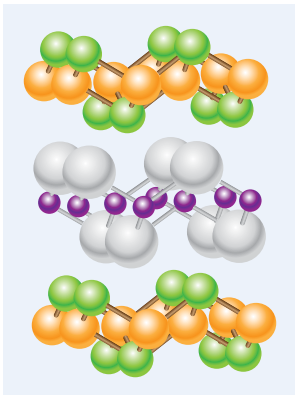
Breakthrough of the Year

New High-Temperature Superconductors

PHYSICISTS DISCOVERED A SECOND FAMILY OF HIGH-TEMPERATURE superconductors, materials that carry electricity without resistance at temperatures inexplicably far above absolute zero. The advance deepened the biggest mystery in condensed-matter physics.

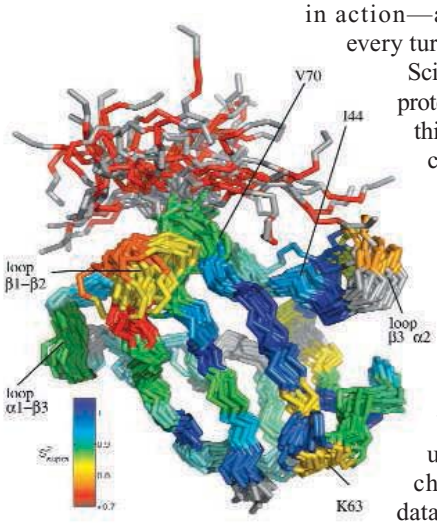
In February, a group in Japan reported the first material, fluorine-doped lanthanum iron arsenic oxide ($LaFeAsO_{(1-x)}F_x$), which is superconducting up to a "critical temperature" of 26 kelvin. Within 3 months, four groups in China had replaced the lanthanum with elements such as praseodymium and samarium and driven the temperature for resistance-free flow up to 55 kelvin. Others have since found compounds with different crystal structures and have bumped the critical temperature up to 56 kelvin.



For a critical temperature, that's not so hot. The record is 138 kelvin for members of the other family of high-temperature superconductors, the copper-and-oxygen, or "cuprate," compounds discovered in 1986. Still, the iron-based materials have created a stir, in part because they might help solve the enduring mystery of how the cuprates work. The $64,000 question is whether the two families work the same way. So far, evidence points in both directions.

Watching Proteins at Work

AFTER STUDYING PROTEINS FOR MORE THAN A CENTURY, BIOCHEMISTS pushed the boundaries of watching the molecules in action—and received surprises at every turn.



Scientists have long debated how proteins bind to their targets. Most think the shape of a target molecule forces a protein to wiggle into a complementary profile. But it's also possible that proteins in solution wiggle among many slightly different conformations until one finds its target. Computational biologists in Germany and the United States offered bold new support for that upstart idea when they crunched extensive experimental data and showed how one long-studied protein seems to dance among dozens of conformations. In another surprise, a U.S. team tracked individual proteins and found that a single random molecular event can switch a bacterial cell from one metabolic state to another.

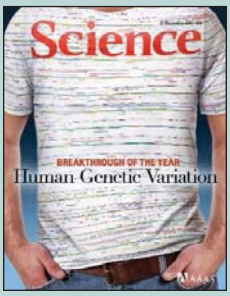
Zooming out to the large scale, proteomics researchers in Germany simultaneously monitored the abundance of up to 6000 proteins in yeast cells and quantified how the expression of individual proteins differed between two different cell types. Their technique could lead to new insights into development and disease. Finally, proteomics researchers in Sweden revealed that different tissues in the body likely get their unique characteristics by controlling not which proteins are expressed but how much of each gets made.

Water to Burn

RENEWABLE ENERGY SOURCES, SUCH AS WIND AND SOLAR POWER, have plenty going for them. They're abundant and carbon-free, and their prices are dropping. But they're part-timers. Even when the sun is shining and the wind is blowing, there is no good way to store excess electricity on an industrial scale. Researchers in the United States reported this year that they've developed a new catalyst that could begin to change that picture.

The catalyst, a mixture of cobalt and phosphorus, uses electricity to split water into hydrogen and oxygen. Hydrogen can then be burned or fed to fuel cells that recombine it with oxygen to produce electricity. Researchers have known for decades that precious metals such as platinum will split water. But platinum's rarity and high cost make it impractical for large-scale use. The cobalt version isn't all the way there yet, either—it still works too slowly for industrial use—but just getting a cheap and abundant metal to do the job is a key step. Now, if researchers can speed it up, on-again-off-again renewables could have a future as fuels that can be used anywhere at any time.

SCORECARD



Rating last year's Areas to Watch

(For this year's predictions, see page 1773.)

A smashing start

The Large Hadron Collider came on smoothly in just a few hours, in keeping with *Science*'s observation that the European particle physics lab, CERN, has a knack for getting new machines running quickly. Nine days later, the enormous particle smasher wrecked so bad that it will be down until summer, fulfilling *Science*'s warning that a mishap could take the machine out of action for months.

