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PopSci Predicts: The Year Ahead

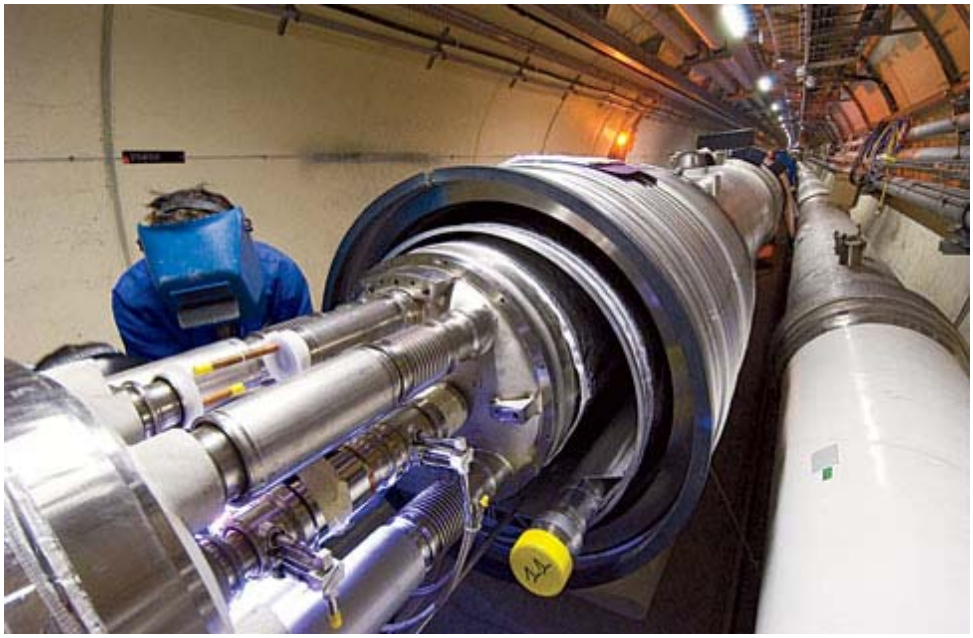
the PopSci Staff

For an illustrated month-by-month calendar of the science stories to watch for in 2007, click 'View Photos' at left

The Answer Machine Arrives
The world's most powerful physics laboratory will take on questions we can't yet imagine

Later this year, the $8-billion science experiment known as the Large Hadron Collider (LHC) will start uncovering clues to some of the biggest mysteries in physics. It was designed more than a decade ago to answer a specific checklist of questions: Why does matter have mass? Does every particle have an unseen partner? In the intervening decade, however, physicists have been developing new ideas about how the universe might be put together. If all goes well, the machine—a 16.8-mile-long proton smasher buried outside Geneva, Switzerland—could discover startling phenomena that could validate (or refute) those nascent theories about the origin and structure of the cosmos.

Jonathan Feng, a theoretical physicist at the University of California at Irvine, has suggested that collisions at the LHC might produce dark matter—the mysterious, invisible stuff that astronomers believe makes up 80 percent of the matter in the universe. This is not something the original planners had in mind. "The idea that the LHC would help with the big cosmological questions was completely off the map when it was proposed," Feng says.



CERN

The subatomic collisions at the LHC could solve many long-standing mysteries of the universe

The same holds true for the search for extra spatial dimensions, which for years were thought to be out of the reach of modern experimental technology. Recently, though, theorists have discussed the possibility of finding indirect proof at the LHC. "You're not going to see the extra dimensions," says physicist Konstantin Matchev of the University of Florida. Instead, he explains, particles such as electrons will suddenly become more massive as they travel through that added space. Matchev and his colleagues will be scouring the data for those telltale weight gains.

