Administration has been slow to pick members for the panel, leaving it so short-handed at times that it was barely able to convene a quorum. But NSF officials credit Neal Lane, the president's science adviser and former NSF director, with shepherding the new nominees—crystallographer Michael G. Rossmann of Purdue University in West Lafayette, Indiana, and ecologist Daniel Simberloff of the University of Tennessee, Knoxville—through the bureaucracy for an announcement on 1 November, giving the Senate plenty of time to confirm them before their 6-year terms begin in May 2000. NSF hopes for similarly rapid action on replacing the remaining eight panelists whose terms end next spring.

A Wrinkle in Space-Time In 1916, Albert Einstein predicted that violent cosmic motions should send gravitational waves rippling through the fabric of space. This week, researchers inaugurated an unusual observatory designed to catch those elusive waves. The $292 million Laser Interferometer Gravitational-Wave Observatory (LIGO)—which has facilities in Livingston, Louisiana, and Hanford, Washington—will use laser beams to continually measure the positions of mirrors suspended in vacuum tubes 4 kilometers apart. Researchers hope the delicate detectors can discern relative wiggles as small as 1/10,000th the diameter of a proton.

"I can't imagine a more exciting new window to open on the universe," says Caltech physicist Gary Sanders, LIGO's deputy director. But LIGO probably won't sense any shimmers in space-time until both facilities are fine-tuned and ready to start eyeing the gravitational universe in early 2002.

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CREDIT: CALTECH