Micromanagers

MicroRNA work surged in 2008, as efforts to use the molecules to understand and modify disease edged forward. The first successful microRNA manipulation in primates lowered cholesterol in African green monkeys, and the molecules slowed virus replication in ailing mice. Companies are rushing to

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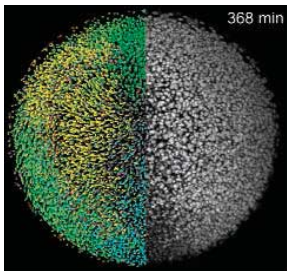
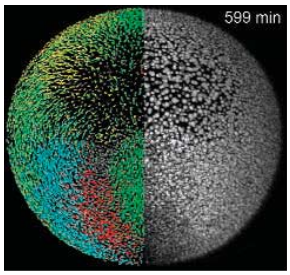
The Video Embryo

THE DANCE OF CELLS AS A FERTILIZED EGG BECOMES AN ORGANISM IS at the center of developmental biology. But most microscopes allow only partial glimpses of the process. This year, scientists observed the ballet in unprecedented detail, recording and analyzing movies that traced the movements of the roughly 16,000 cells that make up the zebrafish embryo by the end of its first day of development.

Researchers in Germany made the movies with a new microscope they designed. It uses a laser beam to scan through a living specimen, capturing real-time images and avoiding the bleaching and light damage that have usually limited such videos to just a few hours. The researchers then used massive computing power to analyze and visualize the recorded movements. They also ran the movies backward to trace the origin of cells that form specific tissues, such as the retina. A movie of a well-known mutant strain of fish revealed for the first time exactly what goes wrong as the embryo develops.

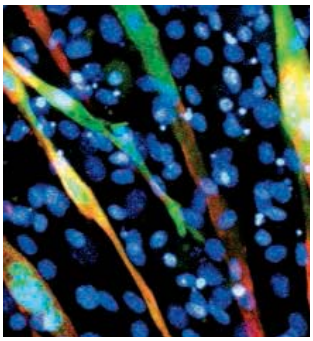




The zebrafish movies are freely available on the Internet, and the developers say they hope the Web site will develop into a full-blown virtual embryo—a sort of developmental biology YouTube with contributions from labs around the world.

Fat of a Different Color

THIS YEAR, RESEARCHERS FINALLY UNCOVERED the mysterious roots of so-called brown fat. Hardly blubber, the energy-using tissue turns out to be one step away from muscle.



Anatomists first noted the distinction between our two fat types more than 400 years ago. White fat is the energy-caching padding that vexes doctors and dieters. If white fat is a quilt, brown fat is an electric blanket. Thanks to plentiful mitochondria, it burns fat molecules to generate heat that warms the body.

Scientists long assumed that both fat varieties developed from the same kind of progenitor cell. Then a team led by U.S. scientists discovered that they could morph brown fat into muscle and vice versa. The researchers knew that the gene *PRDM16* spurs specialization of brown fat. So when they turned down *PRDM16* in brown-fat precursor cells, they expected white fat cells to result.

Instead, the cells stretched out into tube-shaped muscle cells that could even twitch. Reflecting their altered identity, the cells switched off a raft of genes characteristic of brown fat and switched on genes typical of muscle. Coercing cells that had already begun differentiating into muscle to fashion *PRDM16* triggered the reverse transformation, yielding brown fat. Using a technique called lineage tracing, the researchers identified the descendants of the muscle cell clan in mice. They included muscle and brown fat cells but not white fat cells.

The discoveries could mark a step toward antiobesity treatments that melt away bad white fat, either by firing up existing fat-burning brown cells in the body or by transplanting new ones.

develop microRNA-based therapies—but coaxing microRNAs to combat disease is slow going, and safety concerns remain.

Cell to order

Despite high hopes, humanmade microbes are not yet in reach. Researchers did customize cell-signaling circuits in live cells and are exploring new ways of building genomes from scratch. One research group synthesized an entire bacterial genome but has yet to incorporate it into a cell. And designing microbes to make biofuels remains a pipe dream.

Paleogenomics

It was a scramble to get enough sequence done, but a very rough genome of the Neandertal is almost in hand. Along the way, the sequencing team has obtained the complete sequence of Neandertal mitochondrial DNA, finding a few key differences between us and them. Two groups unraveled the mitochondrial genome of extinct cave bears. And sequencing 70% of the woolly mammoth genome prompted speculation about cloning this beast to bring it back to life.

Multiferroics

Multiple electronic, magnetic, and structural behaviors give these materials the potential to carry out both logic and memory functions, now handled separately by semiconductors and metals. Researchers reported steady improvements in performance. Novel multiferroics can change their stripes near room temperature and in low magnetic fields, both important developments for real-world applications. But progress remains muted in turning these materials into complex circuitry.

Megamicrobes

Metagenomics is in full swing, with several key surveys of microbial and viral diversity completed this year in environments as varied as microbial mats, subsurface ecosystems, and the mammalian gut. In addition, DNA sequences from nearly 200 genomes of bacteria associated with humans are finished, and hundreds more are in the pipeline. In October, groups from around the world formed the International Human Microbiome Consortium to study the role the human microbiome plays in health and disease.

New light on neural circuits

This year's Nobel Prize in chemistry honored scientists who turned a luminescent protein from jellyfish into a powerful tool for imaging cells. Building on that work, neuroscientists can now tag neurons with myriad colors to study their connections. And light-sensitive proteins from algae have made it possible to control neural firing with laser pulses. Such methods have great potential for unraveling the function of neural circuits. This year saw steady progress, and the bigger breakthroughs we predicted can't be far off.

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