But even if the LHC fails to reveal either of these events, it should still be a tremendous success. The discovery of the Higgs boson, the "God particle" that may give matter its mass, is a near guarantee, according to most physicists. More important, the LHC is going to generate conditions and energy levels that haven't existed since the big bang. That means it could produce phenomena physicists never even thought to imagine. "The great thing about science," Feng says, "is that you never know what Nature has up her sleeve." —*Gregory Mone* **Supersizing the Space Station**
The deadline: 2010. The key year to meeting that deadline: 2007

When the space shuttle Columbia disintegrated in 2003, only 49 percent of the International Space Station's intended hardware was in place. The

disaster led to the shuttle's mandatory retirement in 2010 and, in so doing, created a hard deadline for the completion of the $100-billion ISS. If the orbital construction project is ever going to be the world-class research facility and moon/Mars stepping stone scientists first envisioned two decades ago, 2007 will be a very busy year indeed.

NASA has scheduled 14 more assembly missions to complete the ISS, five of them this year. If all five prove successful, by this December humanity's only outpost in space will be 30 percent more massive, have 5,000 more cubic feet of space, generate nearly triple the power, and, most remarkably, boast two new state-of-the-art science labs.

NASA

This year's five shuttle missions to the ISS will increase the facility's size by 30 percent.

Europe's Columbus Lab and the Japanese Experiment Module (nicknamed Kibo) are the coming year's marquee payloads. These billion-dollar bus-size modules will greatly expand the outpost's research capabilities in terrestrial science (drug development and climate study, for example) and in work vital for long-duration missions to the moon and Mars, such as space medicine and radiation shielding. Also on the manifest: a Canadian-built robot called Dextre, for Special Purpose Dexterous Manipulator. Once permanently affixed to the station, Dextre will use its two 11.5-foot-long, seven-jointed appendages to perform intricate repairs that would otherwise require spacewalks, giving astronauts more time to spend in the new labs.

This year's efforts will be the most challenging series of space missions ever attempted—"even more complex than Apollo," says NASA spokesperson Allard Beutel. Given the troubled track record of both the ISS and the shuttle, it's not surprising that many doubt the agency's ability to pull it all off on schedule. "The station and shuttle are always surprising us with new problems. The plan is not going to go right by the book," warns Louis Friedman, director of the Planetary Society. "It is very unlikely that we're going to have that many successful flights on so tight a schedule. If we do, we'll be lucky." And we'll see the troubled station become the long-promised training ground for the next generation of space travelers. *—Rena Marie Pacella*

The Year's Top 5 Space Launches

1. *Themis* Probes
   On January 21, NASA will send five small spacecraft into the heart of the violent geomagnetic disturbances in the Earth's magnetosphere. The goal: to uncover how magnetic substorms in the region cause the colorful northern lights.
2. China's *Chang'e 1*
   China's first lunar orbiter will kick off the country's ambitious moon program on April 17. During its year in orbit, the instrument-loaded probe will survey the lunar surface to prepare for an upcoming Chinese lander mission.
3. *Dawn* Spacecraft
   On June 21, NASA's ion-propelled *Dawn* will take off for the asteroid belt between Mars and Jupiter, where it will study the two most massive space rocks in our solar system, Vesta and Ceres, which was recently promoted to dwarf-planet status.
4. *Phoenix* Mars Lander
   The low-cost NASA spacecraft will blast off toward the martian arctic in August to look for signs of life (present or past) in the ice that lies just beneath the Red Planet's surface.
5. GLAST Telescope
   On October 7, the Gamma-ray Large Area Space Telescope will launch into orbit and begin to observe our universe's most fascinating phenomena, including black holes, quasars and neutron stars.

