НАРОДНА УКРАЇНСЬКА АКАДЕМІЯ

ПРАКТИКУМ
З НАУКОВО-ТЕХНІЧНОГО ПЕРЕКЛАДУ
(АНГЛІЙСЬКА МОВА)

Видавництво НУА

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Навчальний посібник
для студентів IV курсу
факультету «Референт-перекладач»

Харків
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П69 **Практикум** з науково-технічного перекладу (англійська мова) : навч. посібник для студентів 4 курсу фак. «Референт-перекладач» / Нар. укр. акад., [каф. теорії та практики пер. ; упоряд. Д. А. Авксентьєва]. – Харків : Вид-во НУА, 2018. – 53 с.

Навчальний посібник розроблено на матеріалах англійських та американських наукових журналів та електронних видань. Посібник розраховано для аудиторної та самостійної роботи студентів 4 курсу з метою формування та закріплення вмінь та навичок перекладу науково-технічної літератури з англійської мови рідною, а також систематизацію, повторення і розширення лексичного мінімуму, необхідного для читання, розуміння та перекладу науково-технічних текстів.

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Preface

Даний методичний посібник розрахований для навчання студентів IV курсу факультету «Референт-перекладач» та розраховано на 34 аудиторні години та 22 години самостійної роботи

Практикум з науково-технічного перекладу має на меті допомогти майбутнім перекладачам у формуванні навичок перекладу оригінальної науково-технічної літератури, роботи зі спеціалізованими словниками, перекладу складних граматичних конструкцій і термінології. Окрім цього, переклад аутентичних тексів сприятиме розвитку мовної думки та інтуїції, вмінню за контекстом визначити та передавати зміст лексичних одиниць.

Здатність орієнтуватися в сучасному інформаційному середовищі, отримувати, обробляти та передавати інформацію, взяту з аутентичних джерел є одним з основних факторів, що забезпечують успішну та ефективну професійну діяльність сучасного спеціаліста.

Посібник складається з 4 уроків за такими темами:

- **Energy and environment**
- **Technologies**
- **Atom and cosmos**
- **Cells and genes**

Тексти з зазначених тем дозволять студентам ознайомитися зі стилем сучасної науково-технічної літератури, а також покращити навички перекладу. Підбір текстів виконано з урахуванням знань англійської мови, отриманими студентами протягом попередніх років навчання на факультеті «Референт-перекладач».

UNIT 1. ENERGY AND ENVIRONMENT

Vocabulary 1

abundance	різноманіття
carbon atoms	атоми вугецю
carbon isotopes	ізотопи вуглецю
contamination	забруднення
elevated traces of tritium	високий вміст залишку тритію
fossil groundwater	ґрунтова вода
hydrogeologist	гідрогеолог
pesticides	пестециди
pollution	забруднення
radioactive hydrogen isotope	радіоактивний ізотоп водню
susceptible	сприйнятливий, уразливий
tritium level	рівень тритію
underground aquifers	підземний водоносний пласт
vulnerable	уразливий

'Fossil' groundwater is not immune to modern-day pollution

Deep well study finds contamination in at least 12,000-year-old water
by Thomas Sumner

Groundwater that has lingered in Earth's depths for more than 12,000 years is surprisingly vulnerable to modern pollution from human activities. Once in place, that pollution could stick around for thousands of years, researchers report online April 25 in *Nature Geoscience*. Scientists previously assumed such deep waters were largely immune to contamination from the surface.

"We can't just drill deep and expect to run away from contaminants on the land surface," says Scott Jasechko, a study coauthor and water resources scientist at the University of Calgary in Canada.

Groundwater quenches the thirst of billions of people worldwide and accounts for roughly 40 percent of the water used in agriculture. Water percolating from the surface into underground aquifers can carry pollutants such as pesticides and salt along for the ride.

Jasechko and colleagues weren't looking for contamination when they tested water from 6,455 water wells around the world. Their goal was to use carbon dating to identify how much of that deep water was "fossil" groundwater formed more than 12,000 years ago. Previous studies had looked at average water age, rather than the age of its individual components.

While there's no C in H_2O, carbon dating can still be used to date groundwater by examining the carbon dissolved in the water. Radioactive carbon atoms decay as the water ages. After around 12,000 years, only stable carbon isotopes remain. Comparing the relative abundance of these carbon isotopes in the various wells, the researchers discovered that over half of wells more than 250 meters deep yielded mostly groundwater at least 12,000 years old. How much older is unknown. Worldwide, the researchers estimate that fossil groundwater accounts for 42 to 85 percent of water in the top kilometer of Earth's crust.

In a second measurement, the researchers looked for a common modern pollutant. They found that around half of wells containing mostly fossil groundwater had elevated traces of tritium, a radioactive hydrogen isotope spread during nuclear bomb tests that's hazardous in very high concentrations. While the tritium levels weren't dangerous, its presence suggests that at least some groundwater in the wells postdates the 1950s nuclear testing. That relatively young water may introduce other contaminants in addition to tritium, the researchers say.

How new groundwater enters deep wells is still unclear, Jasechko says. Old and young waters could mix within an aquifer or, alternatively, the construction and use of the well itself could churn the waters together.

No matter where the young water comes from, the new technique for identifying the percentage of fossil groundwater in a well could be an important tool for communities, says Audrey Sawyer, a hydrogeologist at Ohio State University in Columbus. The study raises awareness that even in wells with mostly older water "a fraction of that same water can be pretty young and susceptible to contamination," she says.

Vocabulary 2

airplane emissions	викиди літаків
carbon footprint	«слід» вуглецю (викид діоксиду вуглецю в атмосферу)
carbon pollution	забруднення (навколишнього середовища) вуглецем
economic obstacles	економічні бар'єри
prototype plane	модель літака
mechanical engineering	машинобудування

New Airplane Design Could Reduce Greenhouse Gas Emissions

A new airplane design could save up to 66 percent in fuel and fly by 2035

Airplane emissions are a big problem for the climate—and steadily rising. If the aviation sector were a country, it would rank seventh worldwide in carbon pollution. Experts predict that aircraft emissions, on their current trajectory, will triple by 2050 as demand for flights increases. To prevent this dire scenario, a team of scientists at the Massachusetts Institute of Technology, along with government and industry collaborators, is attempting to fundamentally redesign airplanes.

Their concept, dubbed the "double-bubble" D8, could significantly reduce aviation's carbon footprint and improve fuel efficiency if validated in full-scale tests. It entails major changes to the standard 180-passenger Boeing 737 and Airbus A320 aircraft—for example, the fuselage has a wider, more oval shape than a conventional jet. "It's like two bubbles [joined] side by side," explains Alejandra

Uranga, an assistant professor of aerospace and mechanical engineering now at the University of Southern California. This modification lets the fuselage itself generate some lift, says Uranga, who is a co-principal investigator for the project, alongside Edward Greitzer of M.I.T. The altered body shape allows the wings and tail to be smaller and lighter, and the aircraft's nose is also more aerodynamic.

The most significant change, though, is the engine position. Air slows down as it flows over the top of a conventional plane, thereby creating drag and making the craft less efficient. But the D8 design moves the jet's engines from their usual spot underneath the wings to atop the plane's body, by the tail—where they suck in and reaccelerate the slow layer of air, greatly reducing drag.

These alterations would make the aircraft use 37 percent less fuel than a typical passenger jet, Uranga says. The project's chief engineer Mark Drela, Uranga, Greitzer and their collaborators at M.I.T., NASA, Aurora Flight Sciences and Pratt & Whitney have already built and tested an 11th-scale model of the aircraft in a NASA wind tunnel. Combining the new design with future technological advances could further reduce fuel use and ultimately add up to 66 percent in fuel savings in two decades, Uranga says.

Other experts note that the D8's developers must still overcome economic obstacles while ensuring that the engines are robust enough to handle the new configuration. Still, “it's a very compelling idea and design,” says Brian J. German, an aerospace engineer at the Georgia Institute of Technology, who was not involved in the work. Aurora is now exploring the development of a half-scale prototype plane. If the effort succeeds, travelers may fly in one of these jets as soon as 2035.

Vocabulary 3

atmospheric pressure	атмосферний тиск
carbon emissions	викиди вуглецю
long-term strategies	довгострокові стратегії
renewable energy	відновлювана енергія
renewable investments	інвестиції у відновлювану енергію
climate trajectory	траєкторія (змін) клімату
solar radiation	сонячне випромінювання
wind energy resources	ресурси вітряної енергії
wind turbines	вітряний генератор

Wind Turbines May Turn Slower in a Warmer World

Changes in global temperatures could affect air flow around the planet

Global warming could be causing long-term shifts in the generation of wind energy.

New research published yesterday in the journal *Nature Geoscience* suggests that future climate change might cause wind resources to decline across the Northern Hemisphere. These losses could be tempered by increases in wind power potential south of the equator, under severe climate change scenarios.

The findings don't disqualify wind as a competitive source of renewable energy, cautioned lead study author Kristopher Karnauskas of the University of Colorado, Boulder. But they do suggest that energy planners should take the future climate into account when creating long-term strategies for renewables. "On a local level, I think this [study] can provide some important information in terms of planning and allocating resources, where to build new wind farms relative to other locations, or deferred maintenance—which ones to service next if you have finite financial resources," he told E&E. "And ultimately it's a recognition that the baseline wind energy resource can't be considered a constant."

It's already known that climate change can affect global wind patterns. One reason winds exist is because certain parts of the planet receive differing levels of solar radiation. The result is varying levels of atmospheric pressure around the globe, which affects the way air flows from one place to another.

So scientists are well-aware that changes in global temperatures—particularly when those changes are occurring faster in some regions, like the Arctic, than in others—may affect the flow of air around the planet. And these changes could have a big impact on the amount of power wind turbines are able to produce from the air flowing around them.

Some studies have previously investigated the issue on a small scale, using individual models or looking at specific regions of the Earth. But according to the authors, the new study is one of the first to examine the issue from a global scale, using an ensemble of different climate models.

The researchers investigated two potential future climate scenarios—a severe climate trajectory, in which average global temperatures could rise by more than 5 degrees Celsius by the end of the century, and a more moderate climate scenario, somewhat closer to what could be achieved by the global commitments made through the Paris climate agreement.

Under both scenarios, wind energy resources declined across the Northern Hemisphere. The changes varied by location—for example, in the central U.S., the study suggested wind power reductions of 8 to 10 percent by the year 2050. Other parts of the Northern Hemisphere could see declines as high as 40 percent by the end of the century.

On the other hand, some increases in wind energy resources were projected for the Southern Hemisphere, which could help to offset the decreases in the North—but only under the more severe climate change scenario.

"That irony was not lost on me when I saw the results that we were getting for the first time," Karnauskas said. "It looks like you get some sliver of good news on the higher-emissions scenario."

But he added that even under this trajectory, the increases in the Southern Hemisphere would be unlikely to totally counter the declines in the Northern Hemisphere.

"The Southern Hemisphere is not where most of the built-out wind farms are and not where most of the consumption is," he said.

According to Daniel Kammen, an expert on energy policy at the University of California, Berkeley, who was not involved with the research, the study reinforces similar findings described by other papers. The results, he said, embody "a disturbing but entirely expected consequence of climate change."

But it's not all bad news either.

The projected declines in the Northern Hemisphere are "not trivial," according to Karnauskas, but certainly not enough to deter decisionmakers from the continued expansion of wind energy. Rather, the study suggests that planners should pay more attention to future climate projections when deciding where to place wind farms and how to balance the portfolio of different renewables—including solar or hydroelectric power—in different regions around the world.

"Wind power should still be considered an important part of the portfolio of renewable investments, as part of the broader strategy to reduce carbon emissions and so forth," Karnauskas said. "And as renewables, including wind, are a part of the strategy, it's just important to make sure we fully understand how the potential efficacy of that strategy may be changing concurrently with the problem itself."

Vocabulary 4

erupt	викидати
fault zone	зона розлому (зона порушення суцільності гірських порід)
geochemistry	геохімія
geodynamics	геоднаміка
hydrothermal fluid	гідротермальна рідина
mud volcano	грязьовий вулкан
natural gas	природній газ
subsurface plumbing system	підповерхнева система паливопроводів
trigger	ініціювати, ставати причиною
volcanic origin	вулканічне походження

Scientists Unearth Revealing Details about the World's Biggest Mud Volcano

In May 2006 boiling mud, gas, water and rock started gushing out of the ground in northeastern Java, one of the islands in the Indonesian archipelago. The massive mud volcano—nicknamed "Lusi"—has continued to spew its hot contents even today, more than 11 years later. Experts say Lusi is the largest mud volcano in the world, now covering seven square kilometers of land. Since 2006 Lusi has dislocated some 60,000 people and caused more than $4 billion in economic damages.

