been deciphered as well. These sequences should provide clues about how vertebrates evolved.

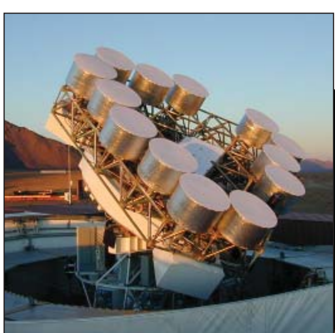
In addition, the sequences of microbial genomes keep pouring in: another strain of anthrax and a bacterium called *Shewanella*, useful for bioremediation, to name just two. And the flood of genome sequences shows no sign of abating: Work has begun on chimp, corn, and poplar. The honey bee, dog, cow, chicken, and sea urchin are supposed to be up next.

#4 **Cosmic twist.**

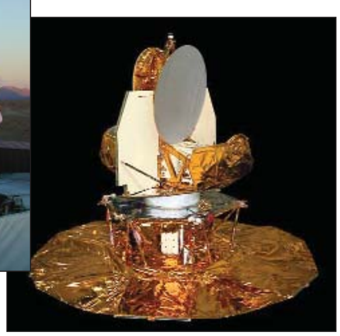
Even though it's less than 3° above absolute zero, the cosmic microwave background (CMB) is very, very hot. In 2002, astronomers and physicists watched the end of the tale of the beginning of the universe.

Discovered in 1965 by Arno Penzias and Robert Wilson of Bell Laboratories in New Jersey, the CMB is the remnant of a time, 400,000 years after the big bang, when free-streaming nuclei and electrons finally cooled and formed atoms. As the electrons settled down into their orbitals, high-energy light, liberated from its cage of matter, streamed forth. Stretched and attenuated by 14 billion years of travel, the CMB appears as a faint but ubiquitous microwave static coming from all regions of the sky.

In 2000 and 2001, airborne and ground-based microwave telescopes generated exquisitely detailed pictures of fluctuations in the CMB, fluctuations that reveal not only the universe's past but its future. Not only did these fluctuations give rise to the agglomerations of galaxies that we see today, but they also revealed the "curvature" of the universe, which shows that the universe will expand forever, rather than recollapsing in a big crunch. In May, the Cosmic Background Imager (CBI), a microwave telescope high atop the Andes mountains in Chile, put an exclamation point on those observations by detecting "peaks"—characteristic patterns in the fluctuations—that revealed structures far smaller than other telescopes had yet seen. In January 2003, other physicists are expected to reveal the first results from the Microwave Anisotropy Probe (MAP), an orbiting satellite that will be the ne plus ultra of fluctuation detection until the end of the decade.



CBI



MAP

CREDITS: (TOP TO BOTTOM) CRYSTAL BALLS: TERRY E. SMITH; CALIFORNIA INSTITUTE OF TECHNOLOGY; NASA/MAO SCIENCE TEAM

But the real CMB triumph this year was the first detection of polarization by the Degree Angular-Scale Interferometer team at the University of Chicago. The discovery of this faint signal heralds the beginning of a new chapter in CMB research—one that might reveal the state of the universe when it was a minuscule fraction of a second old by revealing the subtle scarring caused by gravitational waves during the birth of the cosmos.

#5 **Fast moves.**

If action flicks seem to be getting faster these days, just wait. This year, laser physicists succeeded in making the first-ever movies in which individual frames were measured in attoseconds, or billionths of a billionth of a second. The new high-speed filmmaking techniques are expected to spawn a new genre of cinema devoted to tracking the motion of electrons around atoms.

Laser physicists have been refining their

Scorecard 2002

In which we take our lumps for predictions made last year

Stem cells abroad. The raging political debates of previous years died down in 2002, as more countries settled on regulations governing work with human embryonic stem cells. The pace of headline-grabbing scientific breakthroughs has also slowed as the relatively young field works to decipher the complex mechanisms controlling cell fate—and some scientists complain that access to human embryonic stem cells is still frustratingly slow.

