THE RUNNERS-UP

2 THE LITTLEST HUMAN. Sometimes big discoveries come in small packages. In October, the startling news that a team of Indonesian and Australian researchers had found a new species of tiny hominid in a cave on the Indonesian island of Flores made headlines all over the world, and some researchers described it as the biggest discovery in half a century of anthropological research. If the team is right, the remains of *Homo floresiensis*, as the species was dubbed, suggest that modern humans shared Earth with other hominids as recently as 18,000 years ago. The skeleton's very small brain—a mere 380 cubic centimeters, compared with about 1400 cm^3 for *H. sapiens*—led its discoverers to hypothesize that it had evolved from an earlier population of *H. erectus* that got stuck on the island and then shrank in size to make maximum use of scarce resources.

Such "island dwarfism" is well known among other mammals—including small elephantlike creatures found in the same cave that the diminutive humans may have hunted with sophisticated stone tools. The discovery of *H. floresiensis* marks the first evidence that humans might also have been subject to drastic evolutionary pressure on islands. Many avenues of research suggest that throughout prehistory, humans followed the laws of evolution like any other creature, but this dramatic demonstration remains humbling for those of us who like to see ourselves as the masters of our own fates. Indeed, some skeptical researchers have found this claim of evolutionary downsizing too much to swallow and suggest that the Flores hominid is really a pathological microcephalic modern human.

Startlingly small. Diminutive Flores hominid stood only 1 meter tall.

Just how quickly the debate is resolved remains to be seen, because the best way to solve it—analyzing still-unpublished fragments of other hominids found in the cave—is now threatened by a fresh controversy over who has the right to study the tiny remains. But the discoverers of *H. floresiensis* predict that there are many other small hominids on the islands of Indonesia just waiting to be found.

Pioneer. Woo Suk Hwang created a stir in February with the news that he and his colleagues had produced cloned human embryos.

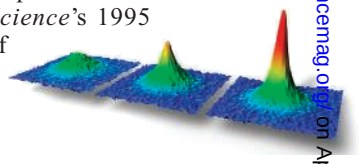
3 CLONE WARS. To tabloid readers, it might have sounded like old news, but the announcement by South Korean researchers that they had managed to produce a human embryo by nuclear transfer was the first scientific evidence that the technique could work with human cells. The researchers were not attempting to create a carbon-copy baby but rather to derive embryonic stem cell lines that could provide new insights into complex diseases or eventually produce replacement cells genetically matched to a patient.

Hundreds of mammals have been cloned since Dolly the sheep burst on the scene in 1997, but the psychological and political impact of the human work is still reverberating. It was the first evidence that cloning in primates is possible, contradicting earlier studies that had suggested that the location of cell-division proteins in primate eggs might thwart such attempts. Two factors were seminal: a gentler method of removing an egg's nucleus and a wealth of raw material. Sixteen young women donors provided 242 eggs for the project.

Eggs pose a key hurdle for those who hope to repeat the experiment. Several U.K.- and U.S.-based ethics boards have said scientists must rely on oocytes from failed in vitro fertilization attempts. Such eggs are scarcer and probably less robust than those freshly harvested from hormone-boosted ovaries.

The political impact of the work has been mixed. On 2 November, California voters, in part fueled by optimism sparked by the South Korean report, approved the creation of a $3 billion fund to support human nuclear transfer and embryonic stem cell work. But elsewhere, consensus has proved elusive. A United Nations debate over a worldwide ban on reproductive cloning ended in stalemate when countries that support the research could find no common ground with those that argue that all cloning research is immoral, in part because it creates embryos only to destroy them.

4 DÉJÀ CONDENSATES. It was another banner year for condensates, ultracold gases that display the signature of quantum mechanics writ large. The first condensates appeared in 1995, when researchers in the United States chilled a collection of atoms called bosons to the point at which they fell into a single quantum state, essentially behaving as one superatom. That achievement garnered *Science*'s 1995 Breakthrough of the Year. Over the past year, the condensate family tree has grown.



Howdy, partner. Signature of a fermi condensate.

