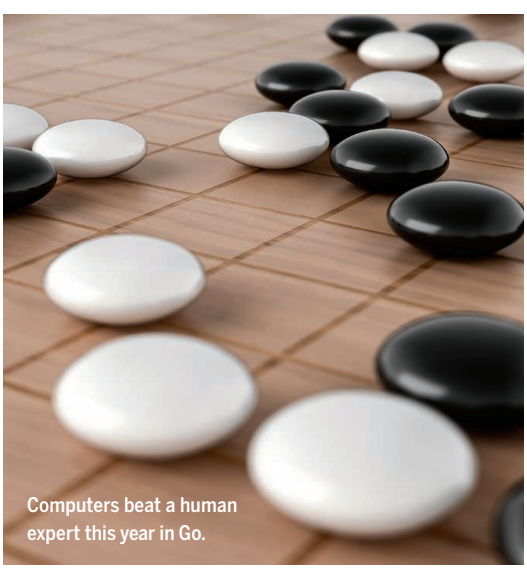
The exoplanet next door

Astronomers have found a small planet around the very closest star, Proxima Centauri. They are hailing the new world as our best opportunity to study in detail a planet outside our solar system, and are already straining to find out what it is like.

Tiny shifts in the frequency of Proxima Centauri's light revealed the planet, dubbed Proxima b. Astronomers monitoring the star detected a periodic increase and decrease in frequency every 11.2 days, caused by Doppler shifts in the light as the unseen planet repeatedly tugged the star toward and away from us. We don't yet know much about Proxima b except that it's at least 1.3 times the mass of Earth and orbits very close to its star—just 5% of the distance between Earth and the sun. That doesn't mean it's blisteringly hot. Because the star is a dim red dwarf, astronomers think the planet's surface may even be cool enough for liquid water to exist. But habitability is a long shot: Proxima Centauri is an unruly star that probably blasts the planet with a fierce solar wind, x-rays, and ultraviolet light.

Astronomers have been watching to see whether Proxima b passes in front of its star. If it does, the resulting dip in the star's brightness could reveal the planet's radius—which, combined with mass, gives its density—and starlight passing through its atmosphere could tell us what it's made of. But simple geometry makes such a "transit" unlikely—only a 1.5% chance—and searches so far have drawn a blank.

Scientists must now wait for better space- and ground-based telescopes planned for the next decade. But others are impatient: In April, the privately funded Breakthrough Starshot project announced plans to send a fleet of tiny spacecraft on a 20-year journey across the 40 trillion kilometers to the Alpha Centauri star system, which includes Proxima Centauri, and another private effort called Project Blue hopes to build a space telescope specifically to take pictures of planets in Alpha Centauri. —*Daniel Clery*



Computers beat a human expert this year in Go.

Artificial intelligence ups its game

This year, artificial intelligence (AI) passed a significant milestone when a computer program called AlphaGo beat the world's No. 2 Go player in a five-game match. It's not the first time that AI has surpassed human mastery of a game. After all, it was 20 years ago that IBM's Deep Blue first beat Garry Kasparov in a game of chess, toppling the world champion the following year in a six-game match. But that is where the similarity ends.

The rules of Go are more straightforward than those of chess: You simply place identical stones on a grid, capturing territory by surrounding your opponent's positions. But that simplicity and openness result in an explosion in the number of possible moves for a player to consider—far more than there are atoms in the known universe. That makes it impossible for AI to beat Go masters with an approach like that used by Deep Blue, which relies on hand-coded strategies from chess experts to evaluate each possible move.

Instead, AlphaGo, designed by the London-based Google subsidiary DeepMind, studied hundreds of thousands of online Go games played between humans, using those sequences of moves as data for a machine-

