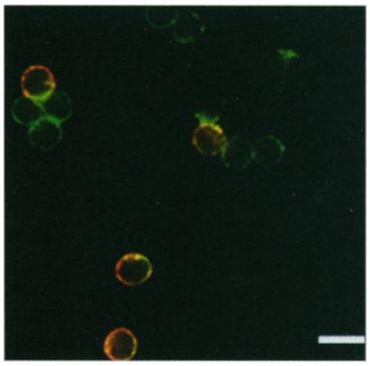
In 1999, researchers recognized the extraordinary potential of stem cells, immature cells with the ability to become different kinds of tissue—and perhaps to heal many kinds of illness

Capturing the Promise of Youth

Old age may have wisdom, but it will always envy youth for its potential. The same might be said for cells, for a young cell's most important trait is its ability to choose among many possible fates and become, say, a neuron passing electrical signals or a blood cell carrying oxygen. Late last year, in a technological breakthrough that triggered a burst of research and a whirlwind of ethical debate, two teams of researchers announced that they had managed to prolong the moment of cellular youth. They kept embryonic and fetal human cells at their maximum potential, ready to be steered into becoming any cell in the body.



New identity. White blood cells descended from neural stem cells are stained yellow, documenting an astonishing switch of fate.

Building on that achievement, in 1999 developmental biologists and biomedical researchers published more than a dozen landmark papers on the remarkable abilities of these so-called stem cells. We salute this work, which raises hopes of dazzling medical applications and also forces scientists to reconsider fundamental ideas about how cells grow up, as 1999's Breakthrough of the Year.

Stem cells may one day be used to treat human diseases in all sorts of ways, from repairing damaged nerves to growing new hearts and livers in the laboratory; enthusiasts envision a whole catalog of replacement parts. Despite such promise, many in society object to using stem cells derived from human embryos, a debate that is sure to continue into 2000 and beyond.

But another astonishing development that occurred in 1999 may ease the ethical dilemma. In defiance of decades of accepted wisdom, researchers in 1999 found that stem cells from adults retain the youthful ability to become several different kinds of tissues: Brain cells can become blood cells, and cells from bone marrow can become liver. Scientists are now speeding ahead with work on adult stem cells, hoping to discover whether their promise will rival that of embryonic stem (ES) cells. Thus, 1999 marks a turning point for this young field, as both science and society recognized—and wrestled with—our newfound power to manipulate a cell's destiny.

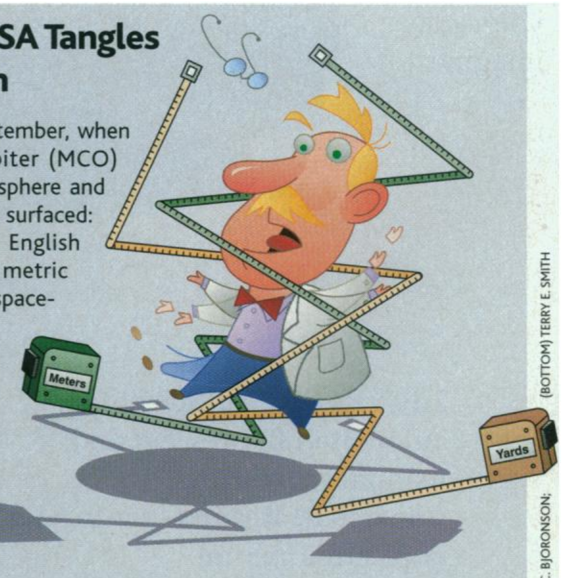
Open future

Researchers have long been familiar with certain types of stem cells. Back in 1981, they discovered how to culture mouse ES cells, treating them with just the right growth factors to keep them dividing but forever immature. Today such cells are common research tools, used, for example, to produce tens of thousands of knockout mice that lack specific genes. In humans, scientists had managed to identify and culture stem cells from several types of adult tissue, such as bone marrow and brain, but had done little work on stem cells from embryos.

Then last November two company-funded teams announced that they had isolated and cultured human embryonic and fetal stem cells, coaxing them to pause their development before they became committed to any particular fate (*Science*, 6 November 1998, pp. 1014 and 1145). Many scientists worldwide were immediately eager to join the field but were hampered by rules in many countries that restrict public funding for research that destroys a human embryo. Instead, while ES cell research moved ahead in a few privately funded labs, ethical debates on the wisdom of using human embryos in experiments sprang up in all sorts of public forums.

The U.K. imposed a 1-year research moratorium to allow for public discussion, for example, and a French high court advised lifting that country's ban on human embryo research. And a U.S. presidential advisory panel recommended that public funds be available for all types of stem cell research. In proposed rules released this month, the National Institutes of Health is a bit more restrictive, prohibiting researchers from using federal funds to derive cell lines from an embryo but allowing them to work with certain cell lines created using private funds (*Science*, 10 December, p. 2050).