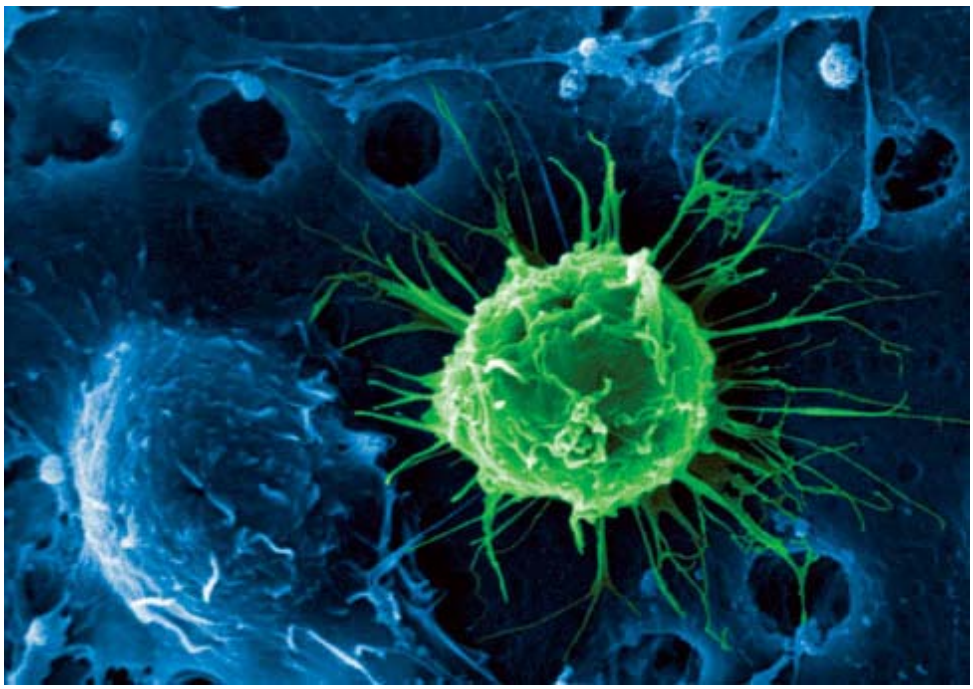
Stem Cells Grow Up

New research into adult cells may reenergize therapeutic research

The promise remains tantalizing: radical new treatments for diabetes, Parkinson's disease and even cancer enabled by stem cells—self-renewing bodies capable of differentiating into other, more specialized cell types. Progress, however, has been achingly slow. The California Institute for Regenerative Medicine, which administers the state's $3-billion stem-cell-research initiative, estimated in October that fully developed stem-cell therapies are still more than a decade out.

Why the wait? Scientists need a far deeper understanding of cell biology, where the bulk of research will be focused for years. And even that task is hindered by laws proscribing the use of human embryonic-stem-cell lines in federally-funded labs.

Small wonder, then, that the most enticing developments are coming from research on adult stem cells—a twist that could render moot the moral objections associated with the use of embryonic cells. Adult stem cells, which regularly repair or replace damaged cells, have been hard to morph into other types of tissue. But that's changing. Last year, researchers at UCLA transformed adult stem cells in fat tissue into muscle cells, a development that could aid in repairing arteries and bladders.



Andrew Paul Leonard

The ability to create embryonic stem cells from adult cells could transform the science.

Even more groundbreaking was the work by two scientists at Kyoto University in Japan who reported last August that they had induced embryonic stem cells from adult skin cells in mice tails. They first isolated four genes present in embryonic cells but inactive in adults. When adult cells received chemical factors from those four genes, they reverted into embryonic cells that could differentiate into any tissue. If the Kyoto research is replicated in humans, it will be a game-changer for the science. "Let's say you could take your skin cells and reprogram the nucleus to create an embryonic-stem-cell line—without an egg," says the California Institute's Mary Maxon. "Therapeutically, that would be huge." *—Kevin Kelleher*

Fighting Water Woes

As global shortages grow, the U.S. turns to high-tech solutions

When three drunken white men drove through the Native American village of Chiloquin, Oregon, in 2001, blasting a portable toilet with a shotgun and yelling, "Sucker lovers, come out and fight!" locals got an Americanized taste of the conflict that might dominate the world's next century: water wars. Irrigation had been cut off to protect endangered suckerfish, considered sacred by the Klamath tribe. As resulting droughts pitted area ranchers and farmers against tribe members, water was becoming a bargaining tool in Uzbekistan and Gaza, a military target in Lebanon, Nepal and Darfur, and a catalyst for riots in Somalia, China, India and Pakistan. "There's always been conflict over water," says environmental scientist Peter Gleick, whose Pacific Institute in Oakland, California, compiles a list of flare-ups dating back to 2500 B.C., "but the tension is growing."