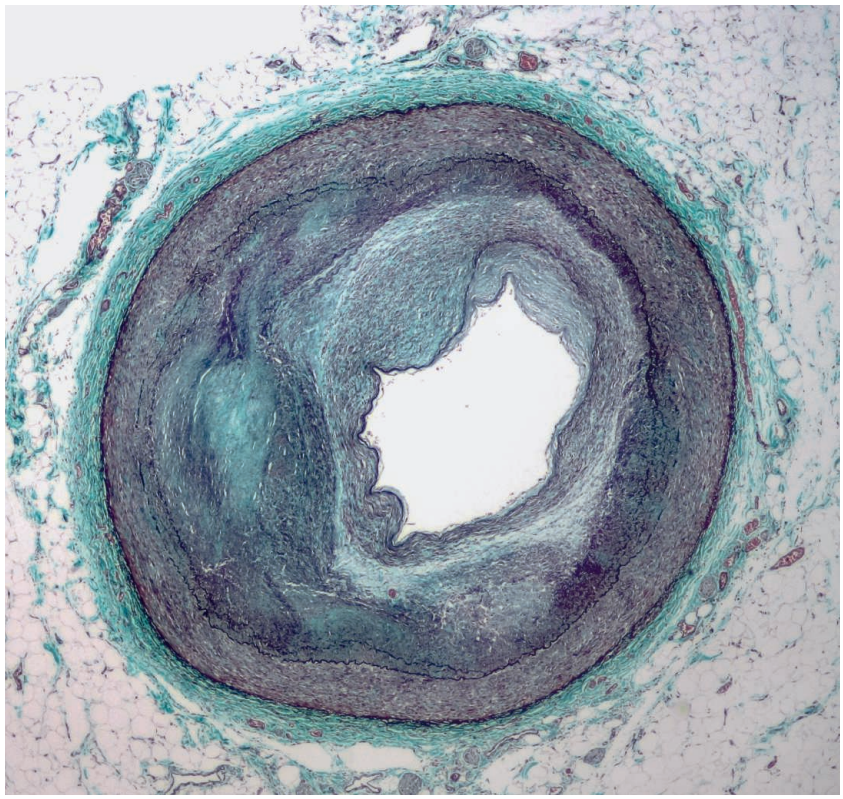
PHOTOS: (TOP TO BOTTOM) ESO/M. KORNMESSER; FPM/ISTOCK PHOTO

An artist's concept of Proxima b orbiting the red dwarf Proxima Centauri.

learning algorithm. Then AlphaGo played against itself—or, rather, slightly different versions of itself—over and over, fine-tuning its strategies with a technique called deep reinforcement learning. The final result is AI that wins not just with brute-force calculation, but with something that looks strikingly like human intuition.

Most of the things we want AI to master involve a seemingly unmanageable number of possible decisions—walking a robot safely through a crowded room, routing driverless cars, making small talk with passengers. Because hard-coded rules fail for such tasks, AlphaGo's triumph shows just how powerful deep reinforcement learning can be. —*John Bohannon*

PHOTO: NEPHRON/CREATIVE COMMONS



Removing worn-out cells might delay the buildup of artery-clogging plaques.

5 Killing old cells to stay young

Pricey plastic surgery won't stop you from getting old. Nor will dietary supplements, testosterone injections, or those wrinkle creams that imply they'll make you look 21 again. But this year, researchers demonstrated one way to postpone some ravages of time—at least in mice. When they selectively weeded out run-down cells, the animals lived longer and remained healthier as they aged.

The infirm cells the scientists targeted had undergone a partial shutdown known as senescence, in which they lose the ability to divide. Researchers think senescence may prevent worn-out, cancer-prone cells from initiating tumors, but it may also promote aging. As we grow older, more and more cells stop reproducing, potentially robbing our tissues of the ability to replace dead or injured cells. Senescent cells also discharge molecules that can cause problems such as abnormal cell growth and inflammation.

The first study showing that eliminating senescent cells can produce health and longevity benefits, at least in middle-aged mice, came out in February. Deterioration of the animals' hearts and kidneys slowed, and they didn't sprout tumors until later in their lives. Some age-related declines, such as in memory and muscle coordination, didn't abate. Nonetheless, the rodents outlived their contemporaries by more than 20%.

In October, the same research team took aim at senescent cells from the immune system that amass in artery-clogging plaques and may drive their formation. Removing these cells from mice that are prone to atherosclerosis reduced the amount of fatty buildup in the animals' arteries by 60%, even though the rodents gorged on fat-laden food.