Mud volcanoes are not actual volcanoes—their temperatures are much cooler, and they erupt a mix of rock, clay and mud rather than lava. Some say Lusi is a combination of these two systems, although others debate this. In fact, Lusi remains a mystery to scientists in many ways. One of the biggest and most contentious questions about Lusi concerns what triggered the eruptions: an earthquake or natural gas drilling? Now, in a new study, researchers have imaged the subsurface plumbing system of Lusi. Their work reveals that—regardless of what triggered the eruption—Lusi likely connects at deep depths to a nearby volcanic system.

Several studies had already analyzed the geochemistry of the materials bursting from Lusi. They showed its innards had a volcanic origin, says Adriano Mazzini, a geoscientist at the Center for Earth Evolution and Dynamics at the University of Oslo in Norway. "We could already infer that somehow Lusi and a neighboring volcanic complex are connected at depth," he says. "What we were missing was a real image of the subsurface that could visually prove this connection between the two." For the new study, published in October in the *Journal of Geophysical Research: Solid Earth*, Mazzini and his team installed a large network of seismometers in three areas: Lusi; the volcanic system; and a tectonic fault zone spanning the two. The group then collected 10 months of data from the seismometers and used that information to piece together a picture of the subsurface across these locations.

Their reconstructed image revealed Lusi and the adjacent volcanic system are indeed physically joined via the fault zone. The scientists also discovered hydrothermal fluids—which originate in the volcanic system and feed Lusi—likely migrated vertically from at least six kilometers below the surface. This would mean that, technically, Lusi is not really a straightforward mud volcano. Rather, it is a hybrid structure—half hydrothermal system, half mud volcano.

This strange combination of geologic phenomena formed the hot mud eruption of Lusi, Mazzini says. "If you inject very hot fluids—hydrothermal fluids—into [an area] with sediments rich in organic matter, you're basically baking this organic matter at very high temperatures. It's like putting a cake in the oven," he says. "This will produce [immense] pressure in the subsurface. And at some point, this system will want to come up to the surface. This is what happened with Lusi."

Some experts who were not part of the research are skeptical about the team's findings. "I think some of their conclusions are stronger than they can probably justify," says Michael Manga, a professor of earth and planetary sciences at the University of California, Berkeley. "But it's an important study because it provides constraints on what's happening underneath the volcanoes as well as the mud eruptions."

Richard Davies, a professor of geology at Newcastle University in England, goes further. "I fundamentally disagree with [the researchers'] interpretation," Davies says, noting that he and Mazzini differ over what triggered the eruption—an earthquake or gas drilling. Davies thinks drilling accidentally caused a huge influx of fluid into a bore hole—the pressure from all that fluid would have become so intense that it fractured surrounding rock, and ultimately resulted in an eruption.

But Stephen Miller, a professor of geodynamics at the University of Neuchâtel in Switzerland, thinks the study's findings fall in line with what previous research has discovered. “The evidence from the beginning was that this is a natural system,” he says. “This [study] further confirms this is connected—a hydraulic link and thermal link to the volcano.”

The argument over what triggered Lusi has simmered since the eruptions began. Although it might seem like an esoteric scientific debate, there is actually a lot at stake. If drilling set off the eruptions, then the oil and gas company would likely be blamed for the destruction Lusi has caused. The Indonesian government already told the company that it must compensate citizens harmed by the disaster, according to *The New York Times*.

Mazzini says his study does not—and was not intended—to resolve this fierce debate over the trigger. “From my point of view, it is entirely irrelevant if this was triggered by an earthquake or drilling—this system was prepared naturally, by long and complex geological processes,” he says. “The trigger itself is a very short event, compared to all the rest that happened before. So this eruption would have happened anyhow at some point.”

The team’s research may not only help geologists decipher the Lusi mud eruptions today—it could also help them better understand ancient natural disasters. Earth has experienced enormous, widespread volcanic eruptions in the past, and these may have caused several mass extinctions. Mazzini notes that in addition to the pure volcanic activity, the geologic record seems to show the planet also had hybrid vents very similar to Lusi, if not identical. But instead of just one, there may have been thousands of them—and they would have released volumes of poisonous gases to the surface, possibly helping drive mass extinction. “Of course, all these systems don’t exist anymore today,” he says. “But we were looking for a modern analogue to understand what happened in the past.” And now they have Lusi.

Vocabulary 5

computer simulation	машине моделювання
core-mantle boundary	межа між ядром та мантією
incarnation	грануляція
magma plume	магматичний викид
mantle circulation	циркуляція (розповсюдження) магми
remnants	залишки
seismic tomography	сейсмотомографія
seismologist	сейсмолог

A sinking, melting ancient tectonic plate may fuel Yellowstone’s supervolcano

Computer simulations suggest that a core-deep plume of magma isn’t needed to power the massive eruptions by Carolyn Gramling

The driving force behind Yellowstone’s long and explosive volcanic history may not be as deep as once thought. A new study suggests that instead of a plume of hot mantle that extends down to Earth’s core, the real culprit is a subducting tectonic plate that began sinking beneath North America hundreds of millions of years ago.

Computer simulations show that movement of broken-up remnants of the ancient Farallon Plate could be stirring the mantle in a way that fuels Yellowstone, researchers report December 18 in *Nature Geoscience*. “The fit is so good,” says study coauthor Lijun Liu, a geodynamicist at the University of Illinois at Urbana-Champaign.

The giant supervolcano now beneath Yellowstone National Park, located mostly in Wyoming, has a 17-million-year history — much of it on the move. In that time, the locus of volcanism has moved northeastward from southwestern Idaho to its current location, where it most recently explosively erupted about 640,000 years ago. These shifting eruptions have created a track of volcanic craters resembling those created by the hot spot that formed the Hawaiian island chain. As a result, scientists have long suspected that a deep plume of magma originating from the core-mantle boundary, similar to the one that fuels Hawaii’s volcanoes, is the source of Yellowstone’s fury.

But the nature of the Yellowstone plume has been the subject of debate. “Usually with plumes, we can trace them to the core-mantle boundary,” says Robert Porritt, a seismologist at the University of Texas at Austin, who was not involved in the new work. To “see” Earth’s structure, seismologists use a technique called seismic tomography, which maps the interior using seismic waves generated by earthquakes. Particularly hot or liquid parts of the mantle slow some seismic waves known as shear waves. Tomographic images of mantle plumes such as the one beneath Hawaii show a low-velocity region that extends all the way down to the boundary between mantle and core, about 2,900 kilometers below Earth’s surface. Such deep plumes are thought to be necessary to provide sufficient heat for the volcanism.

“But at Yellowstone, we don’t have that large low-shear velocity thing at the core-mantle boundary,” Porritt says. Current images suggest a region of low-velocity material extending at least 1,000 kilometers deep — but whether there is a deeper plume is uncertain.

And the region is tectonically complex. About 200 million years ago, a tectonic plate to the west, known as the Farallon Plate, began to slide eastward beneath the North American Plate. The current Juan de Fuca Plate off the Pacific Northwest coast, one of the last remnants of the Farallon Plate, continues to slide beneath the western United States. Some researchers have suggested that, instead of a deep mantle plume, the flexing and melting of the subducting Juan de Fuca Plate are responsible for Yellowstone’s volcanism.

Liu and his colleagues have yet another idea. In 2016, Liu published research suggesting that the sinking ancient Farallon slab was acting like a lid on a deep mantle plume, preventing the plume from rising to the surface (*SN Online: 2/3/16*). “But we kept in mind that the problem was not solved,” Liu says. “The heat source [for Yellowstone] was still missing.”

The researchers created a sophisticated, supercomputer-driven series of simulations to try to find the best scenario that matches the three known knowns: the current tomographic images of the subsurface beneath the western United States; the volcanic history at Yellowstone as well as in the nearby Basin and Range regions; and the movements of the subducting slab since about 20 million years ago.

Yellowstone's volcanism is linked not just to the currently subducting young Juan de Fuca Plate, but also to the remnants of its older incarnation, the Farallon Plate, the simulations suggest. Those remnants have continued to slide deeper and now lie beneath the eastern United States. This downward dive dragged hot mantle eastward along with it. As the Juan de Fuca Plate began to break up beneath the western United States, the hot mantle rose through the cracks. Some of that hot mantle circulated back to the west across the top of the Juan de Fuca Plate, fueling volcanism in the Basin and Range region. And some of it flowed eastward, adding heat to Yellowstone's fire. The study doesn't rule out the presence of a deep magma plume, but it suggests that such a plume plays little role in Yellowstone's volcanism.

Porritt says he's intrigued by the idea that the sinking Farallon slab beneath the central and eastern United States could be driving mantle circulation on such a large scale. However, he says, he isn't convinced that the authors have truly solved the larger mystery of Yellowstone's volcanism — or that a yet-to-be-found deep plume still isn't playing a major role. "It's an interesting debate that's going to be raging, hopefully for decades."

Vocabulary 6

alternative fuels	альтернативні види палива
dry-cask storage	зберігання у сухих контейнерах
greenhouse-emissions-free power	відсутність викидів парникових газів
light water reactors	реактори на легкій воді
molten salt reactor	Рідинно-сольовий реактор
nuclear energy	ядерна енергія
nuclear industry	ядерна промисловість
nuclear physicist	фізик-ядерник
radiation leak	витік радіації
radio-active fuel	радіоактивне паливо
turbine-spinning steam	пара, що обертає турбіну

Why can't we decide what to do about nuclear energy?

Build them up? Or tear them down? By Mary Beth Griggs January 8, 2018

Within sight of the sunbathers at Old Man's surf spot, 55 miles north of San Diego, California, loom a pair of 176-foot-tall orbs. They're a strange backdrop, home of the San Onofre Nuclear Generating Station. Since its first reactor fired up in 1968, the plant has powered millions of lives. But now these concrete and steel domes house a problem. Inside their frames sit millions of pounds of radio-active fuel no longer of use to anyone.

In 2012, a small radiation leak forced the shutdown of one reactor. Rather than go through the regulatory red-tape of restarting the remaining reactor at reduced power, Southern California Edison, the operator, decided to shutter the whole plant. This year, workers will begin dismantling it as part of the costliest and biggest nuclear decommissioning project ever attempted in the U.S. The initial deactivation should take 10 years, with 700,000 metric tons of infrastructure crushed and freighted off to burial plots in Utah, Texas, and Arizona. The most radioactive stuff—3.2 million pounds of spent nuclear waste, including uranium-235—will be interred on-site in steel-and-concrete casks that will dot the landscape like tombstones.

It's a fitting metaphor for what seems like the beginning of the end of America's nuclear-energy ambitions. San Onofre is one of 19 nuclear power plants in the U.S. undergoing decommissioning. Of the 99 remaining reactors in the U.S. fleet, as much as one-third might be taken offline within a decade or two. Some might apply for an extension. But many could close for good thanks to three things that are killing off nuclear energy worldwide: competition from cheap natural gas, the rising affordability of wind and solar generation, and fear of radiation-spewing accidents.

"The nuclear industry is pretty broken in the United States," says Armond Cohen, executive director of the nonprofit Clean Air Task Force, which advocates for low-carbon energies to combat climate change. Cost overruns and delays have hamstrung the few nuclear power plants that were under construction, in South Carolina and Georgia. Even if that weren't the case, nuclear today makes no economic sense, Cohen says. "You could build the most cost-effective reactor in the world, and it wouldn't beat the cost of a combined cycle natural gas plant.*"

It's not just the U.S. industry. A number of other nations are dimming the lights on their nuclear plants. Germany, where eight reactors supply 13 percent of the country's power, has vowed to shut them all by 2022. Switzerland pledged to phase out its five reactors, which provide 40 percent of its energy. And France, which gets 75 percent of its energy from nuclear, vowed to slash consumption to 50 percent by 2025, only to back off that promise in November, worried that a shift from carbon-zero nuclear would prevent it from meeting its climate-change goals and lead to an electricity shortfall.

And yet a handful of other nations are accelerating toward a nuclear future. China, in trying to reduce its expanding reliance on coal, is aggressively pushing for more alternative fuels, with plans to increase its nuclear capacity to as much as 150 gigawatts by 2030, up from about 38 gigawatts in 2017. It is adding 20 new reactors to its current fleet of 37. Russia is building seven, India six, and South Korea three.

China, in particular, is pursuing novel reactor designs expected to run more cheaply, efficiently, and safely than those the world has used for decades. The most common today is the light water reactor, in which water cools solid nuclear fuel and generates turbine-spinning steam. Alternatives include a variation on the light water reactor called a small modular reactor that, in theory, could be built quickly and inexpensively, though its design will put out less energy. Another is a molten salt reactor that employs melted salts to cool fuel and produces less waste than the current fleet.

Critics warn that the U.S. is giving up on a reliable energy source and leaving itself vulnerable to strategic threats.