Last December, physicists in the United States and Austria induced the other broad class of atoms, called fermions, to enter the realm of superatoms. To pull it off, the researchers had to induce fermions to behave like bosons. Bosons carry an internal angular momentum, or spin, with a whole-number value, a condition that allows them to share a single quantum state. But the spin of fermions is an integer plus one-half, which—thanks to the "exclusion principle" of quantum mechanics—prevents them from condensing, much as two negatively charged electrons repel one another when they get too close. The researchers wiggled their way around this inconvenience by inducing fermions to pair up into molecules with whole-number spin, which could condense just like bosons.

The discovery may shed light on one of the trickiest problems in physics: figuring out how electrons behave in complex materials, a key step toward a detailed description

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Areas to Watch in 2005

Recycling pays. It may be harder to pronounce than "apoptosis," but autophagy (self-eating) was on cell biologists' lips more and more this year. In autophagy, cells break down cytoplasmic molecules and portions of their membranes to provide nutrients during times of stress or starvation. After years in obscurity, the process has entered the limelight as scientists have identified genes driving it and used them to show that autophagy plays critical roles in cell growth and development, and even in disease. The momentum looks set to continue. A new journal, *Autophagy*, launches in January, and a Gordon Research Conference devoted to the area will be held in Italy in the spring.

Obesity drugs. As holiday meals once again lead people to vow to exercise more, biotech firms and pharmaceutical companies are racing to find a sweat-free alternative for our battle against obesity. More than 100 drugs targeting obesity are in the pipeline, and several should soon be submitted for Food and Drug Administration approval, especially since the agency has relaxed its guidelines to require only 1 year of safety data for such drugs. The most likely success story is rimonabant, which blocks the same brain receptors that marijuana tickles. Studies this year showed that it promotes long-term weight loss. As an added benefit, it may also curb the craving to smoke.

Big problem. Firms are racing to develop new drugs to help the growing number of obese people.

HapMapping along. The $100 million international Haplotype Map (HapMap) project is slated to wrap up toward the end of 2005—but it should bear fruit before then. The effort is developing maps built around haplotypes, shared stretches of DNA, in three populations: Utah residents with northern or western European ancestry; Chinese and Japanese; and Yoruban. Next year, the HapMap, along with a separate haplotype map assembled by the company Perlegen, may start to reveal the extent to which variation is involved in common human diseases and how DNA patterns shift across ethnicities. But the map's medical applications remain uncertain.

Cassini-Huygens at Saturn. The Huygens probe will likely make the biggest splash in planetary science in 2005, when it parachutes to the surface of Saturn's exotic, big moon Titan. Whether it will make an actual splash at the end of its 3-hour descent is anyone's guess. Cassini's haze-penetrating instruments have so far failed to find the postulated hydrocarbon seas, but Huygens should reveal the nature of the surface at one spot at least. The seven close Cassini flybys of Titan in the coming year could help clear up the mystery as well, but don't ignore the many upcoming Cassini passes by moons, rings, and Saturn itself.

Paper tigers. Are North Korea, Brazil, and Iran striving to develop nuclear arsenals? Conventional wisdom says yes, no, and maybe. Many analysts argue that North Korea's ultimate quest in six-way talks, expected to resume next year, is to bargain away its nuclear ambitions for economic aid and security guarantees. Brazil has barred inspectors from parts of its Resende facility, where it plans to enrich uranium for power reactors. Watchdogs are demanding more openness. After arduous negotiations with European officials, Iran last month agreed to suspend uranium enrichment while continuing to grow a nuclear power industry. In all three cases, the Treaty on the Non-proliferation of Nuclear Weapons has proven to be little more than a paper tiger; look for a revitalized campaign next year to strengthen the treaty.

European Research Council. This grassroots effort to create an agency to fund basic research across Europe gained political momentum in 2004. After endorsement by Europe's research ministers in November, it should take concrete shape in 2005. New European Union research commissioner Janez Potočnik has said he supports incorporating the idea into the Framework 7 funding program, which will begin in 2007.