The U.N. estimates that by 2025, five billion of the world's projected 7.9 billion people will lack access to safe water. Although the most dire crises will certainly be outside our borders, in the U.S.— where the population just surpassed 300 million, water-storing snowpacks are melting in a warming climate, and people use more water per capita than anywhere else (up to 100 gallons a day)—conditions are ripe for conflict. Our aquifers are draining faster than they can be replenished, and the biggest, Ogallala, which stretches from South Dakota to Texas, has seen localized drops in the water table of 150 feet. Seven Western states are stuck trying to wring more water from the drought-ridden Colorado River, which is already reduced to 0.1 percent of its volume by the time it reaches the Gulf of California.

Enter desalination. The world's largest inland plant, an $87-million, 27.5-million-gallons-per-day (MGD) project in El Paso, Texas, will make brackish

A growing population's demand for water has dr Grande in New Mexico.

groundwater potable starting this year—just as the country's first large-scale seawater plant, a troubled 25-MGD facility, finally begins operations in Tampa, Florida. In Arizona, a test reopening of the mothballed Yuma Desalting Plant may mitigate Colorado River losses, and in California as many as 20 desalination projects along the coast will be debated. The fate of the biggest plants, two 50-MGD facilities in Carlsbad and Huntington Beach, could be decided by this summer.

Electricity-hungry desal plants are becoming more economically viable because of advances in water-purifying reverse-osmosis membranes, tens of thousands of which are contained in a large plant: The newest can produce upward of 10,000 gallons a day apiece, up from 5,000 gallons in the late 1990s. Composite materials may soon double a membrane's life—10 years rather than five—and nanotube-based membranes will shorten the length each water molecule must travel. "If this happens, plant productivity will go up 20 times," says Nikolay Voutchkov of Poseidon Resources, the company behind the Carlsbad and Huntington Beach projects. "It's like having a vacuum-tube computer, then switching to the microprocessor." The company's vision for the future doesn't stop there. If the Carlsbad bid goes through, it plans to engineer the city's tap water to have the mineral content and taste of Pellegrino bottled mineral water.

Gleick, meanwhile, cautions that desalination is a supply-side solution to a demand-side problem. He wonders if the price tag and environmental effects—marine kills during intake, discharges of hypersaline brine—are worth it. Indeed, the best solutions to the coming water crisis may be as mundane and varied as low-volume-flush toilets and drought-resistant crops, especially in the developing world, where funds for Pellegrino-spitting facilities are as scarce as water itself. —*McKenzie Funk* **The (Not So) New Nuclear**
Despite resurgent interest in nuclear power, novel plant designs stall

It's been 33 years since a nuclear power plant was commissioned in the U.S. That's likely to change by later this year, when the Nuclear Regulatory Commission could approve a site for a new reactor on American soil. Lured by government incentives, and backed by environmentalists pushing nuclear as an emission-free alternative to fossil fuels, 15 power companies have announced their intention to build new U.S. plants within the next few years.

Nuclear now supplies one fifth of our power, but Americans' appetite for energy is growing—some estimates project a 40 percent jump in consumption by 2030—and our current plants are getting older. Although the next wave of reactors will supply some of that juice and fill the voids left by decommissioned plants, they won't be transformative. There are new reactor designs, but most of the updated features are safety-related; these plants won't support hydrogen production, for example.

This May, however, the Department of Energy will select one of three new designs for a truly next-generation nuclear plant, with the goal of building a commercially viable version by 2021. Each of the proposed designs would generate temperatures in excess of 1,650°F—hot enough for efficient hydrogen production and, potentially, to ignite a hydrogen economy.

But is the current pace of technological development too slow to guarantee continued political support? MIT nuclear engineer Andrew Kadak thinks so, estimating that DOE funding is one third of what it needs to be to keep the program on track. That, he maintains, is unacceptable. "We've got a real

New plants will improve safety (shown here, a te
won't incorporate the smartest new technology.

urgent crisis at hand," he says. "We've got to get off fossil fuels. We can't be waiting until 2021." —*Gregory Mone* **Meet Carbon's Evil Cousin: Methane**

A new understanding of permafrost melt could soon alter global-climate models When scientists fly into remote areas of Siberia to study permafrost, they gaze down on an endless expanse of arctic lakes. Sounds beautiful—but those pools of water are also alarming. A third of this vast region, the world's biggest patch of frozen ground, is covered with lakes that are growing as subterranean ice melts. Although the melting in itself is a troubling indicator of a warming planet, the bigger concern is invisible: The lakes are emitting huge amounts of methane as ancient plant and animal remains thaw and decompose underground.