Proteomics. Fundamental advances in figuring out protein interactions have begun to migrate to medical and biotech applications as hoped. Proteomics companies announced this year that they had discovered novel proteins that appear to be linked to diseases such as cancer and asthma. These companies are now developing novel therapeutics to target the proteins and diagnostics capable of tracking them. Actual drug products based on proteomics have yet to emerge. But developing a new drug typically takes more than a decade. Meanwhile, basic research on mapping biologically important proteins continues. In May, the Human Proteome Organisation, a group seeking to keep proteomics from being locked up in proprietary interests, outlined five initial projects. The U.S. National Institutes of Health, meanwhile, announced an initiative in October to spend $157 million over 7 years to create 10 new proteomics centers.

Eyes on the sky. It's been a very good year for astronomical viewing. Optical systems that automatically adapt to visual conditions have come into their own (see Runner-Up item on p. 2301). Solid discoveries have been popping out of the Sloan Digital Sky Survey this year on quasars (*Science*, 28 June, p. 2317), globular clusters (*Science*, 14 June, p. 1951), and brown dwarfs (*Science*, 4 January, p. 64). And member nations of the International Virtual Observatory Alliance (www.ivoa.net) have ramped up demonstration projects linking the world's astronomical instruments.

Next in genetics. The multiple genes involved in diabetes, cancer, and other complex diseases continue to elude researchers. Some progress was made—a diabetes gene here, a Hirschsprung's disease gene there—but now geneticists are pinning their hopes for progress on the HapMap, a major multiyear undertaking to map variation in stretches of human DNA called haplotypes.

Optical clocks and constants. Last year, the future for clocks and reference standards based on high-frequency optical emissions from atoms looked bright. But the hands on the clock of progress have slowed: Translating the basic breakthroughs in optical physics to practical applications has proven harder than expected. Given the lead times in the field of metrology, the future of optical clocks may still light up in the long term.

Visualization. Powerful computing and clever imaging are combining to create better snapshots of cells and molecules. One technique, cryoelectron tomography, has yielded unprecedented views of cellular machinery (see Runner-Up item on p. 2301). New methods of fluorescent imaging produced dramatic scenes of protein translocation in single cells (*Science*, 8 March, p. 1910), and a new variant of green fluorescent protein offered a novel tool for tracking intracellular protein dynamics. And new initiatives, such as the MIT School of Engineering and Whitehead Institute's proposed center for bioimaging, are seeking to join supercomputing with state-of-the-art imaging methods.

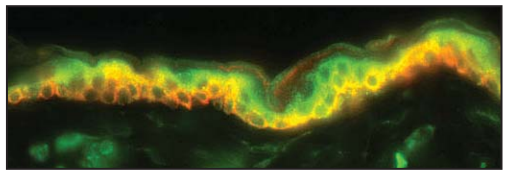
high-speed moviemaking approaches for years. But most rely on the same basic principle, using ultrashort pulses of laser light like bursts from a strobe light to freeze motion in flight. Researchers now routinely use the technique to capture the blur of molecules as they break and weld bonds in a chemical reaction, events that take place on the order of 1 to 100 femtoseconds, or 10^{-15} seconds.

Dutch and French researchers broke the attosecond barrier last year, when they trained ultrashort laser pulses on a gas of argon atoms, which in turn emitted a train of pulses, each lasting just 220 attoseconds. A team of Austrian, Canadian, and German researchers followed hard on their heels with a related technique that turned out individual 650-attosecond pulses, which are more easily used as moviemaking strobes.

This year, researchers turned their new attosecond strobes onto the action within atoms. In October, the Austrian and German members of the original team used their attosecond pulses to excite electrons in krypton atoms, each of which left behind an electron vacancy. With another laser pulse, they were then able to track the timing with which excited electrons gave up some of their energy and fell back into the more stable energy levels. It's not Hitchcock, but attosecond movies will give physicists a whole new view of life inside the atom.

#6

A taste for temperature. The heat of four-alarm chili and the coolness of spearmint chewing gum aren't just metaphorical: To some cells, taste and temperature are the same. This year, researchers tunneled into ion channels that respond to such sensations. They're tuned to warmth, minty coolness, or, in mice at least, another steamy stimulus: pheromones.



Feel the heat. Skin cells host TRP ion channels that respond to warm temperatures.