Regulating nano. Nanotechnology is so broad that no single government agency is responsible for the field as a whole. So regulators in areas from consumer products, workers' health, and the environment are grappling with how best to ensure health and safety without stifling what is expected to be a major economic engine. Academic, legal, industrial, and government experts got a good start this year with meetings aimed at laying the groundwork for developing a standard nomenclature for the field and outlining the needs for research on nano's health and environmental risks. Progress should continue and broaden over the next year as countries strive to integrate their regulatory approaches.

of high-temperature superconductors. By tweaking their fermi condensates to vary the bonding strength between molecular partners, teams around the world systematically probed how their behavior changes as atoms grow farther apart. Already, such probing has revealed a key signature called a "pairing gap" similar to what is seen in high-temperature superconductors. Researchers also created the first supersolid, essentially a condensate in a solid. Because liquids had been condensed previously, researchers have now turned all three classes of matter—gases, liquids, and solids—into condensates.

5 HIDDEN DNA TREASURES. Biologists digging through the DNA between the genes and between a gene's protein-coding regions are unearthing new insights into how genomes work. Protein-coding sequences take up less than 10% of the human genome. The rest, previously considered a genetic wasteland, are proving quite influential for gene function. The wasteland is rich in genetic gems: short stretches of regulatory DNA, transposable elements (sequences that hop from one place to another), coding sequences that yield tiny RNA molecules, and so on.

By dissecting regulatory DNA, molecular biologists are learning about the exquisite controls that cause genes to turn on at the right time and in the right place. Short DNA sequences about 500 bases long, called activators, rev up gene expression by binding to regulatory proteins called transcription factors. Subtle differences in the arrangement of transcription factor binding sites cause gene activity to vary in different ways. Several reports this year have implicated activators as the source of genetic changes leading to the emergence of new species.

CREDIT: GETTY IMAGES

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Junk DNA is chock-full of transposable elements. New work shows that these elements, when present between the coding regions of genes, can slow or halt transcription. They also help make new genes by hopping into existing ones, thereby altering the protein code. One such event involved a key gene for nerve function.

Junk DNA also encodes RNA, already shown to affect gene expression through RNAi (RNA interference). In yeast genes, for example, geneticists discovered that RNAi can block the binding of proteins needed to activate a gene involved in making the amino acid serine.

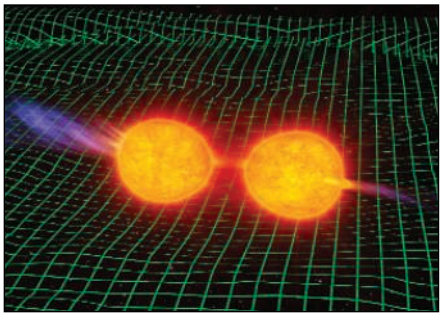
The quest to uncover more gems is revving up. The National Human Genome Research Institute has a new program, Encyclopedia of DNA Elements, that aims to capture and catalog all functional DNA within this "wasteland," starting first with 30 million bases of protein-coding and noncoding sequences.

6 PRIZED PULSAR PAIR. Astrophysicists doubled their pleasure this year by finding the first known binary system of pulsars: spinning neutron stars that whip tight beams of radiation into space. The system's properties have startled both observers and theorists, one of whom describes the discovery as a "watershed event" in the 36-year history of neutron star studies.

The pulsars turned up after the 64-meter Parkes radio telescope in Australia spotted an energetic pulsar, whirling 44 times every second, orbiting a hidden object that they presumed was a nonpulsing neutron star. Deeper scrutiny revealed that the companion also pulses at a leisurely rate of once every 2.8 seconds. But jaws dropped when the discovery team announced that the slower pulsar swoops almost directly in front of the faster one as they orbit in tandem, eclipsing the fast pulsar for nearly 30 seconds each orbit.

There's more. Blasts of particles and radiation from the fast pulsar distort the slow pulsar's magnetic field, making its radio signal flicker and nearly die out. Astrophysicists were thrilled because the eclipses and the complex interactions yield the first direct probe of the blazing plasmas in which pulsars turn on their mysterious beacons. Theorists sifting the clues say the intense wind of charged gas streaming from the fast pulsar may be nearly a million times denser than expected.

Researchers also expect the pulsar pair to provide the most stringent examination yet of Einstein's general theory of relativity. If any deviations from Einstein's theory exist, they are most likely to arise within the superstrong gravity of a neutron star or black hole. Astrophysicists are gauging the pulsars' motions as they gradually spiral inward toward an inevitable crash 85 million



Collision course. The first known pair of closely orbiting pulsars will merge in 85 million years.