Blunder of the Year: NASA Tangles With the Metric System



The year's prize snafu struck in September, when the $87 million Mars Climate Orbiter (MCO) plowed deep into the martian atmosphere and perished. Within days, the root cause surfaced: Navigators had inadvertently used English units of pound-seconds instead of metric newton-seconds as they guided the spacecraft. But as in most catastrophic failures, a slew of otherwise harmless oversights and miscommunications combined to turn the English-metric confusion lethal.

The curse of the Red Planet continued this month when the Mars Polar Lander spacecraft, due for a 3 December touchdown, went missing. This time the problem wasn't units of measurement—a beefed-up team of navigators had honed the spacecraft's approach to within a gnat's eyelash, with nary a pound-second in sight. But nothing has been heard since the spacecraft went quiet, as planned, during final approach. That leaves MCO's lesson to be remembered: Talking "faster, cheaper, better" isn't necessarily the same as achieving it.

CREDITS: (TOP) J. R. RIETZE AND C. BJORONSON; (BOTTOM) TERRY E. SMITH

Career switching

While the public and policy-makers mulled the ethical implications, researchers galvanized by last November's announcements rushed down another avenue of research—on stem cells from adults. Scientists had known for decades that certain kinds of stem cells lurk in adult tissues, for example in bone marrow and skin. But most scientists had assumed that the adult-derived cells have a limited repertoire. Just as years of training usually commit a concert violinist to a career in music, so scientists had assumed that when a young cell takes on an identity and turns various suites of genes on or off, that genetic programming irreversibly commits it to becoming one of just a few cell types.

But this year several startling results have shown that in some cases, those early commitments can be rewritten. In January, Italian and U.S. scientists reported that stem cells taken from the brains of mice could take up residence in the bloodstream and bone marrow and become mature blood cells—a leap roughly equivalent to a music student becoming a successful professional baseball player. That means signals in the immediate environment can in some cases override a cell's history, implying that nature allows developing cells far more freedom than scientists had imagined.

Many scientists initially balked at that idea, but a string of new results seem to back it up. Texas researchers found just a few weeks ago that muscle stem cells could become blood cells, for example. Other scientists reported that stem cells found in rat bone marrow could become liver cells—raising the tantalizing possibility that cells now routinely harvested in bone marrow transplants may have much broader uses. And this fall Pennsylvania scientists reported that mouse marrow cells injected into the brains of newborn mice could develop into brain cells.

As such basic research leaped forward, biomedical scientists sought new ways to use stem cells to help people. For example, researchers this year found that healthy bone marrow stromal cells, which give rise to bone, could strengthen bones and prevent fractures when injected into three children with the bone-weakening disease osteogenesis imperfecta. And in a promising step toward a possible treatment for neural disorders such as multiple sclerosis, researchers in Boston injected neuronal stem cells from healthy mice into the brains of newborn mutant mice that lacked a key protein, part of the protective myelin sheath around neurons. The treated mutant mice produced the missing protein and were less prone to a characteristic tremor. Another group injected bone and muscle stem cells into mice that lacked the protein dystrophin—missing in patients with Duchenne's muscular dystrophy—and within 2 weeks the animals produced the missing protein.

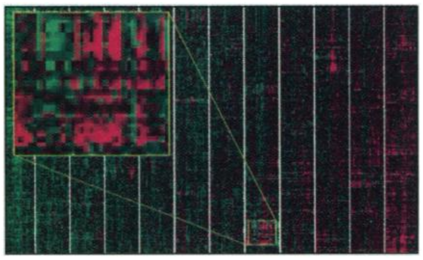
Applications of ES cells could be even more dramatic. This year another set of mutant mice, unable to produce myelin, received mouse ES cells in their brains; the cells soon spread through the brain and produced myelin. And Missouri researchers this month reported that mouse ES cells could help restore some movement to the limbs of partially paralyzed rats.

With dramatic results like these coupled with growing public acceptance, the stem cell field is poised for progress. If it lives up to its early promise, it may one day restore vigor to aged and diseased muscles, hearts, and brains—perhaps even allowing humans to combine the wisdom of old age with the potential of youth. —GRETCHEN VOGEL

THE RUNNERS-UP

Science honors nine additional major discoveries in fields that span the universe, from the edgy dance of subatomic particles to the biological wizardry that imprints memories.

First Runner-Up: Genomics Speeds Ahead. In December 1998, the publication of the first genome of a multicellular organism, the nematode *Caenorhabditis elegans*, ushered in a new era in genomics—that of rapidly comparing thousands of genes in complex organisms. This year every facet of genomic technology accelerated, from sequencing to database management. As a result, genomics swept through biology, as researchers compared the sequences as well as the expression patterns of many thousands of genes at once.



Lighting up. Microarray results show a tumor's gene activity in red and green.