The multibillion-dollar question: Will taking out senescent cells help humans stay young longer? Both studies used genetically modified mice that clear away their senescent cells in response to a particular compound—a technique that isn't feasible in humans. But researchers have created several so-called senolytic drugs that slay senescent cells without genetic tinkering. Next year, scientists will launch the first clinical trial of one of those drugs in people who have arthritis. –*Mitch Leslie*

Chimpanzees, bonobos, and orangutans have a skill thought to be uniquely human.

Mind-reading great apes

Great apes demonstrated a mind-reading skill this year that only humans were thought to fully possess. Known as theory of mind, it is the ability to discern desires, intentions, and knowledge in others. Some tests had shown that our close relatives have enough insight to, for example, deceive a fellow ape or recognize another's motives. But until now, they had always failed in tasks that require the ability to determine when others hold a false belief.

In the classic false belief experiment, a child watches someone hide a chocolate bar in a box and leave the room. Then someone else sneaks in and hides the candy elsewhere. Where will the first person look for it? Children who guess "in the original box" pass the test: Through what amounts to mind reading, they realize the first person holds a false belief. This skill is thought to be essential to deceiving, empathizing, teaching, and perhaps even to using language.

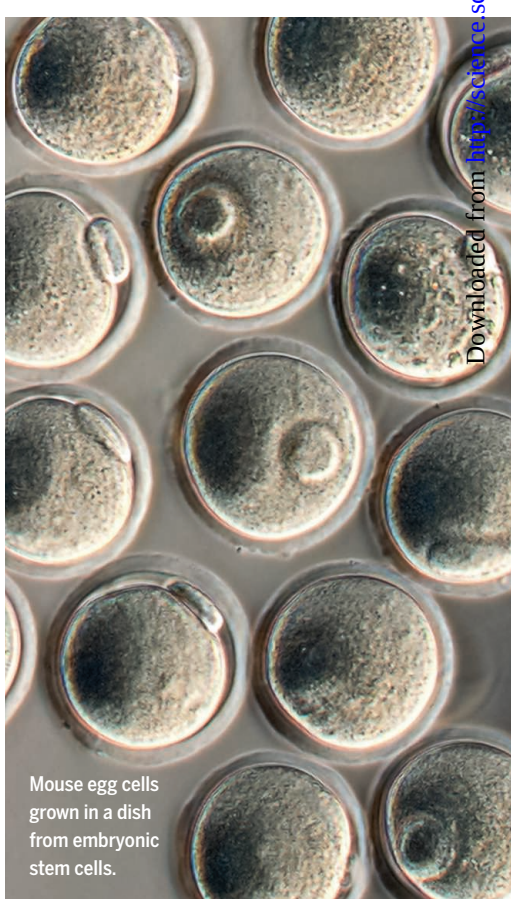
This year, researchers conducted a version of the test on chimpanzees, bonobos, and orangutans. The apes watched a film showing a King Kong–like figure steal a rock from a man and hide it in one of two boxes. The man witnesses this action, but runs away when the Kong figure threatens him. While he is gone, Kong leaves with the rock. When the man returns, where will he search for it?

The researchers used infrared eye-tracking technology to see where the apes focused their attention. Almost all looked at the box where the man erroneously believes that his rock is hidden. Not everyone is yet convinced, but follow-up studies are likely to be in the works—and not just on great apes. The eye-tracking method can be adapted to other animals' faces.
–Virginia Morell

Proteins by design

Proteins are life's workhorses. They speed up vital chemical reactions, enable muscles to tug, carry out communication between and within cells, and defend against invaders. Given proteins' talents, researchers have long wanted to create their own versions. They have modified many existing proteins by making small tweaks to an organism's DNA code, but this year, they took protein modification to a whole new level: They created a suite of designer proteins unlike anything found in nature, setting the stage for novel medicines and materials.