CREDITS (TOP TO BOTTOM): TIM SMITH; LAURENT REBOURS/ASSOCIATED PRESS; JOHN ROWE ANIMATION

Breakdown of the Year: The Unwritten Contract

For more than a half-century, U.S. academic scientists have thrived on a tacit promise from the federal government to support their research in return for working toward the public good and training the next generation of scientists and engineers. Relationships between the government and scientists have occasionally been strained, especially when budgets have been tight, but in general the system has operated in a relatively civil manner. And it has worked well enough for other countries to try to copy, with mixed success.

But in 2004 that social compact took a beating. Groups of researchers accused the Bush Administration of undermining the scientific advisory system and of putting ideology before science in a number of issues from global warming to stem cell research. That elicited a strong rebuttal from the president's science adviser John Marburger, who dismissed a letter from 60 Nobel laureates criticizing the Administration's science policies as "complaints from the Democrats."

The United States wasn't alone in witnessing this breakdown of comity. In France and Italy, researchers staged a yearlong series of protests against what they viewed as attempts to undermine the scientific enterprise, from budget cuts to the proposed elimination of tenure. Across Europe and Asia, scientists felt the sting of activists denouncing work on genetically modified crops or research involving animals. And back in the United States, educators continued to battle antievolutionists seeking to influence science instruction in public schools across the country.

Sign of the times. The unhappy message displayed on a poster of Nobelist Marie Curie—"They are getting crazy, let's rescue research"—during a Paris street protest earlier this year reflects a growing tension between researchers around the world and their governments' science policies.

The scientific community bears some of the blame for this breakdown. The letter writers' overt sympathies for the Democratic nominee, Senator John Kerry, made them vulnerable to countercharges that they were also putting politics and ideology before science. The well-documented sclerosis within the French and Italian research establishment is largely self-induced and can't be cured with slogans and street demonstrations. And when a scientific issue rose to the level of a national debate, as in the controversy over the use of embryonic stem cells in research, the tendency of scientists to view their critics as biomedical Luddites left little room for compromise.

Ironically, politicians have long urged scientists to become more active in the policy arena. But this year was a reminder that there are risks involved, too. As Congress and the Administration look for ways to trim spending next year, scientists will need more friends in high places. And that means finding ways to make peace, not war, with the powers that be.

–JEFFREY MERVIS

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Avian Influenza: Catastrophe Waiting in the Wings?

It's still primarily a bird disease, known to have killed only 32 humans since January. But H5N1, the avian influenza strain that swept across eastern Asia in 2004, killing millions of poultry, has cast a darker cloud over human health than numbers alone can explain. Experts fear that the virus could spawn a new influenza pandemic—a public health disaster of potentially devastating proportions. As Asian farmers saw their livelihoods destroyed this year, scientists made one worrisome discovery after another about the virus, and public health authorities around the globe began to take the risk seriously—only to discover that, should a pandemic erupt tomorrow, the world would be pathetically ill prepared.

Early this year, some believed that the outbreak, which started late 2003, might still be contained by mass culling of infected and exposed birds. This strategy worked well during the first known H5N1 outbreak, in Hong Kong in 1997, and the 2003 explosion in the Netherlands of H7N7, another bird flu strain. That hope is now gone; the virus is too entrenched and the affected area too large for eradication to be feasible. Researchers also discovered that ducks, which often mingle with chickens on small Asian farms, can harbor and shed large amounts of the virus without getting sick, perhaps creating an important, almost intractable reservoir.

The realization that H5N1 is here to stay has led to several shifts in strategy. One is the growing acceptance of the idea of protecting flocks through vaccination. Traditionally, animal health experts have preferred to stamp out bird flu, as they do for many viral diseases, because vaccination can enable the virus to continue circulating below the radar screen and ignite new outbreaks; it can also lead to costly export restrictions. But vaccination has now been added to the armory of weapons to fight H5N1 in several countries.

Bye bye bird. Despite massive poultry culling, the H5N1 flu strain seems here to stay.