As the U.S. retreats from nuclear power, critics warn it is giving up on a source of electricity that is reliable and emits zero carbon, a boon to any nation looking to trade some of its fossil-fuel habit for clean power. Former Obama energy secretary and nuclear physicist Ernest Moniz cautioned as much this past July. At a summit on energy and security, he said abandoning nuclear would leave the nation vulnerable to environmental and strategic threats, by sidelining a greenhouse-emissions-free power and by weakening national-security interests: A brain drain of nuclear engineers and technicians to nuclear-hungry countries is sure to follow.

The historic irony is not subtle. The U.S. ignited the nuclear age, aided by scientists originally from nations such as Germany, Hungary, and Italy. After it demonstrated the horrific power of nuclear energy on Japan in World War II, the U.S. military and commercial researchers looked for ways to exploit the technology. An early success: nuclear powered submarines that could travel underwater almost indefinitely. The sub's reactor design quickly became the basis for the light water reactors we use today. The problem is the uranium in a number of those reactor designs operate at high temperature, requiring a massive amount of water to keep from overheating. If anything—for instance, a natural disaster—disrupts the plant's safety system, the reactor core can melt down, releasing radiation into the environment.

A Cold War nuclear boom saw hundreds of light water reactors spread across the U.S. and Europe. As they proliferated, public fears grew alongside them, and by the 1970s, movies like The China Syndrome evoked the horrors of what might happen if something went wrong. Weeks after that movie's release in 1979, it did. A partial meltdown on March 28 at Three Mile Island, near Harrisburg, Pennsylvania, rattled the nation. In 1986, an explosion at a plant in Chernobyl, Russia, and its subsequent radiation contamination of 90,000 square miles galvanized public opinion. Finally, in 2011, a 9.0 magnitude earthquake and tsunami triggered a series of events that led to a core meltdown in three reactors at Fukushima, Japan. This history of rare yet dramatic accidents was enough to sway public sentiment, but the availability of cheap natural gas made the choice easy. Much of the world that once embraced nuclear is now dealing with hundreds of silenced reactors and with cleaning up thousands of acres dotted with steel and concrete hulks and spent fuel. A $222 billion industry has sprung up to decommission these behemoths.

The choreography of unbuilding a nuclear power plant is complicated and -requires hiring companies and workers that specialize in the process. In the case of

SanOnofre, it's the Los Angeles-based AECOM and EnergySolutions, headquartered in Utah.

The $4.4 billion project aims to sweep clear most of the narrow 85-acre beachfront site. Workers have already moved the plant's spent fuel into steel-lined cooling pools. After it has sat there for several years, workers will transfer it to 73 steel canisters and then tuck these inside 25-foot-tall monoliths next to the domes.

This repository will sit just 125 feet from the Pacific, behind a seawall that rises 28 to 30 feet above sea level. Its proximity to the coast—and to the 8 million people who live within 50 miles—means many of them want the waste gone. Last April, protesters dressed in hazmat suits and carrying surfboards marched through San Diego demanding the waste's removal. The utility wants it gone too, but it has to keep it safely on-site for now. Tom Palmisano, vice president and chief nuclear officer at San Onofre, says that the storage system, known as dry cask, is designed to withstand an airplane crash, tsunami, even ground acceleration from a nearly magnitude 7.4 earthquake.

Though workers could, in theory, move the casks to a permanent resting place, none currently exist in the United States. The Department of Energy is legally bound to take spent commercial nuclear fuel and house it in a permanent spot. But the government never developed a permanent storage place after President Obama scuttled a plan to store commercial and military nuclear waste at Yucca Mountain, Nevada. This past August, the Nuclear Regulatory Commission said it would resume the work needed to eventually open that site. In the meantime, some 70,000 metric tons of nuclear waste is stored across the country.

At San Onofre, workers will place spent fuel in dry-cask storage and then demolish the buildings and offices. First, remotely controlled underwater tools will saw through radioactive steel from inside the empty reactors. Workers will store some of this material on-site for later disposal with the used fuel. They will pack the non-tainted portions—some 75 percent of a total 25 million cubic feet of rebar, concrete, and piping—in steel containers to dispose in the Southwest.

Rail cars will haul low-level radiation debris to specialized landfills. EnergySolutions will cart some of it to its desert facility in Clive, Utah, where workers will bury it beneath thick layers of clay, gravel, and rock.

More of these nuclear graves will cover the landscape as utilities take reactors offline around the globe. And unless renewable energy takes the place of nuclear, more carbon from fossil-fuel-fired plants will fill the air. When San Onofre shut down in 2012, natural-gas-fired electricity plants stepped in—adding 9 million tons of CO2 into the atmosphere in the following 12 months.

Despite the financial pressures from natural gas and the growth in wind- and solar-energy production, Cohen holds fast in his belief that the U.S. should give nuclear energy another chance. "There are new technologies in the works," he says. "This isn't going to be your father's nuclear industry. It might fail, and it ultimately might be unnecessary, but it's worth trying."

For now, though, the nays have it.

Mary Beth Griggs is an assistant editor at Popular Science. She covers space, geology, archaeology, and the environment.

Vocabulary 7

coolant salt pumps	насос сольового теплоносія
drain tank	резервуар для зливу (робочої) рідини
molten salt nuclear reactor	рідинно сольовий ядерний реактор
primary heat exchangers	первинний теплообмінник
radioactive elements	радіоактивні елементи
reactor vessel	бак реактора
steam generator	паровий генератор

This is how a molten salt nuclear reactor works

Keepin' it radioactive. By Ellen Airhart December 26, 2017

Radioactive elements produce heat as they decay. Nuclear plants draw power from this process, and typically stabilize the temperature with water. But during a power outage, H2O—which needs pumps to flow—can't always prevent meltdowns. Molten salt reactors, which instead control heat with melted lithium and potassium fluorides, have a fail-safe: If the electricity dies, a plug will melt, causing the salts to seep down a safety drain and solidify around the uranium, preventing overheating. After a decades-long lull in development, countries from China to Denmark are building new molten salt reactors. Here's how they work.

Reactor vessel

Uranium floats in a stabilizing bath of melted fluoride salts inside this container. As the radioactive atoms split apart, their fission steadily heats the vessel to 1,300 degrees Fahrenheit, the approximate temperature of magma.

Primary heat exchangers

Tubes on either side of the reactor vessel transfer the heat to intermediate pipes, which are filled with clean molten salts. The uncontaminated substance can carry energy without producing any additional radioactive waste.

Coolant salt pumps

These pumps move the clean salts in the heat exchangers away from the radioactive reactor vessel and toward a steam generator housed in a separate building. This limits the hazardous material to a single, isolated location.

Steam generator

The searing salts heat water into steam, which spins a turbine to produce electricity. In one hour, a molten salt reactor may be able to crank out 500,000 kilowatts, enough to power 45 U.S. households for an entire year.

Drain tank

Contaminated reactor salts and radioactive gases filter into a waste-disposal system. These materials remain hazardous for only hundreds of years—compared with hundreds of thousands for traditional reactors' byproducts.

UNIT 2. TECHNOLOGIES

Vocabulary 1

day job	основна робота
artificial intelligence systems	системи штучного інтелекту
digital distrust	недовіра до цифрових технологій
digital divide	"цифрова нерівність", "цифрова прірва" (між тими, хто використовує технології та тими хто не має подібної можливості)
digital technology	цифрові технології
online community	он-лайн спільнота
watchdog	наглядач

Trust in Digital Technology Will Be the Internet's Next Frontier, for 2018 and Beyond

Around the world people are both increasingly dependent on, and distrustful of, digital technology

After decades of unbridled enthusiasm—bordering on addiction – about all things digital, the public may be losing trust in technology. Online information isn't reliable, whether it appears in the form of news, search results or user reviews. Social media, in particular, is vulnerable to manipulation by hackers or foreign powers. Personal data isn't necessarily private. And people are increasingly worried about automation and artificial intelligence taking humans' jobs.

Yet, around the world, people are both increasingly dependent on, and distrustful of, digital technology. They don't behave as if they mistrust technology. Instead, people are using technological tools more intensively in all aspects of daily life. In recent research on digital trust in 42 countries (a collaboration between Tufts University's Fletcher School of Law and Diplomacy, where I work, and Mastercard), my colleagues and I found that this paradox is a global phenomenon.

If today's technology giants don't do anything to address this unease in an environment of growing dependence, people might start looking for more trustworthy companies and systems to use. Then Silicon Valley's powerhouses could see their business boom go bust.

ECONOMIC POWER

Some of the concerns have to do with how big a role the technology companies and their products play in people's lives. U.S. residents already spend 10 hours a day in front of a screen of some kind. One in 5 Americans say they are online "almost constantly." The tech companies have enormous reach and power. More than 2 billion people use Facebook every month.

Ninety percent of search queries worldwide go through Google. Chinese e-retailer, Alibaba, organizes the biggest shopping event worldwide every year on Nov. 11, which this year brought in US$25.3 billion in revenue, more than twice what U.S. retailers sold between Thanksgiving and Cyber Monday last year.

This results in enormous wealth. All six companies in the world worth more than $500 billion are tech firms. The top six most sought-after companies to work for are also in tech. Tech stocks are booming, in ways reminiscent of the giddy days of the dot-com bubble of 1997 to 2001. With emerging technologies, including the "internet of things," self-driving cars, blockchain systems and artificial intelligence, tempting investors and entrepreneurs, the reach and power of the industry is only likely to grow.

This is particularly true because half the world's population is still not online. But networking giant Cisco projects that 58 percent of the world will be online by 2021, and the volume of internet traffic per month per user will grow 150 percent from 2016 to 2021.

All these users will be deciding on how much to trust digital technologies.

DATA, DEMOCRACY AND THE DAY JOB

Even now, the reasons for collective unease about technology are piling up. Consumers are learning to be worried about the security of their personal information: News about a data breach involving 57 million Uber accounts follows on top of reports of a breach of the 145.5 million consumer data records on Equifax and every Yahoo account – 3 billion in all.

Russia was able to meddle with Facebook, Google and Twitter during the 2016 election campaign. That has raised concerns about whether the openness and reach of digital media is a threat to the functioning of democracies.

Another technological threat to society comes from workplace automation. The management consulting firm, McKinsey, estimates that it could displace one-third of the U.S. workforce by 2030, even if a different set of technologies create new "gig" opportunities.

The challenge for tech companies is that they operate in global markets and the extent to which these concerns affect behaviors online varies significantly around the world.

MATURE MARKETS DIFFER FROM EMERGING ONES

Our research uncovers some interesting differences in behaviors across geographies. In areas of the world with smaller digital economies and where technology use is still growing rapidly, users tend to exhibit more trusting behaviors online. These users are more likely to stick with a website even if it loads slowly, is hard to use or requires many steps for making an online purchase. This could be because the experience is still novel and there are fewer convenient alternatives either online or offline.

In the mature digital markets of Western Europe, North America, Japan and South Korea, however, people have been using the internet, mobile phones, social media and smartphone apps for many years. Users in those locations are less trusting, prone to switching away from sites that don't load rapidly or are hard to use, and abandoning online shopping carts if the purchase process is too complex.

Because people in more mature markets have less trust, I would expect tech companies to invest in trust-building in more mature digital markets. For instance, they might speed up and streamline processing of e-commerce transactions and payments, or more clearly label the sources of information presented on social media sites, as the Trust Project is doing, helping to identify authenticated and reliable news sources.

Consider Facebook's situation. In response to criticism for allowing fake Russian accounts to distribute fake news on its site, CEO Mark Zuckerberg boldly declared that, "Protecting our community is more important than maximizing our profits." However, according to the company's chief financial officer, Facebook's 2018 operating expenses could increase by 45 to 60 percent if it were to invest significantly in building trust, such as hiring more humans to review posts and developing artificial intelligence systems to help them. Those costs would lower Facebook's profits.

To strike a balance between profitability and trustworthiness, Facebook will have to set priorities and deploy advanced trust-building technologies (e.g. vetting locally generated news and ads) in only some geographic markets.

THE FUTURE OF DIGITAL DISTRUST

As the boundaries of the digital world expand, and more people become familiar with internet technologies and systems, their distrust will grow. As a result, companies seeking to enjoy consumer trust will need to invest in becoming more trustworthy more widely around the globe. Those that do will likely see a competitive advantage, winning more loyalty from customers.

This risks creating a new type of digital divide. Even as one global inequality disappears—more people have an opportunity to go online—some countries or regions may have significantly more trustworthy online communities than others. Especially in the less-trustworthy regions, users will need governments to enact strong digital policies to protect people from fake news and fraudulent scams, as well as regulatory oversight to protect consumers' data privacy and human rights.

All consumers will need to remain on guard against overreach by heavy-handed authorities or autocratic governments, particularly in parts of the world where consumers are new to using technology and, therefore, more trusting. And they'll need to keep an eye on companies, to make sure they invest in trust-building more evenly around the world, even in less mature markets. Fortunately, digital technology makes watchdogs' work easier, and also can serve as a megaphone—such as on social media—to issue alerts, warnings or praise.