Designing new proteins from scratch has been a hit-or-miss activity. It's easy enough to write any desired DNA code, but researchers have had no way of knowing how the novel strings of amino acids encoded by this DNA would fold into complex 3D shapes. That's a problem, because for proteins, shape dictates function. Recently, however, computational biologists have made heady progress in designing computer programs that

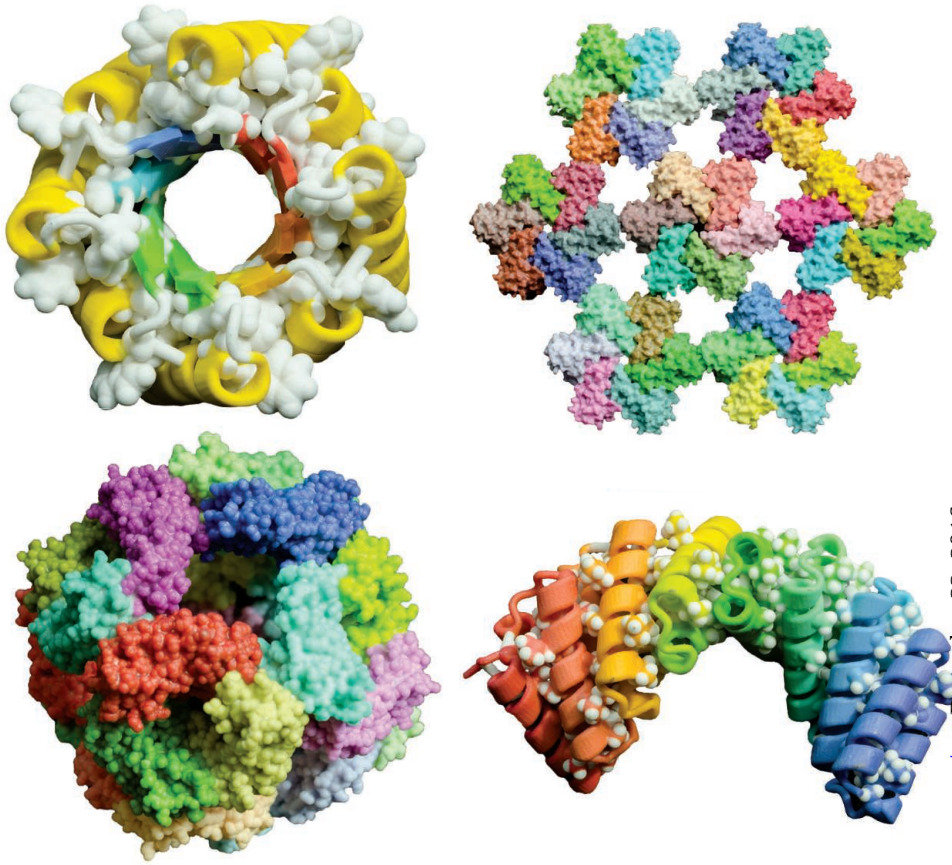


Mouse egg cells grown in a dish from embryonic stem cells.

accurately predict how designer proteins will fold. Those advances made possible this year's surge in designer proteins.

In February, a team led by researchers in Washington state used one such program to design what may become a universal flu vaccine, able to spark immune defenses to all flu strains simultaneously. In July, a team that included many of the same researchers created proteins that self-assemble into hollow cages, which someday could be filled with drugs or snippets of DNA to treat a range of diseases. Another team used a similar program to produce 3D, folded RNA molecules, which present a folding problem similar to proteins, as well as RNA-protein complexes, opening up new research possibilities.

Now, researchers want to use their skills to create everything from novel biosensors to new ways to remove carbon dioxide from the atmosphere. And because life makes only a tiny fraction of all possible proteins, protein designers have a vast new territory to explore. –*Robert F. Service*



Novel proteins, built using computer programs to predict how their amino acid strings will fold, are unlike anything produced in nature.