With respect to human health, H5N1's long-term presence has put the risk of a new pandemic—a phenomenon unseen for 36 years—on the scientific and political agenda. Pandemics arise when new flu strains, to which nobody is immune, evolve ways to replicate easily among humans. In theory, this can happen with any number of strains, but the sheer scale of transmission has now made H5N1 a prime candidate. Adding to the concerns is H5N1's unusually broad host range (it has been shown to infect mice, cats, and tigers, for instance), its high mortality rate among known human victims, and one apparent case of human-to-human transmission in Thailand.

Nobody knows how likely a pandemic is or what its consequences would be. Past experience offers little to go on; pandemics in 1957 and 1968 were relatively mild, whereas experts put the death toll for the "Spanish flu" of 1918–19 at anywhere between 20 million and 100 million. (The world's population was less than 1.9 billion at the time.)

The World Health Organization is urging countries to draw up plans for how to cope, and some—mostly in the developed world—have begun to do so. But the challenges are enormous. A new vaccine would take many months to develop and mass-produce, and most countries don't have that capacity. (Even production of the annual flu vaccine is fragile; a glitch at a British plant almost halved the U.S. supply this year, creating instant shortages and chaotic situations.) Antiviral drugs could help bridge the first months. But few countries are stockpiling them, and many could never afford that option.

Experts say 2004 may well prove to be a pivotal year: one in which the danger multiplied and the world woke up. Time will tell whether it slumbered for too long.

–MARTIN ENSERINK

years from now. These measures—aided by the ultraprecise clocks of the pulsars themselves—may reveal the density and distribution of matter within a neutron star for the first time.

7 DOCUMENTING DIVERSITY DECLINES. From frogs to butterflies, ecologists and environmentalists outdid themselves this year in quantifying peaks and valleys in biodiversity. Disturbing news has come from large studies that show real declines in species richness.

Five hundred herpetologists completed the first global assessment of amphibians, and the news was not good. At workshops hosted by Conservation International and the World Conservation Union, researchers presented data on all 5700 known amphibian species. They concluded that more than 30% were vulnerable to extinction, and some were critically endangered. Half these species might disappear over the next century, victims of overharvesting, loss of habitat, and unknown causes.

Going, going ... This leopard frog is losing ground.

Naturalists who have tracked butterflies, plants, and birds in the United Kingdom for up to 40 years also turned up sobering statistics. Annual surveys in 10-kilometer quadrants showed that on average butterflies had disappeared from 13% of the squares. Researchers calculated that 71% of butterfly species had lost ground. Systematic counts of bird species in the U.K. showed that their numbers had dropped by half.

That work also found that 28% of the native plant species had disappeared from at least one square. Another U.K. study took a systematic look at grasslands growing on nutrient-poor soils. It revealed that species richness drops as the deposition of inorganic nitrogen—a product of industrial processes—increases. In some cases, the number of species declined by 23%.

Diversity data far beyond the British Isles came from a compilation of 40 ecological studies. Lasting 2 to 5 decades, these efforts turned up 20 places where warming had changed the natural history of those areas. For example, red foxes are showing up north of their territory, barging in on Arctic foxes. Plants are flowering earlier. Birds are changing their migration habits and settling in places where food supplies have already peaked.

Bottom line: Biodiversity continues to be in trouble.

CREDITS (TOP TO BOTTOM): USGS; DOAN BAO CHAU/ASSOCIATED PRESS

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8 SPLISH, SPLASH. After a century of intense scientific study, water still gives researchers much to scratch their heads about. This year, a flurry of papers on the structure and chemical behavior of this familiar substance revealed results that, if they hold up, could reshape fields from chemistry to atmospheric sciences.

First and most controversial, a team of researchers from the United States, Germany, Sweden, and the Netherlands reported that the 100-year-old picture of the structure of liquid water might be wrong. Theorists thought slight charge differences between oxygen and hydrogen atoms pulled liquid water into an extended network, with each water molecule bound to four others in a tetrahedral pattern. But the team's synchrotron x-ray results suggest that many water molecules are, in fact, bound to only two neighbors. Don't rewrite the chemistry textbooks just yet: More-recent x-ray data back up the original structure, and debate will likely rage through 2005.