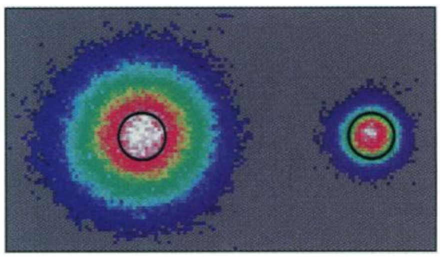
In terms of sequencing, additional complex genomes are now due much sooner than predicted. The fruit fly genome is expected in the next few months rather than years, and the international, publicly funded effort to determine the order of the 3 billion bases that make up the human genome has kicked into hyperdrive, promising to deliver a rough draft of at least 90% of the genome by March 2000. Indeed, the first installment, the sequence of chromosome 22, arrived in 1999. Also this year, the U.S. and British governments pledged more than $100 million to help sequence the mouse genome, which is about the same size as our own and contains many of the same genes.

At the same time, researchers polished off the genomes of several key microbial pathogens, including *Chlamydia pneumoniae*, which causes respiratory infections; the food-borne pathogen *Campylobacter jejuni*; and a virulent strain of *Mycobacterium tuberculosis*. And two chromosomes of the malaria parasite *Plasmodium falciparum* were sequenced and two teams mapped its genome. All these data should yield new targets in the battle against these pathogens.

The outpouring of sequence data also sparked an explosion of technologies to integrate and analyze the flood of information—and thereby to probe questions ranging from how the immune system responds to how humans evolved. Many scientists turned to DNA-chip and low-budget microarray technologies, which allow them to compare gene expression rapidly in adults and embryos, or in healthy and diseased tissues. Faced with a data deluge, bioinformation experts this year revved up their efforts to link different kinds of information, hoping to allow researchers of all stripes to capitalize on the growing genomic riches.

How the other half cools. Four years ago, researchers cooled rubidium atoms into a quantum-mechanical superparticle called the Bose-Einstein condensate, a stunning feat lauded as Molecule of the Year in 1995 (*Science*, 22 December 1995, p. 1902). This year, physicists at the same lab knocked over another milestone, cooling a vapor of ornery atoms in the first step toward creating an even more bizarre macroscopic quantum state.

Every particle of matter comes in one of two types: bosons and fermions. Bosons are content to share the same quantum state, as photons do in laser light and as rubidium atoms do in a Bose-Einstein condensate. But fermions, which include electrons, quarks, and about half the atoms in the periodic table, hate to be forced into the same state; instead, they try to occupy adjacent



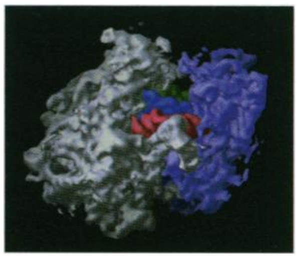
Cold clouds. Two clouds of fermions just after their release from a quantum state.

CREDITS: (TOP TO BOTTOM) J. TRENT; D. JIN states, as electrons do when filling energy shells around an atom.

This year, however, Colorado researchers discovered a new trick to help tame wild fermions. The scientists put fermionic potassium atoms into different quantum states and induced atomic collisions between them. The collisions carried energy away from each fermion, leaving the resulting vapor ever cooler and putting the gas as a whole into a state in which atoms are precisely arranged in a ladder of energies.

This cooling method clears the way for an even more mind-boggling possibility: At still lower temperatures, fermions may be coaxed into pairing up into bosonlike composites, as electrons do when they travel without resistance through superconductors. Such an achievement may lead to the next state of quantum matter: an atomic superfluid of fermions, the first step toward a new generation of atomic clocks and lasers.

Rally for ribosomes. After a prolonged drum roll, the curtain came up this year on the structure of one of the cell's most important players, the ribosome. This massive protein-RNA complex produces proteins, somehow accurately translating genomic information into each of the tens of thousands of molecules necessary for life. Structural biologists had struggled for decades to probe this complex molecular machine but were thwarted until recently by its intricate tangle of 54 proteins and three RNA strands.

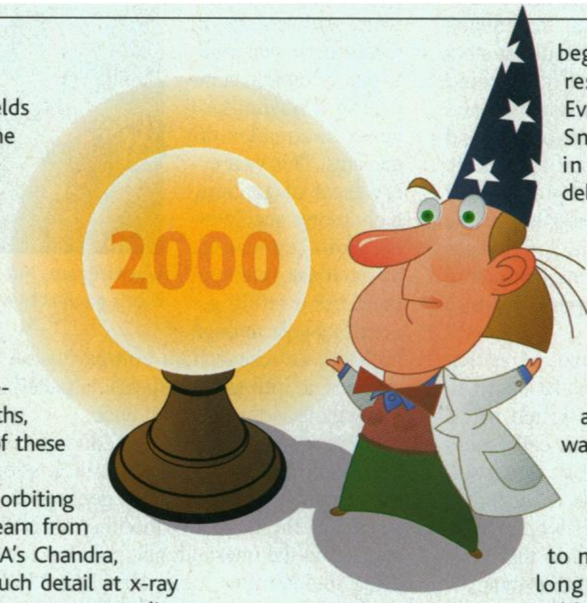


Ribosome revealed. The protein factory comes into full view.