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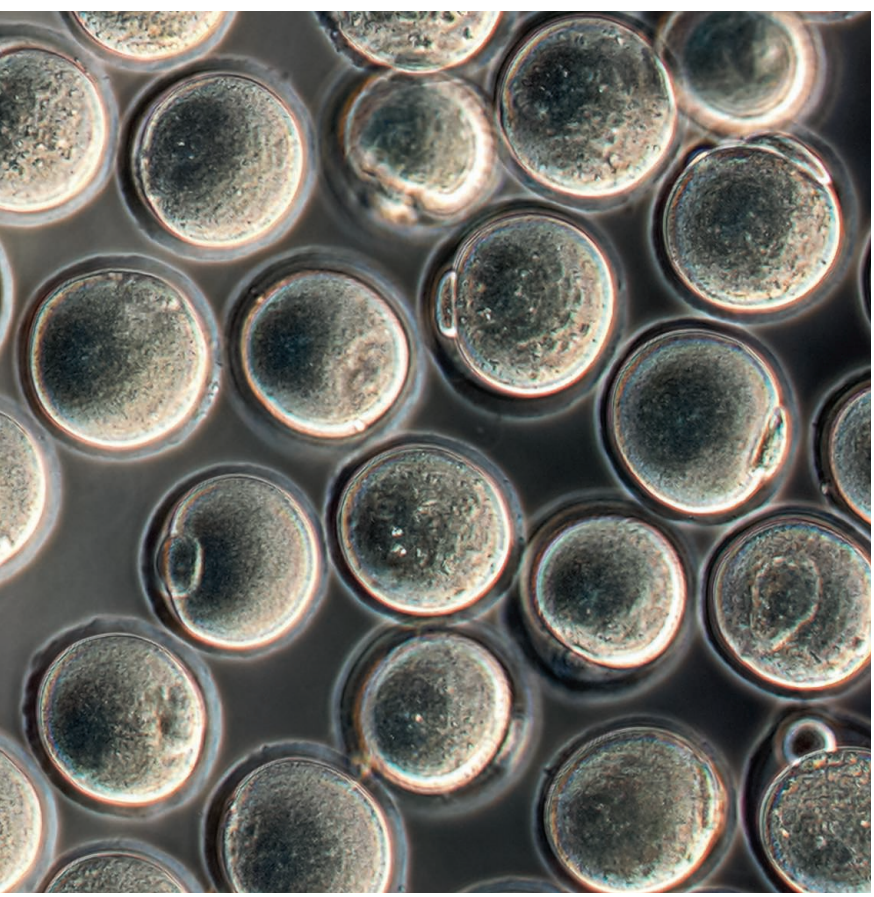


Mouse eggs made in the lab

Giving new meaning to the term "test-tube babies," this year, researchers in Japan produced mouse pups from egg cells grown entirely in a lab dish. This long-sought achievement offers researchers a new way to study egg development and raises the more distant prospect of making human eggs in the lab from almost any type of cell, including genetically altered ones. That possibility has sparked hope for new infertility treatments, but it has also revived fears about designer babies.

In 2012, the same researchers took the first key step: They made fertile egg cells from stem cells. However, that method still required that the immature eggs be implanted back into a living mouse to complete their development. This year, researchers found a way to produce eggs entirely in the lab. Instead of implanting the immature eggs into a mouse, they cultured them inside clusters of cells taken from fetal mouse ovaries. The team then mixed the lab-grown eggs with mouse sperm and implanted the resulting embryos into foster mothers. Only 3% grew into full-term pups, but those pups grew into fertile, apparently healthy adults.

If scientists could perform a similar feat with human stem cells, it could lead to new options for some cases of female infertility. It may even be possible to turn stem cells derived from a man into eggs. Such possibilities are a long way from reality, but the ability to study egg development as it unfolds in a dish could produce insights that will have an impact in the clinic long before any human baby is born from a lab-grown egg. –*Gretchen Vogel*

Genomes from 83 Australian Aborigines showed that Australia was initially settled only once, not twice, as some had suggested.

A single wave of migration from Africa peopled the globe

The story of our species is driven by wanderlust. Born in Africa, *Homo sapiens* expanded into the far corners of the globe in the past 100,000 years, meeting and mingling with more archaic hominins already living there. But researchers have long debated how and when modern humans left Africa: Was it in a single migration or in repeated waves?

In 2016, a burst of genomic data all but clinched the case that most living people outside Africa descend from a single migration; any earlier migrations were mostly swamped by this last wave. In a trio of studies, researchers worked with aboriginal groups to collect and analyze hundreds of genomes from people living in far-flung corners of the world, including previously scarce samples from Australia, Papua New Guinea, and Africa. They tracked the ancient branching of populations recorded in the DNA.

One study analyzed 83 genomes from Australia, long considered a place apart. The DNA showed that, in contrast to previous suggestions, Australia was initially settled only once. Moreover, the ancestors of Aborigines and Eurasians split from Africans around the same time, possibly about 70,000 years ago, suggesting a single exodus from Africa before the split. An independent study analyzing 300 genomes from 142 populations also reported a single wave out of Africa, which diverged into all living non-Africans starting perhaps 50,000 years ago, although the dates are imprecise.