Another dispute centers on where ions in a large body of water hang out. Do they reside at the surface or get sucked into the interior? Conventional wisdom says electrostatic forces at the water's surface repel ions that are abundant in seawater, forcing them to go deep. But researchers tracking sea salt particles in the air over Los Angeles say the particles are so rich in halides (chemical relatives of fluorine) that those ions must be present on the water's surface. This year, computer simulations supported the idea. If true, atmospheric scientists may have to ponder new types of chemical reactions occurring on the surface of aerosol particles.

New experimental techniques are solving other mysteries. In April, a team in California reported that firing femtosecond bursts of electrons at water on a silicon surface had revealed crystallite-like ice structures that help bind water to the surface. And other groups used improved methods for making and tracking water clusters to determine how electrons and protons dissolve in water, providing new insights into aqueous chemistry. At this rate, water researchers won't be swimming in circles 100 years hence.

All wet? Synchrotron x-ray results have researchers rethinking the structure of water.

9 HEALTHY PARTNERSHIPS. A revolution in public health is fundamentally shifting the way medicines are developed and delivered to the world's poorest people. The traditional patchwork of aid givers—foundations, rich countries, various branches of the United Nations, academics, pharmaceutical companies, and charities—have joined forces in myriad joint ventures.

This year, such "public-private partnerships" were behind several headline-making developments, including a promising malaria vaccine trial in Mozambique and the stepped-up efforts to provide anti-HIV drugs to the world's poor. "It's pretty interesting to see how much different it is from 10, 15 years ago," says epidemiologist Roy Widdus, who started the Initiative on Public-Private Partnerships for Health in Geneva, Switzerland. "It really is dramatic."

Widdus dates the movement to the mid-1990s and the formation of the International AIDS Vaccine Initiative (IAVI), which links academics and vaccine manufacturers to develop products for poor countries. His group has identified 91 other health-related public-private partnerships. Roughly 20 of them follow IAVI's lead in developing products that may provide new preventives and treatments for everything from HIV/AIDS, malaria, and tuberculosis to the more obscure tropical diseases. For example, drugmaker Novartis and the Singapore Economic Development Board this year opened the Novartis Institute for Tropical Diseases, which hopes to develop novel drugs for dengue fever and drug-resistant tuberculosis.

Other partnerships aim to improve access to existing medicines. The largest—the Global Fund to Fight AIDS, Tuberculosis, and Malaria—has committed $3 billion to 128 countries since 2002. Widdus estimates that the Bill and Melinda Gates Foundation funds about 75% of the partnerships.

The boom could go bust, however, if the partnerships don't remain accountable, transparent, and productive. "These are 20-year jobs," says Widdus. "Funders and donors change, and they're going to have to reeducate people every couple years and convince them to keep public-private partnerships fashionable items. And if they don't keep funders like Gates going, they're going to be in serious trouble."

10 GENES, GENES EVERYWHERE. It sounds too good to be true: Take water from the ocean or from deep underground, find the DNA in it, sequence the genes, and use them to identify the organisms that live there. Ecologists and evolutionary biologists have tapped such molecular techniques to study the genetic relationships of species they can't grow in the lab. Now ambitious genome sequencers are isolating whole genomes instead of single genes. The genomes provide not only clues about an organism's identity but also a glimpse of how a particular species survives. The work is also turning up thousands of new genes.

One team of biologists sailed across the Sargasso Sea, deciphering genomes from life in 1500 liters of water samples. They turned up more than 1 million new genes. To compensate for the Sargasso's paucity of phosphorus, its denizens had evolved many genes for taking up this mineral. Furthermore, many species are using rhodopsin pigment in lieu of chlorophyll to process carbon. The researchers are now retracing Charles Darwin's voyage on the *Beagle* to explore diversity around the globe.

Another team of environmental genomicists has focused on a small, bizarre microbial community more than a kilometer down, inside an abandoned mine. The organisms thrive without light and instead get their energy by processing iron compounds. DNA in water on the mine floor yielded just five genomes, and the repertoire of enzymes found in each of the five microbes indicated that they had a close relationship, depending on one another to survive in those harsh conditions. With this community's composition in hand, researchers are now tackling a more complex community. They are sampling soil on a farm with the goal of defining the microbial biota there.

Down deep. DNA studies revealed a mine's tight-knit microbial community.

–THE NEWS STAFF

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The Runners-Up

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