Vocabulary 2

artificial intelligence	штучний інтелект
beam splitter	світоділильний пристрій
central processing unit	центральний процесор

chipmaker	виробник інтегральних схем
crossbred computer	гібридний комп’ютер
electronic circuit	електронна схема
energy consumption	витрата енергії
deep-learning chip	мікросхема для ґрунтовного вивчення
lenses	лінзи
magnitude	амплітуда, значення,
matrix multiplication	перемноження матриць
optical computer	оптичний комп’ютер
photonic computer chip	мікрохема фотонного комп’ютера
photon	фотон
quantum computing chip	мікросхема квантової обчислювальної техніки
resistance	протидія, опір
setbacks	перешкода, затримка, зниження, спад

Light-Powered Computers Brighten AI’s Future

Optical computers may have finally found a use—improving artificial intelligence

The idea of building a computer that uses light rather than electricity goes back more than half a century. “Optical computing” has long promised faster performance while consuming much less energy than conventional electronic computers. The prospect of a practical optical computer has languished, however, as scientists have struggled to make the light-based components needed to outshine existing computers. Despite these setbacks, optical computers might now get a fresh start—researchers are testing a new type of photonic computer chip, which could pave the way for artificially intelligent devices as smart as self-driving cars, but small enough to fit in one’s pocket.

A conventional computer relies on electronic circuits that switch one another on and off in a dance carefully choreographed to correspond to, say, the multiplication of two numbers. Optical computing follows a similar principle, but instead of streams of electrons, the calculations are performed by beams of photons that interact with one another and with guiding components such as lenses and beam splitters. Unlike electrons, which must flow through twists and turns of circuitry against a tide of resistance, photons have no mass, travel at light-speed and draw no additional power once generated.

DILEMMA

Deep learning has become so central to AI that companies including Google and high-performance chipmaker Nvidia have sunk millions into developing specialized chips for it. The chips take advantage of the fact that most of an artificial neural network’s time is spent on “matrix multiplications”—operations in which each neuron sums its inputs, placing a different value on each one. In a facial-recognition neural network, for example, some neurons might be looking for signs of noses. Those neurons would place a greater value on inputs corresponding to small, dark regions (likely nostrils), a slightly lower value on light patches (possibly skin) and very little on, say, the color neon green (highly unlikely to adorn someone's nose). A specialized deep-learning chip performs many of these weighted sums simultaneously by farming them out to the chip's hundreds of small, independent processors, yielding a substantial speedup.

That type of workload demands processing power equivalent to a mini supercomputer. Audi and other companies building self-driving vehicles have the luxury of stuffing a whole rack of computers in the trunk, but good luck trying to fit that kind of processing power in an artificially intelligent drone or a mobile phone. And even when a neural network can be run on large server farms, as with Google Translate or Facebook's facial recognition, such heavy-duty computing can run up multimillion-dollar electricity bills.

In 2015 Yichen Shen, a postdoctoral associate at MIT and the new paper's lead author, was seeking a novel approach to deep learning to solve these power and size issues. He came across the work of co-author Nicholas Harris, a PhD candidate at MIT in electrical engineering and computer science, who had built a new kind of optical computing chip. Although most previous optical computers had failed, Shen realized the optical chip could be hybridized with a conventional computer to open new vistas to deep learning.

CROSSBRED COMPUTERS

Many researchers had long since given up on optical computing. From the 1960's onward Bell Labs and others spent a fortune designing optical computer parts, but ultimately their efforts bore little benefit. "The optical equivalent of the electronic transistor was never developed," says University of Upper Alsace optical computing professor Pierre Ambs, and light beams were unable to perform basic logical operations.

Unlike most previous optical computers, though, Harris's new chip was not trying to replace a conventional CPU (central processing unit). It was designed to perform only specialized calculations for quantum computing, which exploits quantum states of subatomic particles to perform some computations faster than conventional computers. When Shen attended a talk by Harris on the new chip, he noticed the quantum calculations were identical to the matrix multiplications holding back deep learning. He realized deep learning might be the "killer app" that had eluded optical computing for decades. Inspired, the MIT team hooked up Harris's photonic chip to a regular computer, allowing a deep-learning program to offload its matrix multiplications to the optical hardware.

When their computer needs a matrix multiplication—that is, a bunch of weighted sums of some numbers—it first converts the numbers into optical signals, with larger numbers represented as brighter beams. The optical chip then breaks down the full multiplication problem into many smaller multiplications, each handled by a single "cell" of the chip. To understand the operation of a cell, imagine two streams of water flowing into it (the input beams of light) and two streams flowing out. The cell acts like a lattice of sluices and pumps—splitting up the streams, speeding them up or slowing them down, and mixing them back together. By controlling the speed of the pumps, the cell can guide different amounts of water to each of the output streams.

The optical equivalent of pumps are heated channels of silicon. When heated, Harris explains, "[silicon] atoms will spread out a bit, and this causes light to travel at a different speed," leading the light waves to either boost or suppress each other much as sound waves do. (Suppression of the latter is how noise canceling headphones work.) The conventional computer sets the heaters so the amount of light streaming out each of the cell's output channels is a weighted sum of the inputs, with the heaters determining the weights.

LET THERE BE LIGHT?

Shen and Harris tested their chip by training a simple neural network to identify different vowel sounds. The results were middling, but Shen attributes that to repurposing an imperfectly suited device. For example, the components for converting digital numbers to and from optical signals were rough proofs of concept, chosen only because they were easy to hook up to Harris's quantum computing chip. A more polished version of their computer fabricated specifically for deep learning could provide the same accuracy as the best conventional chips while slashing the energy consumption by orders of magnitude and offering 100 times the speed, according to their *Nature Photonics* paper. That would enable even handheld devices to have AI capabilities built into them without outsourcing the heavy lifting to large servers, something that would otherwise be next to impossible.

Of course, optical computing's checkered history leaves plenty of room for skepticism. "We should not get too excited," Ambs cautions. Shen and Harris's team has not yet demonstrated a full system, and Ambs's experience suggests it is sometimes "very difficult to improve the rudimentary system so dramatically."

Still, even Ambs agrees the work is "great progress compared to the [optical] processors of the '90s." Shen and Harris are optimistic as well. They are founding a start-up to commercialize their technology, and they're confident a larger deep-learning chip would work. All the factors they blame for their current chip's errors have known solutions, Harris argues, so "it's just an engineering challenge of getting the right people and actually building the thing."

Vocabulary 3

Android applications	програми для Android
cybercrime	кіберзлочинність
malicious software	шкідливе програмне забезпечення
query databases	база даних запитів
ransomware	вірус-вимагач, програма-шантазист
software vulnerabilities	уразливе програмне забезпечення
SQL	язык структурированных запросов

SQL injection	ін'єкція SQL

What Are Software Vulnerabilities, and Why Are There So Many of Them?

It can be useful to think of hackers as burglars and malicious software as their burglary tools

The recent WannaCry ransomware attack spread like wildfire, taking advantage of flaws in the Windows operating system to take control of hundreds of thousands of computers worldwide. But what exactly does that mean?

It can be useful to think of hackers as burglars and malicious software as their burglary tools. Having researched cybercrime and technology use among criminal populations for more than a decade, I know that both types of miscreants want to find ways into secure places—computers and networks, and homes and businesses. They have a range of options for how to get in.

Some burglars may choose to simply smash in a window or door with a crowbar, while others may be stealthier and try to pick a lock or sneak in a door that was left open. Hackers operate in a similar fashion, though they have more potential points of entry than a burglar, who is typically dependent on windows or doors.

The weaknesses hackers exploit aren't broken windowpanes or rusty hinges. Rather, they are flaws in software programs running on a computer. Programs are written by humans, and are inherently imperfect. Nobody writes software completely free of errors that create openings for potential attackers.

WHAT ARE THESE FLAWS, REALLY?

In simple terms, a vulnerability can be an error in the way that user management occurs in the system, an error in the code or a flaw in how it responds to certain requests. One common vulnerability allows an attack called a SQL injection. It works on websites that query databases, such as to search for keywords. An attacker creates a query that itself contains code in a database programming language called SQL.

If a site is not properly protected, its search function will execute the SQL commands, which can allow the attacker access to the database and potentially control of the website.

Similarly, many people use programs that are supported by the Java programming language, such as Adobe Flash Player and various Android applications. There are numerous vulnerabilities in the Java platform, all of which can be exploited in different ways, but most commonly through getting individuals to download "plug-ins" or "codecs" to software. These plug-ins actually contain malicious code that will take advantage of the vulnerability and compromise the machine.

FLAWS ARE EVERYWHERE

Vulnerabilities exist in all types of software. Several versions of the Microsoft Windows operating system were open to the WannaCry attack. For instance, the popular open-source web browser Firefox has had more than 100 vulnerabilities identified in its code each year since 2009. Fifteen different vulnerabilities have been identified in Microsoft Internet Explorer browser variants since the start of 2017.

Software development is not a perfect process. Programmers often work on timelines set by management teams that attempt to set reasonable goals, though it can be a challenge to meet those deadlines. As a result, developers do their best to design secure products as they progress but may not be able to identify all flaws before an anticipated release date. Delays may be costly; many companies will release an initial version of a product and then, when they find problems (or get reports from users or researchers), fix them by releasing security updates, sometimes called patches because they cover the holes.

But software companies can’t support their products forever—to stay in business, they have to keep improving programs and selling copies of the updated versions. So after some amount of time goes by, they stop issuing patches for older programs.

Not every customer buys the latest software, though—so many users are still running old programs that might have unpatched flaws. That gives attackers a chance to find weaknesses in old software, even if newer versions don’t have the same flaws.

EXPLOITING THE WEAKNESSES

Once an attacker identifies a vulnerability, he can write a new computer program that uses that opportunity to get into a machine and take it over. In this respect, an exploit is similar to the way burglars use tools like crowbars, lock picks or other means of entry into a physical location.

They find a weak point in the system’s defenses, perhaps a network connection that hasn’t been properly secured. If attackers can manage to gain contact with a target computer, they can learn about what sort of system it is. That lets them identify particular approaches—accessing specific files or running certain programs—that can give them increasing control over the machine and its data. In recent years, attackers began targeting web browsers, which are allowed to connect to the internet and often to run small programs; they have many vulnerabilities that can be exploited. Those initial openings can give an attacker control of a target computer, which in turn can be used as a point of intrusion into a larger sensitive network.

Sometimes the vulnerabilities are discovered by the software developers themselves, or users or researchers who alert the company that a fix is needed. But other times, hackers or government spy agencies figure out how to break into systems and don’t tell the company. These weaknesses are called “zero days,” because the developer has had no time to fix them. As a result, the software or hardware has been compromised until a patch or fix can be created and distributed to users.

The best way users can protect themselves is to regularly install software updates, as soon as updates are available.

Vocabulary 4

biocompatible	біологічно сумісний
electric eels	електричний вугор
electrocytes	електроскат
health sensors	сенсор працездатності
high-tech contact lenses	високотехнологічні кантактні лінзи
hydrogel	гідрогель
insulin pumps	дозатор інсуліну
potassium	калій
power source	джерело енергії
sodium atoms	атоми натрію
water-based polymer mixes	полімерні суміші на водній основі
zap	енергія, життєва сила

Electric eels provide a zap of inspiration for a new kind of power source

Battery-like devices mimic how a charge builds up in the animal's cells

New power sources bear a shocking resemblance to the electricity-making organs inside electric eels.

These artificial electric eel organs are made up of water-based polymer mixes called hydrogels. Such soft, flexible battery-like devices, described online December 13 in *Nature*, could power soft robots or next-gen wearable and implantable tech.

"It's a very smart approach" to building potentially biocompatible, environmentally friendly energy sources and "has a bright future for commercialization," says Jian Xu, an engineer at Louisiana State University in Baton Rouge not involved in the work.

This new type of power source is modeled after rows of cells called electrocytes in the electric organ that runs along an electric eel's body. When an eel zaps its prey, positively charged potassium and sodium atoms inside and between these cells flow toward the eel's head, making each electrocyte's front end positive and tail end negative. This setup creates a voltage of about 150 millivolts across each cell. The voltages of these electrocytes add up, like a lineup of AAA batteries powering a flashlight, explains Michael Mayer, a biophysicist at the University of Fribourg in Switzerland. Collectively, an eel's electrocytes can generate hundreds of volts.

Mayer and his colleagues concocted four hydrogels that, when queued up in a particular order, mimic the function of an electrocyte. The researchers devised a couple of strategies for stringing a four-gel artificial cell to other cells. One technique involved printing hydrogel grids onto two polyester sheets, and then laying one sheet on top of the other so the hydrogels crisscrossed like zipper teeth. Alternatively, printing all the hydrogels on a single sheet and then folding the sheet stacked the gels like pancakes.