In 1999, however, three x-ray crystallography groups—capitalizing on earlier, blurred glimpses of the molecules plus innovative ways to analyze x-ray data—partially resolved the structures of the ribosome's two subunits. In addition, a fourth team described a slightly less detailed structure of the entire ribosome, showing how the two components interact. That group also captured the ribosome bound to messenger RNA, which carries the genetic

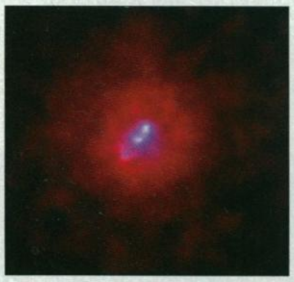
Peering Into 2000

We turned our crystal ball on high to spot fields that may rise to the top in the first year of the new millennium. Here are *Science*'s picks for areas to watch in 2000.



Unraveling Alzheimer's. Next year should bring the acid test for the popular but controversial notion that amyloid plaques cause the mental deterioration of Alzheimer's disease. This year researchers tentatively identified two enzymes called secretases, which make particular cuts in a precursor protein and together free the plaque-forming amyloid fragments. In the next few months, drug companies plan the first trials of inhibitors of these enzymes in people.

X-ray astronomy. By early next year, a trio of orbiting telescopes will be observing the x-rays that stream from the most energetic objects in the universe. NASA's Chandra, launched last summer, is already revealing as much detail at x-ray wavelengths as most scopes discern in visible light. This month, Europeans launched the X-ray Multi-Mirror mission to pick up even fainter x-rays, and a Japanese satellite tuned to the very shortest wavelengths is set to follow early next year. Expect new insights into exotic corners of the universe such as black holes, neutron stars, and supernova remnants.



Epigenetics explosion. As sequenced DNA piles up, expect genetics to take another great leap next year into epigenetics, the study of how DNA sequences are packaged and expressed. Epigenetic changes in gene expression, such as silencing one copy of a gene, aren't linked to DNA alterations. Yet studies have suggested that such changes can be passed from one cell to another and sometimes from parent to offspring, violating Mendelian principles. In 2000, watch for more insights on how epigenetics affects gene regulation, development, and even cancer.

Restoring rivers. Big plans are afoot to undo past damage wrought by diverting and damming U.S. waterways. Next year officials will mull over or begin huge projects aimed at restoring water flow to the Everglades, salmon runs in the Snake River, and wetlands in the San Francisco Bay delta. Much more than simple cleanups, these projects all have long timetables, hefty price tags—a proposed $7.8 billion for the Everglades alone—and their share of critics. In 2000, expect more debate as ecologists worldwide watch the outcome.

New paths to nanocomputers. Researchers seeking to shrink computer chips to molecular dimensions have long been stumped by a key problem: how to wire up their minicomponents—mere molecules that perform as electrical switches and wires—into circuits in which every device works perfectly. This year, however, a handful of teams scored initial success with a bold strategy that allows some components to fail and simply routes around circuitry that doesn't work. And several teams created molecular and nanotube electronic devices that can connect to other components. Expect new types of components and more complex circuits in 2000.

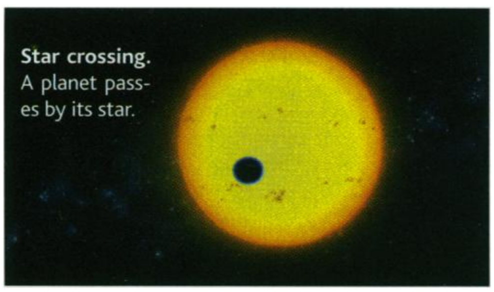
Farewell to polio. In the 1950s, polio crippled more than half a million children every year. But a World Health Organization (WHO) campaign to wipe the disease off the planet by the end of 2000 has slashed cases by more than 90% since 1988 and pushed the virus into ever-shrinking corners of South Asia and Central Africa. Still, 1999 brought thousands of scattered new cases and a major outbreak in Angola. Boosted by an infusion of cash from Bill Gates and Ted Turner, WHO has stepped up immunization and surveillance, and observers say that the all-but-final blow to this scourge is likely to come next year.

CREDITS: (CLOCKWISE FROM TOP) CATE *ET AL.*; TERRY E. SMITH; DAVID G. HOUSER/CORBIS; NASA/CXC/SAO data needed to make proteins, as well as to transfer RNA, which supplies the amino acids needed to build the proteins.