The third study, which analyzed 379 genomes from 125 populations, reported mostly this same pattern, with a wrinkle: About 2% of the genome of Papua New Guineans may stem from a separate, earlier migration out of Africa, perhaps 100,000 years ago. Fossils show that some modern humans had made it to the Middle East by about this time, and a trail of stone tools in Arabia and India hints at such an early exodus. But the flood of new genomic data indicates that this earlier migration died out almost completely, leaving at most a trace in some living people. —*Elizabeth Culotta*

Genome sequencing in the hand and bush

Genome sequencing may be on the verge of becoming a ubiquitous tool in biology, both in the lab and—perhaps more important—in the field, thanks to a handheld device that became widely available for the first time this year. It is already generating scores of research papers.

The device uses a breakthrough technology called nanopore sequencing to read the letters of DNA directly: As a strand of DNA passes through a narrow pore, the bases alter an ionic current in a unique, readable way. The big advantages over traditional sequencing are that the startup cost for a nanopore sequencer is relatively low and it can, in theory, decipher unlimited lengths of DNA; the genome doesn't have to be chopped up and the sequences pieced together later by a computer. And because it's quick and portable—the device can churn out sequences in a matter of hours—it can potentially be used for biosurveillance, clinical diagnosis, and the investigation of disease outbreaks onsite.

Nanopore sequencing has been under development for years, and after more than a year of beta testing, a U.K.-based company, Oxford Nanopore Technologies, began marketing the first device this year. More than 30 papers based on the device are already on the biology preprint site bioRxiv. Researchers have identified Ebola and other viruses in just a few hours, sequenced microbes in the gut, deciphered the 53-million-base genome of a fungal pest of maize, and, as they announced earlier this month, sequenced a human genome. Even astronauts on the International Space Station used it to sequence a mixture of microbes in soil. Longtimers in the field point out that few of these advances have been documented in peer-reviewed publications, but others see this year as a turning point for a sequencing approach that is capturing the imagination of researchers who never considered genomic studies to be within their reach. –*Elizabeth Pennisi*