The researchers designed the four hydrogels' chemical makeup so that as soon as all the gels of a single cell touched, their positively charged sodium atoms surged toward one end of the lineup and negative chloride atoms flooded toward the other. Much like a real electrocyte, each four-gel artificial cell generated 130 to 185 millivolts of electricity, and 612 artificial eel cells in tandem produced 110 volts — about the energy of a household outlet.

Unfortunately, the artificial eel organs don't expend their energy as efficiently as their biological counterparts, Mayer says. So the hydrogel systems built for this study could only energize very low-power instruments. "The device we're closest to powering is probably a pacemaker," Mayer says. But he thinks that tweaking the hydrogel setup to more closely imitate a real eel electric organ — like by printing thinner gels — could give these energy sources more oomph.

Mayer also wants to devise a new way to recharge the artificial organs. Researchers currently have to hook the devices up to an external power source that drives the hydrogels' charged particles back to their starting positions, kind of like plugging a battery into a charging dock.

"The holy grail, at least to me, would be to design this thing so it can recharge itself inside the body," Mayer says. He imagines artificial eel organs tapping into the energy stored by natural charge separations throughout the body, like between the stomach — which is relatively positively charged — and surrounding tissue. Such flexible, biofriendly and transparent energy sources could someday energize implanted health sensors, insulin pumps or high-tech contact lenses that project virtual displays onto the wearer's line of sight.

Vocabulary 5

bioengineer	фахівець в галузі біомедичної техніки; біоінженер
buoyancy	плавучість; піднімальна сила
oxygen gas	газоподібний кисень
locomotion	здатність пересуватися
search-and-rescue operations	пошуково-рятувальні операції
translucent wings	напівпрозорі крила

This is the lightest robot that can fly, swim and take off from water

The insect-inspired machine is about 1,000 times lighter than previous aerial-aquatic bots

By Mariah Quintanilla

A new insect-inspired tiny robot that can move between air and water is a lightweight.

Weighing the same as about six grains of rice, it is the lightest robot that can fly, swim and launch itself from water, an international team of researchers reports October 25 in *Science Robotics*. The bot is about 1,000 times lighter than other previously developed aerial-aquatic robots. In the future, this kind of aquatic flier could be used to perform search-and-rescue operations, sample water quality or simply explore by air or sea.

To hover, the bot flaps its translucent wings 220 to 300 times per second, somewhat faster than a housefly. Once submerged, the tiny robot surfaces by slowly flapping its wings at about nine beats per second to maintain stability underwater.

For the tricky water-to-air transition, the bot does some chemistry. After water has collected inside the machine's central container, the bot uses a device to split water into hydrogen and oxygen gas. As the chamber fills with gas, the buoyancy lifts the vehicle high enough to hoist the wings out of the water. An onboard "sparker" then creates a miniature explosion that sends the bot rocketing about 37 centimeters — roughly the average length of a men's shoe box — into the air. Microscopic holes at the top of the chamber release excess pressure, preventing a loss of robot limbs.

Still, the design needs work: The machine doesn't land well, and it can only pierce the water's surface with the help of soap, which lowers the surface tension. More importantly, the experiment points to the possibilities of incorporating different forms of locomotion into a single robot, says study coauthor Robert Wood, a bioengineer at Harvard University.

Vocabulary 6

automated air-traffic control	автоматична диспетчерська служба повітряного руху
automated passenger drones	автоматичні пасажирські дрони
electric propulsion	електрична тяга, електрична установка
electric power	електросила
hybrid	гібрид
quadcopters	квадрокоптер
roadable aircraft	гібридний літальний апарат

Forget Flying Cars: Passenger Drones May Be Hovering Soon at a Location Near You

Self-piloting quadcopters make more sense than an airplane–automobile hybrid—but safety and logistics problems remain

The dream of the flying car could come down to earth before it gets off the ground. Rising in its place: a network of self-flying drones big enough to ferry individual commuters around town. That's the future envisioned by several start-ups that are developing so-called "passenger drones," which could shrink commute times from hours to minutes.

At first blush, human-carrying drones sound no more realistic than flying cars. Until recently inventors had never been able to marry automobiles and aircraft in a practical way. Yet a few companies have kept at it: Woburn, Mass.–based Terrafugia, for example, has since 2006 been developing Transition, a "roadable aircraft" that resembles a small airplane that can fold its wings and drive on roads. A personal flying car in every garage has proved to be a tough sell, however, and there are serious safety concerns about asking the average commuter to train for a pilot's license and take to the skies.

Passenger drones, by contrast, would operate autonomously and leave the "roadable" part behind in favor of larger versions of aircraft that already exist. Chinese start-up EHANG last month announced it would debut its passenger drone service in Dubai in July. The EHANG184 autonomous aerial vehicle resembles an overgrown quadcopter with a passenger cab perched on top. Last October ride-hailing service Uber publicized its Elevate program for urban air transportation and announced support for companies building vehicles similar to the 184. Uber recently bolstered its plans by hiring Mark Moore, an aircraft engineer at NASA Langley Research Center and pioneer in vertical takeoff and landing (VTOL) aircraft designs. Several other companies, including Joby Aviation and Silicon Valley start-ups Zee.Aero and Kitty Hawk—the latter two backed by Google co-founder Larry Page—are racing to develop electric-powered VTOL aircraft that could help make Elevate a reality. Terrafugia likewise plans to eventually offer a VTOL flying vehicle—the TF-X—in addition to the Transition.

Passenger drone designs favor "distributed electric propulsion," meaning instead of one large rotor powered by a large engine they have multiple propellers each powered by its own, smaller motor. This sacrifices lifting power and flight performance in exchange for mechanical simplicity and lighter weight—factors that could make them cheaper to operate. Quieter electric power would make the noise tolerable to city residents, although it remains to be seen how much weight such a vehicle could lift, and for how long.

With any of these vehicles, safety is the biggest concern and extends to both the aircraft and the automated systems flying them. Advanced artificial intelligence is needed to fly large numbers of autonomous aircraft without crashing them into one another or, say, the local news channel's traffic helicopter. Carrying people from points A to B seems simple enough, but even the best AI struggles with surprises: What, for example, would a drone do if a landing area suddenly became unavailable? asks Sanjiv Singh, a Carnegie Mellon University robotics researcher and CEO of Near Earth Autonomy, a start-up developing intelligent flight systems. Instead of leaping to fully automated passenger drones, he suggests first testing the necessary AI in unmanned cargo runs. Early passenger services might include pilots assisted by AI co-pilots—a "mixed mode" approach that Singh helped develop for the U.S. military's "Transformer" project (which more recently morphed into Lockheed Martin's ARES project) to build a drone that could carry cargo or wounded soldiers.

Nevertheless, some experts are cautiously optimistic. The technological challenges can be overcome, says Marilyn Smith, associate director of the Vertical Lift Research Center of Excellence at Georgia Institute of Technology. “I think the big roadblock is the regulatory infrastructure that has to be put into place” to ensure safety, Smith says.

Regulators from the Federal Aviation Administration (FAA) have not issued guidance on passenger drones yet. The FAA is, however, working with NASA and private industry on ways to manage swarms of smaller delivery and emergency responder drones—rules that might also apply to larger self-flying aircraft. NASA’s approach relies on drone operators sending flight information to a centralized system—like an automated air-traffic control—that tracks the location of autonomous aircraft, says Parimal Kopardekar, principal investigator for NASA's Unmanned Aircraft Systems Traffic Management project. The system under development would provide a “common picture of what is going on in the airspace” so that drones can steer clear of other aircraft, Kopardekar says. A related NASA project—the Unmanned Aircraft Systems Integration in the National Airspace System is developing a “detect and avoid” system for drones to avert midair collisions.

Technical challenges aside, EHANG, Uber and others promoting the technology will have to find a way to convince the public to give their drones a whirl, something that requires a much bigger leap of faith than getting into the backseat of a self-driving car. Passenger drone makers are “obviously still in the incubation stages of technology development and improving the basics,” says Mike Hirschberg, executive director of the American Helicopter Society International, an organization for engineers and scientists that promotes VTOL technology. “But 20 or 30 years from now life may be a little like *The Jetsons* where you take advantage of the third dimension and have much more mobility, especially in urban close quarters where ground transportation is gridlocked.”

Passenger drone progress, however, may follow a sloping takeoff rather than vertical leap, depending on whom you ask. “This is not your father’s flying car,” Hirschberg says. “This is really serious work— and it’s going to happen.” Still, Carnegie Mellon’s Singh sees a long road ahead filled with lots of testing, analysis, regulation and efforts to win the public’s trust before the technology becomes a viable transportation option. “There is the danger of someone moving too fast and then having a problem that sets the industry back for some time,” he says.

UNIT 3. ATOM AND COSMOS

Vocabulary 1

cosmic microwave background	реліктове випромінювання
cosmologist	спеціаліст з космології
dark energy	темна енергія
gravitational waves	гравітаційна хвиля
magnitude	зоряна величина
neutron star merger	злиття нейтронних зірок
particle	частка

What detecting gravitational waves means for the expansion of the universe

Speed of spacetime ripples rules out some alternatives to dark energy

Ripples in spacetime travel at the speed of light. That fact, confirmed by the recent detection of a pair of colliding stellar corpses, kills a whole category of theories that mess with the laws of gravity to explain why the universe is expanding as fast as it is.

On October 16, physicists announced that the Advanced Laser Interferometer Gravitational-Wave Observatory, LIGO, had detected gravitational waves from a neutron star merger (*SN Online: 10/16/17*). Also, the neutron stars emitted high-energy light shortly after merging. The Fermi space telescope spotted that light coming from the same region of the sky 1.7 seconds after the gravitational wave detection. That observation showed for the first time that gravitational waves, the shivers in spacetime set off when massive bodies move, travel at the speed of light to within a tenth of a trillionth of a percent.

Within a day, five papers were posted at arXiv.org mourning hundreds of expanding universe theories that predicted gravitational waves should travel faster than light — an impossibility without changes to Einstein's laws of gravity. These theories "are very, very dead," says the coauthor of one of the papers, cosmologist Miguel Zumalacárregui of the Nordic Institute for Theoretical Physics, or NORDITA, in Stockholm. "We need to go back to our blackboards and start thinking of other alternatives."

In the 1990s, observations of exploding stars showed that more distant explosions were dimmer than existing theories predicted. That suggested that the universe is expanding at an ever-increasing rate (*SN: 10/22/11, p. 13*). Cosmologists have struggled ever since to explain why.

The most popular explanation for the speedup is that spacetime is filled with a peculiar entity dubbed dark energy. "You can think of it like a mysterious fluid that pushes everything apart and counteracts gravity," says cosmologist Jeremy Sakstein of the University of Pennsylvania, coauthor of another new paper.

In the simplest version of this theory, the density of this dark energy has not changed over the history of the universe, so physicists call it a cosmological constant. This doesn't require any changes to gravity — which is good, because gravity has been well-tested inside the solar system.

The cosmological constant idea matches observations of the wider universe, but it has some theoretical difficulties. Dark energy is about 120 orders of magnitude weaker than theorists calculate it should be (*SN Online: 11/18/13*), a mismatch that makes scientists uncomfortable.

Also, different methods for measuring the rate of expansion come up with slightly different numbers (*SN: 8/6/16, p. 10*). Measurements based on exploding stars suggest that distant galaxies are speeding away from each other at 73 kilometers per second for each megaparsec (about 3.3 million light-years) of space between them. But observations based on the cosmic microwave background, ancient light that encodes information about the conditions of the early universe, found that the expansion rate is 67 km/s per megaparsec. The disagreement suggests that either one of the measurements is wrong, or the theory behind dark energy needs a tweak.

So instead of invoking a substance to counteract gravity, theorists tried to explain the expanding universe by weakening gravity itself. Any modifications to gravity need to leave the solar system intact. “It’s quite hard to build a theory that accelerates the universe and also doesn’t mess up the solar system,” says cosmologist Tessa Baker of the University of Oxford, coauthor of still another paper.

These theories take hundreds of forms. “This field of modified gravity theories is a zoo,” says Baker. Some suggest that gravity leaks out into extra dimensions of space and time. Many others account for the universe’s speedy spreading by adding a different mysterious entity — some unknown particle perhaps — that drains gravity’s strength as the universe evolves.

But the new entity would have another crucial effect: It could slow the speed of light waves, similar to the way light travels more slowly through water than through air. That means that the best alternatives to dark energy required gravitational waves to travel faster than light — which they don’t.

Justin Khoury, a theoretical physicist at the University of Pennsylvania who has worked on several of the alternative gravity theories but was not involved in the new papers, was surprised that one gravitational-wave observation ruled out so many theories at once. He’s hardly disappointed, though.

“The fact that we’re learning something about dark energy because of this measurement is incredibly exciting,” he says.

Observing gravitational waves and light waves at the same time offers a third, independent way to measure how fast the universe is expanding. For now, that rate lies frustratingly right between the two clashing measurements scientists already had, at 70 km/s per megaparsec. But it’s still imprecise. Once LIGO and other observatories have seen 10 or 20 more neutron star collisions, researchers should be able to tell which measurement is correct and figure out whether dark energy needs an update, Zumalacárregui says.