This first good look at the ribosome's internal connections only made researchers eager for more—in particular, for new views of this star cellular player in action. In the next year or two, expect structures with near-atomic-level resolution to reveal the precise connections between each protein and RNA. And advances in cryoelectron microscopy, in which electron microscopy specimens are quick-frozen in glassy ice, promise to image ribosomes at work as they move along the messenger RNA. For ribosome fans, 1999 opened what promises to be a long, successful run of discoveries.

Plentiful planets. Theorists think the universe is teeming with planets, but astronomers detected the first extrasolar planet only 4 years ago. They spotted the wobbles induced in its parent star, an indirect method that left room for skepticism. But in 1999 astronomers unequivocally confirmed the existence of exoplanets: They caught one transiting the face of its star, significantly dimming that star's brightness for a few hours every 3.5 days. Astronomers even sketched the planet's characteristics: It is 200 times more massive than Earth, has a diameter significantly larger than Jupiter's, and like Jupiter is composed mainly of hydrogen and helium.

Also in 1999, another team found tantalizing (but still unconfirmed) evidence of starlight reflected off a different exoplanet.



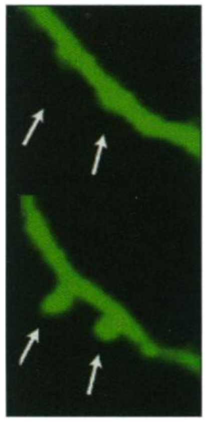
Star crossing. A planet passes by its star.

CREDITS: (LEFT TO RIGHT) LYNETTE COOK; TOBIAS BONHOEFFER

And discoveries of new planets flowed in steadily all year, bringing the total number of known extrasolar planets to nearly 30. The latest haul even contains worlds that orbit in the habitable zone of their parent stars, where liquid water and life could exist. Unfortunately, all planets detected so far are gas giants like Jupiter, lacking a solid surface. Moreover, most of them move in very eccentric orbits, unlike the planets in our solar system, leaving theorists scrambling to explain why. Although the string of new data confirms that planets are common, at this stage it seems that planetary systems configured like our own are rare indeed.

Making memories. From an old nursery rhyme to the name of someone you just met, memories of all kinds are etched into your brain by a molecular cast of epic proportions. The actors in this drama are molecules rushing into and out of the synapse, the gap between neurons. Their movements strengthen the connections between certain neurons, making those synapses more likely to fire in the future. Exactly how the enhanced firing calls up and stores memories remains a mystery, but this year researchers used new methods to film a neuron's most intimate connections for the first time.

Researchers have long cast one molecule, the NMDA receptor, in a starring role in learning and memory: When activated, this receptor makes a neuron more sensitive to incoming signals, a process called long-term potentiation (LTP). But this past spring the spotlight swung to an unsung molecule called the AMPA receptor. Using a new laser microscopy technique, researchers watched fluorescently labeled AMPA receptors stream into the little nubs known as spines that form the receiving end of synapses. The AMPA receptors then allowed activation of the spines' NMDA receptors, triggering more LTP.



A spine is born. New spines were filmed growing in a synapse.

Also playing at the synapse film festival were movies made by the same technique that showed brand-new spines pop up next to synapses that had undergone LTP. And last month researchers showed that those new spines quickly form twin synapses next to the original, effectively doubling its strength.

Another celebrated result came in September, when a Princeton team genetically engineered mice to produce more of a certain NMDA receptor found in young animals. The altered mice were better at learning mazes, dramatically demonstrating the large-scale effects of this molecular drama.

Flat and happy. Cosmologists can hardly believe how their luck has changed. New observations often send theorists scurrying back to

Scorecard '98

Each year we choose six fields that we predict will make news in the next 12 months. But forecasting is no exact science; here's whether *Science*'s crystal ball was cloudy or clear.

Coming of age, slowly. This year's crop of studies linked genes that control aging to key hormones such as insulin. And as predicted, there was a flurry of work on telomeres, DNA sequences on the ends of chromosomes thought to shorten with age. But the telomere studies didn't deal directly with aging, and the basic biology behind why and how cells—and people—grow old remains a mystery.

Biowarfare worries. Although there were no attacks, last year's concerns about bioweapons grew more visible in 1999, as did efforts to counter the threat. A new book, *Biohazard*, documented a former Soviet scheme to pack long-range missiles with pathogens. The U.S. Department of Defense began vaccinating troops against anthrax attacks by rogue nations or terrorists, and other agencies announced growing budgets for biowarfare defense.

Crystal-clear materials. 1999 was a banner year for photonic crystals—latticelike structures that promise to control photons the way semiconductors control electrons (see Runner-up, p. 2242). Researchers reported the first photonic crystal laser and developed photonic crystal waveguides that steer light around sharp corners, a key step toward crafting optical circuits.

