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.

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-

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

CREDIT: CALTECH

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.

Contributors: Eliot Marshall, Rachelle H.B. Fishman, Jeffrey Mervis, Robert Irion

pital in Memphis, Tennessee, dismisses her doubts, however: "We don't have any evidence whatsoever that [killer] T cells can stimulate each other."

The Emory team also showed that, far from being nonfunctional look-alikes, the long-lived memory T cells were in a "ready-to-hit" mode. When he and his colleagues restimulated the cells with viral antigens in a petri dish, they churned out the immune messenger interferon γ, an early step in the immune response, just as fast as their counterparts from MHC-bearing recipients.

The memory T cells also seemed to renew themselves continually, as more than 20% divided within a 1-week period in both MHC class I–positive and deficient mice. "That tells us that unlike naïve T cells, memory T cells have developed a new way of proliferation that is independent of either antigen or MHC," says Ahmed.

Swain's team studied another kind of immunologic memory, that of T helper cells, so-called because they help jump-start other immune cells, including the antibody-producing B cells. Working with a genetically modified mouse strain in which almost all T cells were specific for the same antigen, Swain and her colleagues extracted spleen cells and activated them with the appropriate antigen. Four days later, presumably before memory cells had developed, they transplanted the cells into hosts that lacked MHC class II molecules, which are needed to present antigen to T helper cells.

There, the T helper cells gave rise to memory T cells that again persisted. And because the memory cells seem to have developed after the helper cells were transplanted to antigen-free mice, Swain thinks that memory is only established once the antigen has been cleared from the body. "A persisting antigen might be counterproductive" for generating T cell memory, she says, because it could push T cells into overdrive and ultimately trigger cell suicide. If so, says Beverley, promising vaccines should be designed to degrade rapidly, or else memory might not develop.

In contrast to the slow renewal of memory T cells that Ahmed's group observed, almost all of the transgenic T helper memory cells were quiescent. "They seem to persist mainly as nondividing cells, similar to the long-lived neurons of the brain," suggests Swain.

But even though the two findings don't agree on every point, most experts are convinced that memory T cells don't need constant stimulation by either antigen or MHC molecules to stay in shape. The great unknown now is the nature of the signal—if there is one—that keeps memory T cells alive and kicking, says Ahmed: "My guess is that this work will set the stage for the next 5 years of T cell memory research."

–MICHAEL HAGMANN

NUCLEAR CITIES

U.S. Cuts Retraining of Russian Weaponeers

Congress has slashed by 75% a planned expansion of an effort to produce 20,000 civilian jobs for weapons scientists and engineers in 10 closed cities in Russia. But while the Department of Energy (DOE) is reeling from the blow to its 1-year-old Nuclear Cities Initiative (NCI), European countries hope to start their own program next year to keep nuclear scientists employed—and perhaps avert a brain drain to rogue countries.

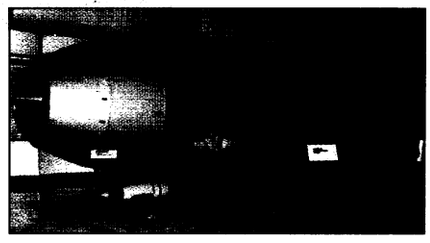
During the Cold War, the Soviet Union set up a secret network of cities to build the country's nuclear arsenal. Soon after the superpower fissioned in 1991, Russia and the United States began allowing their nuclear scientists to strike up collaborations. The pace picked up last year, after Russia's Ministry of Atomic Energy announced that as many as 50,000 workers in the nuclear cities would need new jobs in the next several years. "The cities are in desperate shape and suffering terribly," says Jack Segal, director for nonproliferation and export controls at the U.S. National Security Council.

NUCLEAR CITIES PROJECTS

Project	City	Jobs created	Workforce in 2004
Expanding			
Advanced Computing Ctr.	Sarov	90	500 to 600
Nonproliferation Ctr.	Sarov	30	50
Advanced Computing Ctr.	Snezhinsk	50	500 to 600
Intl. Development Ctr.	Zheleznogorsk	3	3–4
Delayed			
Mercury lamp recycling	Sarov, Snezhinsk		
Rare earth metals plant	Zheleznogorsk		
Start projects in weapons production facility	Zarechnyy		

To stimulate job creation, DOE launched NCI last fall with $15 million. The agency modeled the effort after a program it began in 1994, the Initiatives for Proliferation Prevention (IPP), which matches U.S. national labs and companies with former Soviet weapons scientists engaged in peaceful work with commercial promise (*Science*, 8 January, p. 160). In February, however, the General Accounting Office reported that the $25 million IPP program was spending only 37% of its funds on former Soviet institutes and pouring the majority into the U.S.–based collaborators. More damning, the report charged that the IPP "has not achieved its broader nonproliferation goal of long-term employment" for weapons scientists but rather is keeping them afloat on R&D contracts. Given IPP's lack of success, the report concluded, the NCI "is likely to be a subsidy program for Russia for many years." The current NCI program "is not selling and may not even be working," says Kenneth Luongo, director of the Russian-American Nuclear Security Advisory Council (RANSAC), a private research group focused on the Russian nuclear complex.

Such doubts spelled trouble for NCI, which hoped to see its budget double, to $30 million, in 2000. Picking up on the report, the House committee that oversees DOE's budget declared "it is not clear that [DOE] is the best agency to implement this program since the most important training needed in these cities is marketing and business expertise"—not traditional strengths of the U.S. national labs. NCI was launched "with a lot of money, a lot of fanfare, and not a lot of programmatic planning," says Madelyn Creedon, counsel for the Senate Armed Services Committee, which reviews Defense Department efforts to reduce the former Soviet nuclear threat. The House wanted to nix all but $1.5 million for NCI, but House-Senate conferees agreed to provide $7.5 million, half the current level, in 2000. "This reduced funding is absolutely insufficient to support business activity in even a single city," says Olga Vorontsova, deputy director of international relations at the nuclear center in Sarov. Unless the program expands, she predicts, NCI will "contribute little to the reduction of the nuclear weapons workforce."



Fewer cities. DOE will limit aid in 2000 to existing Russian sites, such as Snezhinsk, home of the largest hydrogen bomb ever made.

CREDITS: (TOP TO BOTTOM) DOE; SNEZHINSK NUCLEAR CENTER

The funding cuts mean that DOE will have to postpone plans to expand NCI beyond its three current sites (see table). DOE officials, meanwhile, have stepped up their outreach to Congress and also hope to win support from the seven other federal bodies on NCI's advisory board. "I would applaud and encourage facilitation of a team approach," says NCI senior adviser Terry Plummer. But DOE and the national labs "have built trust and confidence with the nuclear