“Gravitational waves may kill these models, but eventually they have the potential to tell us if this discrepancy is for real,” he says. “That’s something that is in itself very beautiful.”

Vocabulary 2

supermassive black hole	надмасивна чорна діра
gargantuan sizes	величезні розміри
quasars	квазари
cosmic history	історія космосу
reionization	повторна іонізація
ion	іон

Oldest Supermassive Black Hole Found from Universe's Infancy

The object grew to more than 800 million times the mass of the sun when the cosmos was only 5 percent its present age

Astronomers have discovered the oldest supermassive black hole ever found—a behemoth that grew to 800 million times the mass of the sun when the universe was just 5 percent of its current age, a new study finds.

This newfound giant black hole, which formed just 690 million years after the Big Bang, could one day help shed light on a number of cosmic mysteries, such as how black holes could have reached gargantuan sizes quickly after the Big Bang and how the universe got cleared of the murky fog that once filled the entire cosmos, the researchers said in the new study.

Supermassive black holes with masses millions to billions of times that of the sun are thought to lurk at the hearts of most, if not all, galaxies. Previous research suggested these giants release extraordinarily large amounts of light when they rip apart stars and devour matter, and likely are the driving force behind quasars, which are among the brightest objects in the universe. [The Strangest Black Holes in the Universe]

Astronomers can detect quasars from the farthest corners of the cosmos, making quasars among the most distant objects known. The farthest quasars are also the earliest known quasars—the more distant one is, the more time its light took to reach Earth.

The previous record for the earliest, most distant quasar was set by ULAS J1120+0641. That quasar is located 13.04 billion light-years from Earth and existed about 750 million years after the Big Bang. The newfound quasar (and its black hole), named ULAS J1342+0928, is 13.1 billion light-years away.

HOW BLACK-HOLE MONSTERS GROW

Explaining how black holes could have gobbled up enough matter to reach supermassive sizes early in cosmic history has proved extraordinarily challenging for scientists. As such, researchers want to look at as many early supermassive black holes as possible to learn more about their growth and their effects on the rest of the cosmos.

"The most distant quasars can provide key insights to outstanding questions in astrophysics," said study lead author Eduardo Bañados, an astrophysicist at the Carnegie Institution for Science.

The researchers predicted that only 20 to 100 quasars as bright and as distant as the newfound quasar exist in the whole sky visible from Earth.

"This particular quasar is so bright that it will become a gold mine for follow-up studies and will be a crucial laboratory to study the early universe," Bañados told Space.com. "We have already secured observations for this object with a number of the most powerful telescopes in the world. More surprises may arise."

FINDING A BEHEMOTH

The researchers detected and analyzed quasar ULAS J1342+0928 using one of the Magellan Telescopes at Las Campanas Observatory in Chile, as well as the Large Binocular Telescope in Arizona and the Gemini North telescope in Hawaii. Its central black hole has a mass about 800 million times that of the sun and existed when the universe was just 690 million years old, or just 5 percent of its current age. [No Escape: The Anatomy of a Black Hole (Infographic)]

"All that mass—almost 1 billion times the mass of the sun—needs to be gathered in less than 690 million years," Bañados said. "That is extremely difficult to achieve and is something that theorists will need to explain in their models."

Quasars like J1342+0928 are rare. The researchers searched one-tenth of the entire sky visible from Earth and found just one quasar from this early epoch.

Only about 60 million years separate this newfound quasar from the previous record holder. Still, this span of time was "about 10 percent of the age of the universe at those early cosmic epochs, when things were evolving very rapidly," Bañados said. That means this difference in time could yield important clues about the evolution of the early universe.

This new quasar is also of interest to scientists because it comes from a time known as "the epoch of reionization," when the universe emerged from its dark ages. "It was the universe's last major transition and one of the current frontiers of astrophysics," Bañados said in a statement.

Right after the Big Bang, the universe was a rapidly expanding hot soup of ions, or electrically charged particles. About 380,000 years later, these ions cooled and coalesced into neutral hydrogen gas. The universe stayed dark until gravity pulled matter together into the first stars. The intense ultraviolet light from this era caused this murky neutral hydrogen to get excited and ionize, or gain electric charge, and the gas has remained in that state since that time. Once the universe became reionized, light could travel freely through space.

GLIMPSING THE EARLY UNIVERSE

Much remains unknown about the epoch of reionization, such as what sources of light caused reionization. Some prior work suggested that massive stars were mostly responsible for reionization, but other research hinted that black holes were a significant, and potentially dominant, culprit behind this event. [7 Surprising Things About the Universe]

"How and when the reionization of the universe occurred has fundamental implications on how the universe evolved," Bañados said.

The new findings revealed that a large fraction of the hydrogen in the immediate vicinity of the newfound quasar was neutrally charged. This suggests that this quasar comes from well within the epoch of reionization, and further analysis of it could yield insight into what happened during this pivotal time.

However, to really learn more about the epoch of reionization, scientists need more than just one or two early, distant quasars to look at. "We need to find more of these quasars at similar or larger distances," Bañados said. "This is extremely difficult, as they are very rare. This is really like finding the needle in a haystack."

Still, the fact that this newfound quasar is so bright and large suggests that "it's probably not the first quasar ever formed, so we need to keep searching," Bañados said.

The scientists detailed their findings in the Dec. 7 issue of the journal Nature. The researchers also released a companion paper in The Astrophysical Journal Letters.

Vocabulary 3

atmospheric chemistry	хімічний склад атмосфери
derelict satellites	покинутий супутник
middle atmosphere	середні шари атмосфери
ozone depletion	виснаження озонового шару
rocket-engine emissions	викиди реактивного двигуна
solid rocket-booster motor	двигун твердопаливного прискорювача
space debris	космічне сміття, орбітальне сміття
space junk	космічне сміття
upper atmosphere	верхній шар атмосфери
vaporization	випаровування, пароутворення

How Much Air Pollution Is Produced by Rockets?

With economic activity poised to surge in space, scientists are reexamining how rockets might harm Earth's atmosphere

Nobody knows the extent to which rocket launches and re-entering space debris affect Earth's atmosphere — but such ignorance could be remedied soon.

The issue of rocket emissions—which deliver gases and particles directly into the middle and upper atmosphere—will be included in a forthcoming United Nations 2018 Quadrennial Global Ozone Assessment that delves into the substances responsible for ozone depletion.

"The 2018 assessment is really the first one to have a substantial section on rocket emissions, not just a passing thought," said Martin Ross, a lead author of the relevant section in the upcoming report. [The World's Tallest Rockets: How They Stack Up]

"The climate impact of rockets has not really been seriously addressed as yet," Ross, a senior project engineer for civil and commercial launch projects at The Aerospace Corporation in El Segundo, California, told Space.com. "But with respect to ozone, we now understand that the climate and ozone impacts of rocket exhaust are completely intertwined."

Rocket soot accumulates in the upper stratosphere, where the particles absorb sunlight, Ross said. This accumulation heats the upper stratosphere, changing chemical reaction rates and likely leading to ozone loss, he added.

In flagging the issue, Ross said he hopes the scientific community becomes interested enough to start running atmospheric models of the phenomenon—especially because the pace of rocket launches is expected to ramp up significantly in the coming decades.

"I think we're at about that point," Ross said.

NO YARDSTICK

A key study focus is the climate impact of major rocket-engine emissions: carbon dioxide, water, black carbon and alumina particles discharged by solid rocket-booster motors.

A recent finding, Ross said, is that alumina particles, previously thought to cool the Earth by scattering solar flux back to space, actually warm the planet, by absorbing outgoing terrestrial, long-wave radiation. However, fully appreciating the microphysics of alumina and other rocket emissions introduced into the atmosphere requires more research, he added.

For example, the interactions between Earth's atmosphere and exhaust from methane-fueled rocket engines have not been modeled, "so we really don't know" the effects these rockets have, Ross said.

There's no yardstick by which to assess how significant the impacts of rocket exhaust may be, he added.

"The notion of what is the metric by which rocket exhaust is to be judged … that is a completely open question," Ross said. "Then, compare that metric to the expected growth in launch rates. That really needs to be done. Just saying the ozone loss is too big—that's not an acceptable metric."

There has been a lot of buzz recently about spaceflight companies shooting for frequent "airline-like operations," but scientists, engineers and policy makers generally are not "putting two and two together with respect to the emissions that are implied by that idea," Ross said.

RE-ENTRY SMOKE PARTICLES

Space hardware falling back to Earth can affect the atmosphere as well, so re-entering orbital debris should also be studied, Ross said.

"Vaporize" may mean "disappear" in most people's minds, but that's assuredly not the case with re-entering space junk, Ross said. Such debris, he said, generates "re-entry smoke particles" (RSPs) of unknown composition and reactivity. Scientific models suggest that at least 50 percent of a given debris object will end up as RSPs during re-entry.

"In that crucial 20 seconds of re-entry, you go from heating to melting to vaporization and then back into dust. How does that happen? What is that composition? We don't know at all. We need to get away from this idea that vaporization equals disappearance," Ross said. "Vaporization equals dust production. That process isn't well-understood at all. Again, we need to know the microphysics of these recondensed particles."

BURNING COMPUTERS

The plunge into Earth's atmosphere of derelict satellites, rocket stages and other space flotsam is a common occurrence. For spacecraft re-entries, that process is "basically burning computers," Ross said.

During re-entry, big chunks of aluminum and other materials are subjected to intense heating. The chemical kinetics of the particles that are produced in this way have not been examined, Ross said. Some particles are very reactive, so small amounts of them could have a significant effect on atmospheric chemistry, he added.

"So far, nobody has deemed it important enough to study, and I believe it is," Ross said.

Vocabulary 4

interstellar asteroid	міжзоряний астероїд
hyperbolic excess velocity	гіперболічна надлишкова швидкість
astronomer	астроном
inner solar system	внутрішня сонячна система
satellite	супутник

SpaceX's Planned Giant Rocket Could Chase Down Interstellar Asteroid

A new study charts potential courses for missions to 'Oumuamua, an oddly-shaped space rock from another star

There may be yet another future use for SpaceX's huge Mars-colonization rocket.

That rocket, called the BFR, could launch a probe toward 'Oumuamua, theinterstellar asteroidthat zoomed past Earth last month, a new study suggests.

The 1,300-foot-long (400 meters) 'Oumuamua is currently speeding away from us at about 58,160 mph (93,600 km/h, or 26 km/s). That's far faster than any spacecraft has ever traveled upon escaping Earth (though some have gone faster as they approached big bodies, such as the sun). But a mission employing the in-development BFR, with speed-boosting flybys of Jupiter and the sun, could theoretically chase 'Oumuamua down, the study said. ['Oumuamua: An Interstellar Visitor Explained in Photos]

This potential architecture is based on concepts drawn up by researchers at the Keck Institute for Space Studies (KISS) and NASA's Jet Propulsion Laboratory (JPL) in California, the study's authors noted.

"The KISS Interstellar Medium study computed that a hyperbolic excess velocity of 70 km/s was possible via this technique, a value which achieves an intercept at about 85 AU in 2039 for a 2025 launch," the authors wrote in the study, one version of which was published on the siteCentauri Dreams. (AU is short for "astronomical unit," the distance from Earth to the sun, which is about 93 million miles, or 150 million km. And "hyperbolic excess velocity" just refers to the spacecraft's speed.)

"More-modest figures can still fulfill the mission, such as 40 km/s with an intercept at 155 AU in 2051," the authors added. "With the high approach speed, a hyper-velocity impactor to produce a gas 'puff' to sample with a mass spectrometer could be the serious option to get in-situ data."

To be clear: The KISS and JPL concepts don't deal specifically with 'Oumuamua or the BFR. Those two ideas were devised before 'Oumuamua was discovered, and before SpaceX founder and CEO Elon Musk unveiled the company's latest thinking about the BFR—a point stressed by KISS researchers recently.

"KISS didconvene a programto study possibilities for future missions to reach the interstellar medium outside the solar system, but that study took place before the discovery of 'Oumuamua and is not applicable to that object," the researchers wrote in a statementabout the new study.

An 'Oumuamua mission would really round out the reusable BFR's portfolio. SpaceX already envisions using the giant rocket—along with its paired spaceship—forall manner of tasks, including launching satellites, carrying people on superfast point-to-point journeys around the globe and cleaning up space junk.

But the BFR is not the only option for an 'Oumuamua mission, the study authors wrote. Tiny, laser-propelled sail craft, like the ones the $100 millionBreakthrough Starshot projectaims to launch to other star systems, could do the job as well. (But a 2025 launch date for a sail-craft swarm is unrealistic; the Starshot team has estimated the probes may be ready for prime time in 20 years or so if everything goes well.)