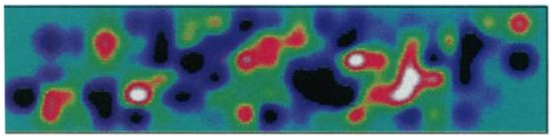
Still seeking a sink. Despite a busy year, climate researchers puzzling over where Earth's excess carbon dioxide is being stored have yet to answer the question. A study of land-use records since 1700 found that North America's plants may *not* be sopping up massive amounts of CO_2, as proposed in 1998. But researchers are still waiting for new data on how much carbon is sequestered by soils, oceans, and forests.

No relief from sneezing and wheezing. Some clues surfaced as to the complex causes of allergies and asthma, including new data suggesting that a treatment's success may depend on the patient's genetic makeup. But although many clinical trials began in 1999, they have yet to produce good news for patients.

Climate mysteries. Understanding climate swings from millennium to millennium is proving to be just as hard as forecasting the atmosphere's day-to-day gyrations. This year researchers linked the Little Ice Age of the 18th century with a 1500-year climate cycle, and they concluded from layered sediments in a high Andean lake that El Niño has waxed and waned over millennia. But the underlying causes of such long-term swings remain elusive.

their equations, but this year, measurements of one of the cosmos's most basic numbers gave the answer theorists had hoped for: The universe appears to contain just the amount of matter and energy that the most elegant picture of its origins requires.

This theory, called inflation, holds that a burst of expansion in the first instant of time stretched space almost perfectly flat, so that parallel light rays stay parallel forever. But until recently, the universe seemed irredeemably



Spot on. Microwave fluctuations, seen by a South Pole telescope, reveal a flat universe.

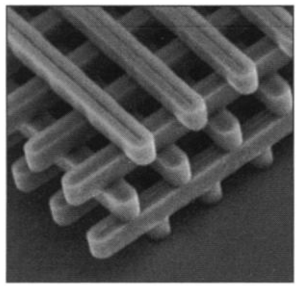
curved. Because mass can change the shape of space-time, cosmologists thought a flat universe implied a specific density of matter. And as hard as they tried, they could only find a third of the density needed.

Last year, a possible salvation appeared: Measurements of distant exploding stars suggested that a mysterious energy in empty space is accelerating the expansion of the universe. Energy can curve space just as matter can, and the finding suggested that energy might fill in for matter and flatten the universe (see last year's Breakthrough of the Year, 18 December 1998, p. 2156).

Now, the cool cosmic glow called the microwave background has yielded a sign that it does. The microwave glow retains the faint imprint of lumps in the newborn universe, in the form of slightly hotter and cooler regions. These fluctuations are a kind of test pattern for cosmic geometry: Space is flat if their apparent size on the sky tends to be about 1 degree of arc. Observations from high in the Andes, the South Pole, and balloons now agree that the 1-degree peak is there, and theorists are cheering.

New light on photonics. Semiconductors transformed the communications and computing industries by channeling electrons faster than giant old vacuum tubes could. And many observers expect that in the 21st century these industries will be transformed again, by photonic crystals, latticelike structures that have the potential to manipulate photons as semiconductors do electrons—but at the speed of light. In 1999, researchers hailed a string of firsts in crafting photonic structures, paving the way to true photonic optical devices.

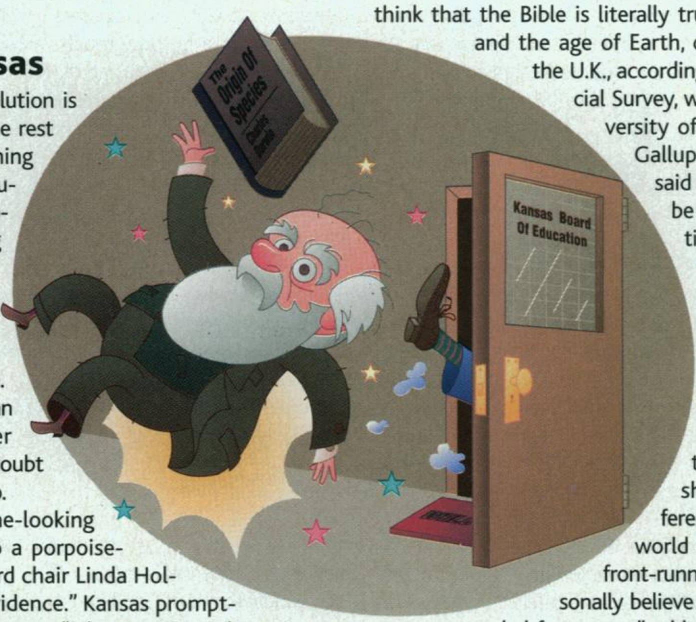
Photonic crystals are made of a lattice of materials of differing optical properties, which excludes light of certain wavelengths. Introducing a defect into the crystal allows the forbidden wavelengths to travel along the defect. This year, several independent groups demonstrated the crystals' potential as light guides. One team created a photonic bandgap mirror, which completely reflects light of certain wavelengths, and rolled it into a tube that can steer light around sharp corners without



Photonic future. A tiny lattice channels light.