So-called transient receptor potential (TRP) ion channels are proteins that snake in and out of the cell membrane. When they're tickled appropriately, they allow calcium or other ions to surge into a cell. In neurons, this can make the cell fire off a signal to its neighbors. Mammals harbor at least 21 flavors of TRP channels, but most of their functions are unknown.

The first report that certain TRP channels promiscuously respond to either a chemical or a thermal stimulus came in 1997, with the identification of a TRP channel that gets steamed up by either hot temperatures (above 43°C) or capsaicin, the active ingredient in chili peppers. This year, a similar multitasking channel was found in nerves of the mouth and skin. It reacts when exposed to either cool temperatures (15° to 25°C) or menthol, the chemical that makes mint minty.

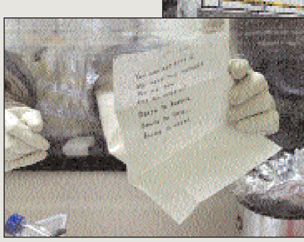
A warmth-sensitive (~34°C) TRP channel debuted this year as well. It is concentrated in skin cells, suggesting that the skin itself senses heat and passes the message to neurons.

Bioterrorism: The Calm After the Storm

The 11 September terrorist attacks and the mysterious anthrax letters, mailed a few weeks later, are beginning to put their stamp on the research enterprise, especially in the United States. But although 2002 has been marked by much talk about bioterror, it has also become a year of waiting for action, with major decisions on research funding, regulation, and smallpox vaccination stalled by politics and technical debate.

Meanwhile, despite one of the most expansive investigations in FBI history and a $2 million reward, the anthrax killer is still on the loose.

Infectious-disease researchers are confident that the attacks will eventually produce a funding windfall. In his 2003 budget, President George W. Bush requested a $1.5 billion increase for the National Institute of Allergy and Infectious Diseases, which in turn has asked researchers for proposals on everything from new drugs and vaccines to new research centers and specialized labs. Congress was supposed to approve the spending by 1 October, but election-year politics has stalled any decision until at least January.



Poisoned letters. A year after anthrax-laced letters killed five people, including two postal workers, the killer remained at large.

Still, the vulnerability of the United States to the ultimate bioterror nightmare—a smallpox attack—has diminished considerably. Old smallpox vaccine supplies were dusted off and proven to still work. Together with new vaccine produced by Acambis, a government contractor, there's now enough to cover the entire U.S. population. But government officials were locked in debate for months about how many people should get preemptive shots, primarily because the vaccine is known to cause severe infections and death in a small number of recipients.

Last week, the Administration finally announced plans to start vaccinating half a million health care workers and first responders, and another half million in the military. But eventually, the vaccine will be made available to anyone who wants it—a decision that's drawing outspoken criticism from public health experts (see News Focus story).

Another topic of intense but unfinished debate is how best to balance security needs against scientific freedom. Researchers are anxious, for example, about upcoming regulations on work with potential bioweapons. Poorly written rules could lead to misguided law enforcement, they say, pointing to the case of Tomas Foral, a 26-year-old graduate student at the University of Connecticut, Storrs, who became the first researcher to be criminally charged with mishandling dangerous agents after he allegedly stored anthrax samples in a lab freezer.

Foral avoided indictment by agreeing to perform community service, but research leaders worry that the incident heralds a new, chilly era in their labs. And the National Academy of Sciences' decision to censor a "sensitive" chapter from a recent report about agricultural bioterrorism has helped spark debate about what kinds of unclassified information scientists should withhold from the public in the name of security.

The trail of the real anthrax killer, meanwhile, appears to have grown cold, despite extensive help from anthrax scientists. In August, a break in the case appeared imminent after FBI sleuths twice searched the home of Steven Hatfill, a former Army microbiologist with an interest in bioterrorism. Hatfill lost his job as a bioterrorism preparedness instructor at Louisiana State University, Baton Rouge, after Attorney General John Ashcroft called him a "person of interest," but he was never charged with any offense.

–MARTIN ENSERINK

CREDITS: (TOP TO BOTTOM) A. M. PEIER *ET AL., SCIENCE* **296**, 2046 (2002); MIKE STOCKER/*SOUTH FLORIDA SUN-SENTINEL*/CORBIS SYGMA; AP PHOTO/FBI