A greenhouse gas 20 times as potent as carbon dioxide, methane is being released into the atmosphere five times as fast as previously thought, according to findings from late 2006. In fact, the feedback loop of higher temperatures melting more permafrost and producing even more methane is so powerful, it has the potential to supercharge the warming of the entire planet.

Two important efforts are under way to get a handle on the reality. First, a coalition of polar-research groups has banded together to reach a consensus estimate of how much carbon is sitting in cold storage in the earth's permafrost (they hope to release their findings by the end of this year).

Courtesy Dr. Katey Walter

Methane release, as from this Siberian lake, could influence climate change.

At the same time, climatologists will start trying to model the planetary implications of permafrost melt. "In the next year or so, we're going to add permafrost to the global climate model simulations," says ecologist Ted Schuur of the University of Florida. "That will mark a big change in how we understand climate change."

One possibility for this year and beyond is an unprece-dented event that Schuur calls a "catastrophic thawing" of permafrost, in which a large region melts all at once. "It's like the ice shelves on Antarctica. We don't know they're going to break off, then—boom!—it happens," he says. "There's no reason it couldn't happen in the next year." —*Jebediah Reed* **Addiction on the Brain**

From vaccines to versatile drugs, new cures are all about chemistry

It's a great time to be an addict. Long viewed as a moral failing, addiction is increasingly being redefined by scientists and physicians as a chronic relapsing disease—one that can be treated chemically.

This year, we will find out whether an entirely new solution fulfills its early potential: vaccination. Anti-addiction vaccines produce antibodies that detect molecules from abused drugs and bind to them, keeping them out of the brain and blocking their pleasurable effects.

First up is an anti-nicotine vaccine with a promising past. In early studies, 40 percent of people receiving the vaccine (called NicVAX) quit smoking without suffering withdrawal symptoms. More trials will be carried out this year, and the government is likely to fast-track approval if the vaccine does well.

Courtesy Dr. Nora D. Volkow/Brookhaven National Laboratory

Brain scans show that many forms of addiction—including compulsive behaviors like gluttony—have the same roots in the brain.

The major momentum, though, remains with finding drugs to help people stop using drugs. Fifty clinical trials of drugs for alcohol dependence are going on right now. One high-profile example is rimonabant, approved in Europe for weight control. Researchers are study- ing it not only for its anti-alcohol properties but also as a smoking-cessation drug.

How can a single drug work against different types of substance abuse? Because addictions of many kinds often make use of the same brain pathways. Although there is no single "addiction gene," research has shown that various forms of addiction may share genes as well as brain circuits.

By early this year, studies will reveal gene variants that increase vulnerability to nicotine and alcohol addiction. Those same genetic variations will probably appear in future studies of cocaine and opiate abuse—and lead to still more treatments. —*Tabitha M. Powledge* **Want To Win in 2007? Get Innovating Build a Flying Car**
In early August, competitors will put their small craft through a series of tests in the NASA-sponsored Personal Air Vehicle Challenge. The battle to develop tomorrow's flying car will be held in Santa Rosa, California. cafefoundation.org
Prize: $100,000

Run a Space Elevator
To win a piece of the purse in October's third annual Space Elevator Competition, your light-beam-powered "elevator" must climb 328 feet up a vertical cable at a speed of at least 6.6 feet per second—twice as fast and twice as high as in last year's event. spaceward.org
Prize: $500,000

Invent a Robo-Vehicle
Darpa has upped the stakes in its third Grand Challenge, to be held on November 3. Autonomous robot cars have only six hours to negotiate 60 miles of traffic- ridden mock city streets and carry out a simulated military supply mission. darpa.mil/grandchallenge
Prize: $2 million

Track an Asteroid
The Apophis Mission Design Challenge awards the team with the best plan for a mission to put a tracking device on or near the asteroid Apophis, which has a small probability of smashing into Earth in 2036. planetary.org
Prize: $50,000