Breakdown of the Year: Creationists Win in Kansas

Scientists who realized long ago that evolution is the key to biology—and assumed that the rest of the world agreed—got a rude awakening courtesy of the Kansas State Board of Education, which in August voted to drop evolution from statewide science teaching standards. Exactly what students are taught will depend on their teachers, but as the standards form the basis for new state tests, students won't have to know much about evolution at exam time. And the Kansas educators tossed more than Darwin into limbo—they worded other passages of the standards so as to cast doubt on the big bang and radiometric dating too.



"Where is the evidence for that canine-looking creature that somehow has turned into a porpoise-looking creature?" wondered school board chair Linda Holloway on NBC TV. "I haven't seen that evidence." Kansas promptly became a laughingstock in some quarters. "Uh, sorry Dorothy, it's Kansas all right—Oz is not this strange," gibed Robert Park of the American Physical Society in his newsletter.

But Kansas educators are not alone. Alabama textbooks have carried a disclaimer saying that evolution is only a "controversial theory" since 1996. And even though a Louisiana appeals court ruled against a similar practice—oral disclaimers by teachers—in August, Oklahoma ordered publishers this fall to insert a disclaimer just like that used in Alabama. In New Mexico, just as newly elected scientists on the school board got that state's evolution prohibition reversed this fall (*Science*, 22 October, p. 659), a Kentucky panel was eliminating "evolution" and substituting "change through time" in its standards.

Perhaps the most disturbing aspect for scientists is that these moves reflect widespread beliefs: About 35% of American adults think that the Bible is literally true, including on creation and the age of Earth, compared to only 7% in the U.K., according to the International Social Survey, which is run from the University of Chicago. And in a 1997 Gallup poll, 68% of Americans said that "creationism should be taught along with evolution" in public schools.

Presidential candidates have been quick to pick up on that sentiment: When queried after the Kansas decision, not one took an unequivocal stand in favor of evolution. "I believe children should be exposed to different theories about how the world started," said Republican front-runner George W. Bush. "I personally believe my children were not descended from apes," added Republican Gary Bauer. Even Vice President Al Gore couldn't resist a waffle: He favors teaching evolution, said a spokesperson, but "localities should be free to teach creationism as well." Gore later backed off, saying creationism should be confined to religion courses.

All this suggests that the future of evolution in many U.S. schools is "grim," says Eugenie Scott of the National Center for Science Education in El Cerrito, California. All the same, scientists can stem the tide, say Scott and others; observers note that four of the five religious conservatives on the Kansas board will be up for reelection next year. Science will win out in the end, predicts Wayne Carley, head of the National Association of Biology Teachers in Reston, Virginia. "It took 300 years to accept Galileo. Another 300 years and maybe the U.S. will catch up with the rest of the world." —CONSTANCE HOLDEN

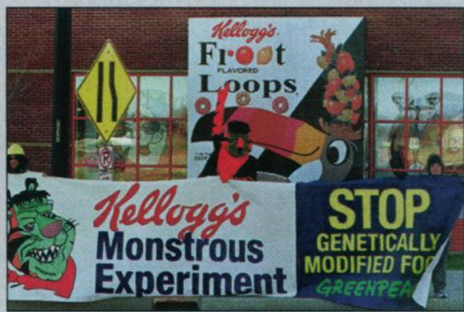
CREDITS: (LEFT TO RIGHT) GREG GRIFFIN; TERRY E. SMITH; SANDIA

Controversy of the Year: GM Foods Under Attack

The debate over genetically modified (GM) foods exploded in 1999, becoming a worldwide public relations disaster for the biotech industry and casting science in the role of villain. Although most fiery in the United Kingdom, where headlines warned of "the horrors of GM foods" and "the mad forces of genetic darkness," the public fervor spread through Europe, leading the European Union to suspend the introduction of new GM crops pending new legislation, which could be 3 years away (*Science*, 26 November, pp. 1662–1668).

The effects even reverberated in the United States, where the GM revolution had been proceeding all but silently. U.S. farmers, who planted roughly half of their corn, cotton, and soy fields with transgenic crops this year, watched with dismay as their export markets shrank. And at recent public hearings organized by the Food and Drug Administration, many speakers voiced concerns that the crops—often tailored to resist insects or herbicides—might be hazardous to human health or could cross-pollinate with wild plants and create "superweeds."

This eruption of public feeling was fueled by a few critical studies published this year. One showed, for example, that monarch butterfly caterpillars in the lab died when fed transgenic pollen containing Bt, a bacterial insecticide. Another reported that rats' gut linings were somewhat swollen after the animals ate transgenic potatoes. But such work was preliminary and controversial—it's not clear yet how much Bt caterpillars would eat in the wild, and Britain's Royal Society called the potato study "deeply flawed."