"An important result of our analysis is that the value of a laser-beaming infrastructure from the Breakthrough Initiatives' Project Starshot would be the flexibility to react quickly to future unexpected events, such as sending a swarm of probes to the next object like 1I/'Oumuamua," the new study said. (The "1I" in front of 'Oumuamua references the object's official scientific designation: 1I/2017 U1.)

"With such an infrastructure in place today, intercept missions could have reached 1I/'Oumuamua within a year," they added.

Even if an 'Oumuamua mission never comes to pass, astronomers could still get an up-close look at a visitor from another solar system in the not-too-distant future: Such interstellar interlopers may zoom through the inner solar system as often as every year or so, scientists have said. (But spotting them appears to be a tall order, given that 'Oumuamua is the first one we've ever identified.)

Vocabulary 5

careen	відхилятись від курсу
chain reaction	ланцюгова реакція
debris cloud	хмара сміття
dust-and-gas disk	диск космічного сміття та газу

exoplanet	екзопланета
gravitational tug	гравітаційний буксир
motion resonance	резонанс руху
oblong orbit	витягнута орбіта
protoplanetary	протопланетарний

Exoplanets Lurking in Dusty Disks Reveal Their Secrets

A new mathematical model suggests planets interact with these structures in complex ways

A disk of gas and dust around a star some 450 light-years from Earth had astronomers puzzled. When observations of the star HL Tauri revealed a glowing disk split by crisp bands, some assumed unseen planets were carving out paths as they orbited. But new simulations suggest a more complex picture. Those gaps may actually result from gravitational tugs of planets elsewhere in the disk, even outside of the disk, and learning to read these patterns could speed the detection of currently hard-to-find planets.

“We’re going to start seeing more of these coming out very soon, a lot of these beautiful, high signal-to-noise ratio disks that we can see with these structures,” says Maryam Tabeshian, developer of the model and researcher at Western University in Ontario.

Astronomers love such planet-forming, or protoplanetary, disks as well as their less gaseous cousins, debris disks, for the same reason paparazzi love a crowd: a quick glance can usually tell you where your target is. But rather than fame, Tabeshian proposes relying on orbital jostling motions to aid the search.

These dust-and-gas disks may look solid, but they are composed of grains, boulders and mini planets all orbiting at different speeds—faster up close to the star and slower farther out. When a planet syncs up with a distant particle orbiting, say, two times slower or three times faster, it is known as “mean motion resonance.” Each time the planet aligns with a particle, it gives it a gravitational nudge, which can ultimately eject it from the disk entirely.

When this process is spread out along an entire ring, it can open holes far from the planet responsible. Features such as the width, location and shape of the gap could be used to predict the planet’s mass and orbit, according to a pair of papers, the latest of which was published in September by *The Astrophysical Journal*. For example, a planet orbiting beyond a disk’s radius would produce two rotating arc-shaped holes whereas one orbiting in its interior would create only one, Tabeshian says. An extra gap of a certain type would suggest a planet with a more oblong orbit, and wider gaps point to the presence of more massive planets.

Tabeshian has already put the theory into practice. A study currently under review, prepared with Western University astronomer Paul Wiegert, shows that via resonances, three properly placed exoplanetscould produce five of HL Tauri’s gaps. Educated guesses like these could narrow the haystack that exoplanet hunters have to search or, in the case of exterior planets, hint that certain needles lie outside the haystack entirely. “It’s great that theorists like Maryam and Paul are preparing these tools,” says astronomer Erika Nesvold of the Carnegie Institution of Washington, “so then when observers do take interesting pictures, they can get an idea of what they’re looking at.”

But the dusty signs Tabeshian’s simulation predicts may prove hard to read. The view of these disks from Earth has to be just right: top-down, not edge-on. What’s more, the patterns sit right on the technological edge of what current tools can resolve. “The trick is to figure out whether you can do it with either our current telescopes or the next generation of telescopes,” notes Nesvold, who was not involved in the research.

Nesvold is no stranger to the challenges of applying theory to reality: She developed her own model that simulates the chain reaction of collisions a planet sets off when it careens through a debris cloud. Still, she sees these disk techniques as natural complements to well-established planet-detection methods.

Looking for planets based on stars that wobble or flicker tends to reveal big exoplanets with tight orbits—more like Mercury than Earth—but debris disks register disturbances from bodies both near and far. More distant planets would actually be easier to detect, Nesvold says, because the star’s light washes out inner-disk regions. Then, if disk behavior hints at outlying bodies, astronomers will have a better idea where to aim telescopes for the money shot—imaging them directly. This detection method also favors planets orbiting distantly from their stars.

As they refine their techniques, however, direct imagers will strive to find planets closer to their bright host stars, and those who search for wobbles and flickers will push outward toward wider orbits. No method has found an exact Earth twin yet, but Nesvold suggests debris disk models can help the two methods meet in the middle. “To get to Earth orbit,” she says, “we’re kind of coming at it from both ends.”

Vocabulary 6

irregular galaxy	неправильна (пекулярна) галактика
local star	місцева система зірок
magnetar	магнетар, намагнічена нейтронна зірка
magnetic field	магнітне пое
neutron star	нейтронна зірка
star's core	ядро зірки
supermassive star	надмасивна зірка
supernova	наднова (зірка)
rotational energy	енергія обертального руху

Bizarre Supernova Defies Understanding

Supernovas are thought to be the explosive deaths of stars. So what happens when one is found repeating?

The appearance of a years-long supernova explosion challenges scientist's current understanding of star formation and death, and work is underway to explain the bizarre phenomenon.

Stars more than eight times the mass of the sun end their lives in fantastic explosions called supernovas. These are among the most energetic phenomena in the universe. The brightness of a single dying star can briefly rival that of an entire galaxy. Supernovas that form from supermassive stars typically rise quickly to a peak brightness and then fade over the course of around 100 days as the shock wave loses energy.

In contrast, the newly analyzed supernova iPTF14hls grew dimmer and brighter over the span of more than two years, according to a statement by Las Cumbres Observatory in Goleta, California, which tracked the object. Details of the discovery appeared on Nov. 8 in the journal Nature. [First Supernova Shock Wave Image Snapped by Planet-Hunting Telescope]

AN INCONSPICUOUS DISCOVERY

Supernova iPTF14hls was unremarkable when first detected by a partner telescope in San Diego on Sept. 22, 2014. The light spectrum was a textbook example of a Type II-P supernova, the most common type astronomers see, lead author Iair Arcavi, an astronomer at the University of California, Santa Barbara, told Space.com. And the supernova looked like it was already fading, he said.

The observatory was in the middle of a 7.5-year collaborative survey, so Arcavi focused on more-promising objects. But in February, 2015, Zheng Chuen Wong, a student working for Arcavi that winter, noticed the object had become brighter over the past five months.

"He showed me the data," Arcavi said, "and he [asked], 'Is this normal?' and I said, 'Absolutely not. That is very strange. Supernovae don't do that,'" Arcavi said.

At first, Arcavi thought it might be a local star in our galaxy, which would appear brighter because it was closer, he said. Many stars are also known to have variable brightness. But the light signature revealed that the object was indeed located in a small, irregular galaxy about 500 million light-years from Earth.

And the object only got weirder. After 100 days, the supernova looked just 30 days old. Two years later, the supernova's spectrum still looked the way it would if the explosion were only 60 days old. The supernova recently emerged from behind Earth's sun, and Arcavi said it's still bright, after roughly three years. But at one one-hundredth of its peak brightness, the object appears to finally be fading out.

"Just to be clear, though, there is no existing model or theory that explains all of the observations we have," said Arcavi. The supernova may fade out; it may grow brighter, or it may suddenly disappear.

One reason for Arcavi's uncertainty is that a supernova was seen in the same location in 1954. This means that the event Acavi has been observing, whatever it is, may actually be 60 years running. There's a 1 to 5 percent chance the two events are unrelated, but that would be even more surprising, said Arcavi. Astronomers have never observed unrelated supernova in the same place decades apart. "We are beyond the cutting-edge of models," Arcavi said.

BEYOND CUTTING EDGE

"I'm not sure, and I don't think anyone else is sure, just what the hell is happening," astrophysicist Stanford Woosley, at University of California, Santa Cruz, told Space.com. "And yet it happened, and so it begs explanation."

Woosley is not affiliated with the study, but he is among the theoreticians working to understand the event. Two hypotheses show promise in explaining it, he said.

The first involves the famous equation E = mc2. With this formula , Albert Einstein demonstrated that matter and energy are fundamentally interchangeable. Stars burn by converting matter into energy, fusing lighter elements like hydrogen and helium into heavier elements, which build up in the star's core and also release energy. When a star more than 80 times the mass of the sun reaches a temperature of 1 billion degrees Celsius (1.8 billion degrees Fahrenheit), this energy-matter equivalence produces pairs of electrons and their antiparticle counterparts, positrons, Woosley said. The process robs the star of energy, and so the object shrinks.

But as this happens, the temperature rises in the star's core. At 3 billion C (5.4 billion F), oxygen fuses explosively, blowing off massive amounts of material and resetting the cycle. This process repeats until the star reaches a stable mass, explained Woosley. When the front of an ejected shell of material hits the trailing edge of a previous shell, it releases energy as light.

The star continues to fuse oxygen and the elements of greater masses, up until iron, at which point the reaction fails to release enough energy to keep the star from collapsing in on itself.Eventually, a star like the one that gave rise to iPTF14hls will collapse into a black hole without another explosion, said Woosley.

This phenomenon, called a pulsation pair instability (PPI) supernova, could account for iPTF14hls' sustained luminosity as well as the object's varying brightness. This explanation would require the star to have been 105 times the mass of the sun, said Woosley. However, the PPI model cannot account for the tremendous amount of energy iPTF14hls has released. The first explosion of 2014 had more energy than the model predicts for all the explosions combined, said Arcavi.

What's more, this phenomenon has yet to be verified observationally. "Stars between 80 and 140 solar masses, which do this kind of thing, have to exist," said Woosley, "and they have to die, and so, somewhere, this has to be going on." But no one has seen it yet, he said.

A MAGNETIC SUPERSTORM

An alternative explanation involves a star 20 to 30 times the mass of Earth's sun. After a more conventional supernova, such a star could have condensed into a rapidly spinning neutron star, called a magnetar.

A neutron star packs the mass of 1.5 suns into an object with a diameter about the size of New York City. A neutron star rotating at 1,000 times per second would have more energy than a supernova, according to Woosley. It would also generate a magnetic field 100 trillion to 1 quadrillion times the strength of Earth's field. As the star spun down over the course of several months, its incredible magnetic field could transfer the star's rotational energy into the remnants of the supernova that it formed from, releasing light, Woosley explained.

"It's like there's a lighthouse down in the middle of the supernova," said Woolsey.

But the magnetar explanation is not perfect, either. It has trouble explaining the dips and peaks in iPTF14hls' brightness, and the physics behind how such a phenomenon might work is still uncertain, said Woosley.

As iPTF14hls sheds energy, Arcavi said he hopes to be able to see deeper into the object's structure. If it is a magnetar, then he expects to see X-rays, previously obscured by the supernova itself, beginning to break through, he said. "Maybe by combining pulsation pair instability with [a magnetar], you can start to explain the supernova," Arcavi said.

KEEPING BUSY WHILE KEEPING WATCH

The existence of iPTF14hls has far-reaching implications, the researchers said. At 500 million light-years away, the supernova is still relatively close to Earth, and the universe is practically the same today—in terms of composition and organization —as it was when this event occurred, according to Arcavi. If the event was a PPI supernova, it tells astronomers that stars more than 100 times the mass of the sun—thought to be more prevalent in the early universe—are still forming today.

The event also had far more hydrogen than researchers expected to see. The explosion in 1954 should have expelled nearly all of the star's hydrogen, said Arcavi. Astrophysicists will have to revisit their models of supernovas to understand how this can occur, he said.

The finding has ramifications for the study of galaxies as well. "The energy of the gravity that's keeping that galaxy together is about the same order of magnitude as the energy that was released in the supernova," Arcavi said. "So, a few of these in a galaxy could actually unbind the entire galaxy."

Arcavi and his team plan to continue monitoring iPTF14hls for at least one to two years. And a suite of international telescopes and observatories will join the effort. Swedish colleagues at the Nordic Optical Telescope, in the Canary Islands, will track the object as it continues to dim beyond what Arcavi's telescope array can detect. NASA's Swift spacecraft will look for X-ray emissions, while the Hubble Space Telescope is scheduled to image the location beginning in December, and others will follow, Arcavi said.

For now, the event remains a mystery. "It's just a puzzle in the sky," said Woosley. "That's what we live for, what astronomers love."

UNIT 4. CELLS AND GENES

Vocabulary 1

brain stem cells	стовбурові клітини мозку
cell	клітина
lissencephaly	ліссенцефалія
microscope slides	предметне скло мікроскопу
mutation	мутація
nutrients	поживні речовини
organoids	органоїди

Mini brains may wrinkle and fold just like ours

Growing organoids on glass provides a window into the push and pull of brain cells

PHILADELPHIA — Flat brains growing on microscope slides may have revealed a new wrinkle in the story of how the brain folds.