3

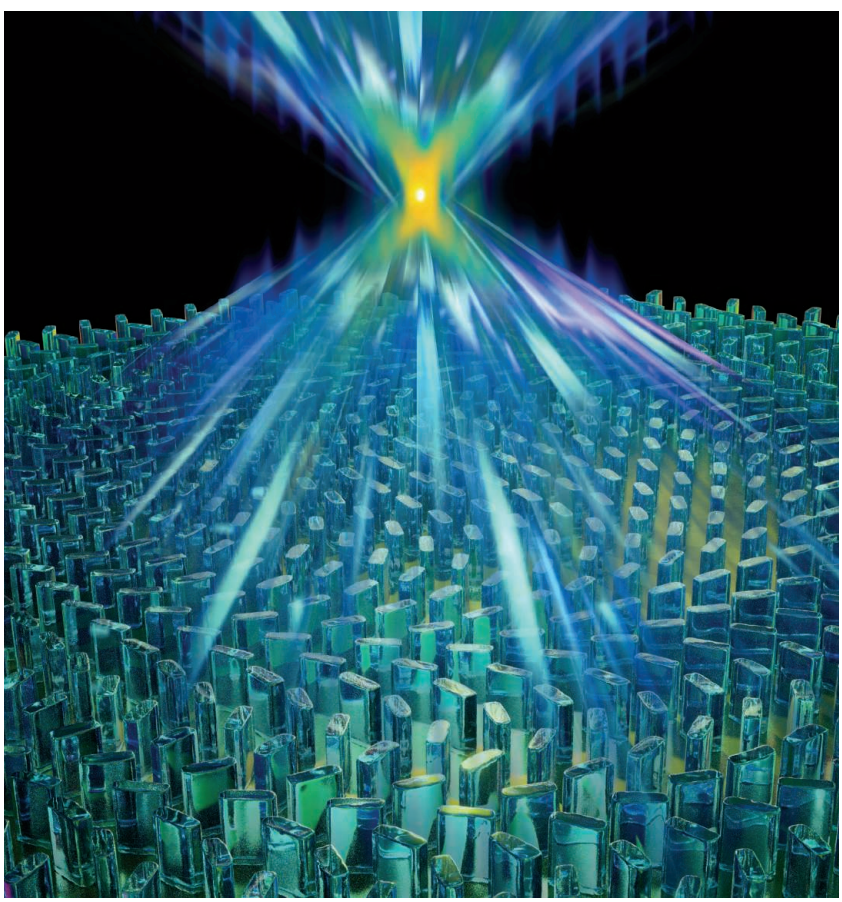
PHOTO: © IMAGEBROKER/ALAMY

Metalenses, megapromise

Glass lenses were one of humanity's earliest high-tech innovations. They enabled Galileo to see Jupiter's moons, Antonie van Leeuwenhoek to spy microbes, and millions of people to just plain see clearly. But lenses are still made roughly the same way as they were centuries ago—by grinding and polishing glass and other transparent materials so that they focus light without aberration. Now, lens technology is poised to take a major leap. This year, researchers used computer chip–patterning techniques to create the first metamaterial lens, or metalens, that can focus the full spectrum of visible light. Because metalenses are cheap to produce, thinner than a sheet of paper, and far lighter than glass, they could revolutionize everything from microscopes to virtual reality displays to cameras—including the ones in your smartphone.

Metamaterials are composed of arrays of tiny pillars, rings, and other arrangements of materials, which work together to manipulate light waves as they pass by. In recent years, researchers have designed metamaterial-based "invisibility shields" that steer light around objects, as well as light filters and antennas. But previous efforts to make metalenses succeeded only with infrared and other long wavelengths of light; the patterning techniques didn't work as well with materials transparent to visible light.

This year, researchers figured out how to use a conventional chip-patterning technique, known as atomic layer deposition, to precisely pattern arrays of pillars of titanium dioxide. Just 600 nanometers high, the pillars are transparent to visible light, and they can focus it to produce a magnification of up to 170 times—as good as state-of-the-art-glass optics. The team tested its metalens techniques by using them to make holograms and carry out detailed spectroscopy, opening the way for other potential applications. Watch for the high-tech optics to make cellphones even sleeker, lead to new scientific instruments, and transform virtual reality headsets.
—Robert F. Service



PHOTOS: (LEFT TO RIGHT) SECOND BAY STUDIOS; DARKO VRCAN/ALAMY STOCK PHOTO

Light passing upward through a metalens is focused by nanoscale fins.

Scorecard for 2016

Last year, *Science*'s writers and editors picked three areas we considered ripe for new discoveries. How prescient were we? Our self-evaluations (the box scores) are mixed. Predictions for 2017 are on p. 1524.

WHO LET THE DOGS IN?

Last year, we predicted that 2016 might finally be the year we figure out where dogs came from. Scientists have fiercely debated whether our canine pals evolved from wolves in Europe or in Asia, and a new international collaboration of researchers promised to solve the mystery once and for all. We don't have an answer yet, but a study published this year suggests both sides of the debate might be right: Dogs may have been domesticated twice, once in Asia and once in Europe or the Near East.

FALLING BODIES

We recommended keeping an eye on a satellite called MicroSCOPE, which is testing whether two free-falling objects made of different materials accelerate at the same rate under Earth's gravity. Galileo supposedly tested that equivalence by dropping balls from the Leaning Tower of Pisa in Italy, and it is a cornerstone of Einstein's theory of gravity, general relativity. MicroSCOPE was launched successfully on 25 April, testing was completed this month, and researchers have begun an 18-month data run. Keep watching.

GRAVITATIONAL WAVES

It was a fairly safe bet a year ago when we made gravitational waves an area to watch for 2016. The Laser Interferometer Gravitational-Wave Observatory (LIGO) had recently undergone a major upgrade, physicists were sifting through early data, and rumors were swirling that they had detected ripples in spacetime: gravitational waves. Indeed, they had. LIGO has spotted two events so far, and many more are expected from LIGO and other planned detectors. These achievements earned our pick as *Science*'s Breakthrough of the Year.

The runners-up
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Editor's Summary

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