Sowing fear. Pressure to abandon GM crops is rising.

Critics have pointed out that the lack of good data works both ways—there's no clear evidence that transgenic crops are totally innocuous. But this year's turbulence seems to have stemmed less from data and more from the public's knee-jerk reaction to moving genes from one species to another, a fear sometimes compounded by peculiar political circumstances. In Great Britain, for example, public trust in food safety laws had been eroded by the government's attempts to play down the mad cow disease crisis in the early '90s. British biotech opponents also happen to have a prominent organic farmer on their side: the Prince of Wales, who once likened tinkering with genes to playing God. Resistance may have been further inflamed by unspoken resentment against big corporations, perhaps with a pinch of anti-Americanism; that might explain why U.S. biotech giant Monsanto was a favored target, and why French farmers directed their anger at local McDonald's.

Whatever the causes, the power of protest groups is a fact of life that agricultural biotech firms are slowly learning to deal with. Meanwhile, they hope resistance will fade within a few years, as new GM fruits and vegetables with extra vitamins or antioxidants tempt consumers. The new wave could be a real boon for developing countries. Rice with added vitamin A and iron could help prevent blindness and anemia in millions, for example.

But attitudes toward GM foods will have to thaw considerably before such benefits materialize. It may take years before we know whether the 1999 backlash was a mere ripple in the introduction of biotech crops—or whether millions of consumers have renounced them for good.

dissipating. Other groups took a different tack, using a pattern of holes in an optical fiber cable to trap light. These light guides can carry high-intensity light that could damage conventional optical fibers and promise advances in industrial welding and machining.

Also this year, California researchers developed the first photonic crystal laser. Using photonic waveguides to link dozens or hundreds of such lasers within a crystal would create an integrated optical circuit, with uses ranging from telecommunications circuits to lightning-fast optical computers.

Tracking distant ancestors. Geochemists added a billion years to the history of complex cells in 1999, by finding chemical traces of eukaryotic cells—which make up plants, fungi, and animals, including humans—in rocks 2.7 billion years old. Their discovery not only rewrites our early history, it demonstrates the power of a promising technique that marries geochemistry and biology and may help researchers read the most ancient chapters in the history of life.

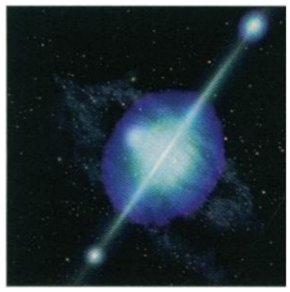
Scientists have argued for decades over the origins of eukaryotes, which unlike bacteria or archaea have a nucleus. But clear fossil evidence has been sparse; the oldest undisputed eukaryote fossils are less than 2 billion years old.

Although eukaryotes can be hard to distinguish in fossils, these cells do make more complex molecules than their simpler cousins, a fact researchers took advantage of this year. They extracted chemical residues from Australian shale and found traces of steranes, derivatives of cholesterol and related molecules that today are made only by eukaryotes. That suggests that eukaryotes—or at least their close precursors—are much older than many scientists had thought.

This same rock sample also included molecules characteristic of cyanobacteria, or blue-green algae—microbes credited with producing much of the early Earth's oxygen—pushing back their origins by 600 million years. In response to the new finds, biologists are gathering more chemical and fossil evidence, hoping to fill in the gap between the two kinds of data.

Mystery flashes unveiled. Gamma ray bursts—cosmic explosions that emit more power in a few seconds than the sun does in 10 billion years—have posed a mystery for more than 30 years. But since 1997, astronomers have employed an armada of ground-based telescopes to make rapid follow-up observations of the bursts' feeble afterglows. As a result, researchers now seem to be closing in on the true nature of the massive blasts: At least some are apparently the birth cries of black holes, formed when rapidly rotating, supermassive stars collapse upon themselves. Powerful jets of matter from the nascent black hole plow through the collapsing star, blowing it to smithereens in a titanic supernova explosion and producing huge amounts of gamma rays in the process.

The first tentative link between a gamma ray burst and a supernova was made back in April 1998. Now this year's findings by teams from Pasadena, California, Chicago, and Amsterdam seem to close the case, by revealing the telltale glows of supernovae superimposed on the fading afterglows of at least three gamma ray bursts.


Big blast. A gamma ray burst spews energy.

Details of the explosion mechanism may fill in as astronomers continue to pounce quickly on the bursts. And two NASA satellites carrying rapid-response telescopes, to be launched in January and in 2003, are likely to shed even more light on the physics of these colossal explosions.

—The News and Editorial Staffs

For an expanded version of this section, with references and links, see *Science* Online at www.sciencemag.org/content/vol286/issue5448/#special

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