Cells inside the brains contract, while cells on the outside grow and push outward, researchers at the Weizmann Institute of Science in Rehovot, Israel, discovered from working with the lab-grown brains, or organoids. This push and pull results in folds in the organoids similar to those found in full-size brains. Orly Reiner reported the results December 5 at the joint meeting of the American Society for Cell Biology and the European Molecular Biology Organization.

Reiner and her colleagues sandwiched human brain stem cells between a glass microscope slide and a porous membrane. The apparatus allowed the cells access to nutrients and oxygen while giving the researchers a peek at how the organoids grew. The cells formed layered sheets that closed up at the edges, making the organoids resemble pita bread, Reiner said. Wrinkles began to form in the outer layers of the organoids about six days after the mini brains started growing.

These brain organoids may help explain why people with lissencephaly — a rare brain malformation in which the ridges and folds are missing — have smooth brains. The researchers used the CRISPR/Cas9 gene-editing system to make a mutation in the *LIS1* gene. People with lissencephaly often have mutations in that gene. Cells carrying the mutation didn't contract or move normally, the team found.

Reiner and her colleagues aren't the first to propose the push-pull idea for how brains fold. But the researchers were able to show the concept at work in their experimental system, says biophysicist Xavier Trepat of the Institute for Bioengineering of Catalonia in Barcelona, who was not involved in the study. "They really were able to reproduce the shape of what we all imagine the brain should look like," he says. "It's not a brain, but they see structures that look like it."

Vocabulary 2

DNA	ДНК, дезоксирибонуклеїнова кислота
embryonic development	ембріональний розвиток;
embryonic stem cells	стовбурові клітини ембріона
genetic code	генетичний год
ribosomal building blocks	рибосомні складові
ribosomal components	рибосомні компоненти
ribosome	рибосома
RNA	РНК, рибонуклеїнова кислота

Not all of a cell’s protein-making machines do the same job

Some ribosomes specialize and may even play a role in embryonic development, early work suggests

PHILADELPHIA — Protein-manufacturing factories within cells are picky about which widgets they construct, new research suggests. These ribosomes may not build all kinds of proteins, instead opting to craft only specialty products.

Some of that specialization may influence the course of embryo development, developmental biologist and geneticist Maria Barna of Stanford University School of Medicine and colleagues discovered. Barna reported the findings December 5 at the joint meeting of the American Society for Cell Biology and European Molecular Biology Organization.

Ribosomes, which are themselves made up of many proteins and RNAs, read genetic instructions copied from DNA into messenger RNAs. The ribosomes then translate those instructions into other proteins that build cells and carry out cellular functions. A typical mammalian cell may carry 10 million ribosomes. “The textbook view of ribosomes is that they are all the same,” Barna said. Even many cell biologists have paid little attention to the structures, viewing them as “backstage players in controlling the genetic code.”

But that view may soon change. Ribosomes actually come in many varieties, incorporating different proteins, Barna and colleagues found. Each variety of ribosome may be responsible for reading a subset of messenger RNAs, recent studies suggest. For instance, ribosomes containing the ribosomal protein RPS25 build all of the proteins involved in processing vitamin B12, Barna and colleagues reported July 6 in *Molecular Cell*. Vitamin B12 helps red blood cells and nerves work properly, among other functions. Perhaps other biological processes are also controlled, in part, by having specific types of ribosomes build particular proteins, Barna said.

In unpublished work presented at the meeting, Barna and colleagues also found that certain ribosome varieties may be important at different stages of embryonic development. The researchers coaxed embryonic stem cells growing in lab dishes to develop into many types of cells. The team then examined the ribosomal proteins found in each type of cell. Of the 80 ribosomal proteins examined, 31 changed protein levels in at least one cell type, Barna said. The finding may indicate that specialized ribosomes help set a cell's identity.

Although Barna's idea of diverse ribosomes goes against the classical textbook view, "the concept is not heretical at all," says Vassie Ware, a molecular cell biologist at Lehigh University in Bethlehem, Pa., not involved in the work.

These findings may help explain why some people with mutations in certain ribosomal protein genes develop conditions such as Diamond-Blackfan anemia — a blood disorder in which the bone marrow doesn't make enough red blood cells — but don't have problems in other body tissues, Ware says.

That disease is caused by mutations in the *RPL5* and *RPL11* genes, which encode ribosomal building blocks. If all ribosomes were alike, people with mutations in ribosomal components should have malfunctions all over their bodies, or might not ever be born. RPL5 and RPL11 proteins may be part of specialized ribosomes that are important in the bone marrow but not elsewhere in the body.

Vocabulary 3

bacteria strains' genetic makeup	генетична характеристика штамів бактерій
blood sample	проба крові
extra genes	додатковий ген
foodborne illness	хвороби, що передаються аліментарним шляхом
genetic diversity	генетичне розмаїття
genetic variation	генетична варіація
immune responses	імунологічна реакція
immune system	імунна система
microbe	мікроб
strep bacteria	бактерія стрептокока
supplementary gene	додатковий ген

Not all strep infections are alike and it may have nothing to do with you

Variation in bacteria strains' genetic makeup, not your immune system, could be to blame

One person infected with strep bacteria might get a painful sore throat; another might face a life-threatening blood infection. Now, scientists are trying to pin down why.

Variation between individuals' immune systems may not be entirely to blame. Instead, extra genes picked up by some pathogens can cause different strains to have wildly different effects on the immune system, even in the same person, researchers report January 11 in *PLOS Pathogens*.

The idea that different strains of bacteria can behave differently in the body isn't new. Take *E. coli:* Some strains of the bacteria that can cause foodborne illness make people far sicker than other strains. But bacteria have exceptionally large amounts of genetic variation, even between members of the same species. Scientists are still trying to figure out how that genetic diversity affects the way microbes interact with the immune system.

Any species of bacteria has a core set of genes that all its members share. Then there's a whole pot of genes that different strains of the species pick and choose to create what's known as an accessory genome. These genes are custom add-ons that specific strains have acquired over time, from their environment or from other microbes — something like an expansion pack for a card game. Sometimes, that extra genetic material gives bacteria new traits.

Uri Sela and his colleagues at the Rockefeller University in New York City tested the way these extra genes influenced the way two common species of bacteria, *Staphylococcus aureus* and *Streptococcus pyogenes*, interacted with the immune system. *Staphylococcus* bacteria can cause everything from rashes to food poisoning to blood infections. *Streptococcus* bacteria can cause strep throat, as well as a host of more serious illnesses (*SN: 10/4/14, p. 22*).

Different strains of the same species provoked wildly different immune responses in blood samples collected from the same patient, the researchers first showed. But the strain-specific responses were consistent across patients. Some strains triggered lots of T cells to be made in every sample, for example; others increased B cell activity. (T cells and B cells are the two main weapons of the adaptive immune response, which enables the body to build long-lasting immunity against a particular pathogen.) In tests of strains missing some of their extra genes, though, the T cells didn't respond as strongly as they did to a matching strain that contained the extra genes. This finding suggests that the variation in immune response across strains was coming, at least in part, from differences in these supplementary genes.

"Currently when a patient comes to the hospital with an infection, we don't define the strain of the species" for common infections like strep and staph, says Sela, an immunologist. In the future, he says, information about the strain could help doctors predict how a patient's illness will unfold and decide on the best treatment.

The new study "adds fuel to an active debate" about the role of accessory genes, says Alan McNally, a microbiologist at the University of Birmingham in England — whether or not the collections of genetic add-ons that bacteria maintain are shaped by natural selection, the process that fuels evolution. This research suggests that for some kinds of bacteria, genetic customization might aid survival of certain strains by enabling them to provoke a tailored immune response.

But more research needs to be done to link the strain-to-strain variation in immune response to the accessory genome, he says, as this study looked at only a few extra genes, not the entire accessory genome.

Vocabulary 4

body clock	біологічні часи
cellular gears	клітинний механізм

chronic sleep deprivation	хронічне позбавлення сну
circadian clocks	циркадіанний годинник
circadian rhythms	циркадіанні ритми
daily rhythms	щоденні ритми
geneticist	генетик
jet lag	синдром зміни часових поясів,

Cracking the body clock code wins trio a Nobel Prize

Three Americans recognized for discovering the cellular gears that drive circadian rhythms

Discoveries about the molecular ups and downs of fruit flies' daily lives have won Jeffrey C. Hall, Michael Rosbashand Michael W. Young the Nobel Prize in physiology or medicine.

These three Americans were honored October 2 by the Nobel Assembly at the Karolinska Institute in Stockholm for their work in discovering important gears in the circadian clocks of animals. The trio will equally split the 9 million Swedish kronor prize — each taking home the equivalent of $367,000.

The researchers did their work in fruit flies. But "an awful lot of what was subsequently found out in the fruit flies turns out also to be true and of huge relevance to humans," says John O'Neill, a circadian cell biologist at the MRC Laboratory of Molecular Biology in Cambridge, England. Mammals, humans included, have circadian clocks that work with the same logic and many of the same gears found in fruit flies, say Jennifer Loros and Jay Dunlap, geneticists at the Geisel School of Medicine at Dartmouth College.

Circadian clocks are networks of genes and proteins that govern daily rhythms and cycles such as sleep, the release of hormones, the rise and fall of body temperature and blood pressure, as well as other body processes. Circadian rhythms help organisms, including humans, anticipate and adapt to cyclic changes of light, dark and temperature caused by Earth's rotation. When circadian rhythms are thrown out of whack, jet lag results. Shift workers and people with chronic sleep deprivation experience long-term jet lag that has been linked to serious health consequences including cancer, diabetes, heart disease, obesity and depression.

Before the laureates did their work, other scientists had established that plants and animals have circadian rhythms. In 1971, Seymour Benzer and Ronald Konopka (both now deceased and ineligible for the Nobel Prize) found that fruit flies with mutations in a single gene called *period* had disrupted circadian rhythms, which caused the flies to move around at different times of day than normal.

"But then people got stuck," says chronobiologist Erik Herzog of Washington University in St. Louis. "We couldn't figure out what that gene was or how that gene worked."

At Brandeis University in Waltham, Mass., Hall, a geneticist, teamed up with molecular biologist Rosbash to identify the *period* gene at the molecular level in 1984. Young of the Rockefeller University in New York City simultaneously deciphered the gene’s DNA makeup. “In the beginning, we didn’t even know the other group was working on it, until we all showed up at a conference together and discovered we were working on the same thing,” says Young. “We said, ‘Well, let’s forge ahead. Best of luck.’”

t wasn’t immediately apparent how the gene regulated fruit fly activity. In 1990, Hall and Rosbash determined that levels of *period*’s messenger RNA — an intermediate step between DNA and protein — fell as levels of *period*’s protein, called PER, rose. That finding indicated that PER protein shuts down its own gene’s activity.

A clock, however, isn’t composed of just one gear, Young says. He discovered in 1994 another gene called *timeless*. That gene’s protein, called TIM, works with PER to drive the clock. Young also discovered other circadian clockworks, including *doubletime* and its protein DBT, which set the clock’s pace. Rosbash and Hall discovered yet more gears and the two groups competed and collaborated with each other. “This whole thing would not have turned out nearly as nicely if we’d been the only ones working on it, or they had,” Young says.

Since those discoveries, researchers have found that nearly every cell in the body contains a circadian clock, and almost every gene follows circadian rhythms in at least one type of cell. Some genes may have rhythm in the liver, but not the skin cells, for instance. “It’s normal to oscillate,” Herzog says.

Trouble arises when those clocks get out of sync with each other, says neuroscientist Joseph Takahashi at the University of Texas Southwestern Medical Center in Dallas. For instance, genes such as *cMyc* and *p53* help control cell growth and division. Scientists now know they are governed, in part, by the circadian clock. Disrupting the circadian clock’s smooth running could lead to cancer-promoting mistakes.

But while bad timing might lead to diseases, there’s also a potential upside. Scientists have also realized that giving drugs at the right time might make them more effective, Herzog says.

Rosbash joked during a news conference that his own circadian rhythms had been disrupted by the Nobel committee’s early morning phone call. When he heard the news that he’d won the prize, “I was shocked, breathless really. Literally. My wife said, ‘Start breathing,’" he told an interviewer from the Nobel committee.

Young’s sleep was untroubled by the call from Sweden. His home phone is the kitchen, and he didn’t hear it ring, so the committee was unable to reach him before making the announcement. “The rest of the world knew, but I didn’t,” he says. Rockefeller University president Richard Lifton called him on his cell phone and shared the news, throwing Young’s timing off, too. “This really did take me surprise,” Young said during a news conference. “I had trouble even putting my shoes on this morning. I’d go pick up the shoes and realize I needed the socks. And then ‘I should put my pants on first.’”

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