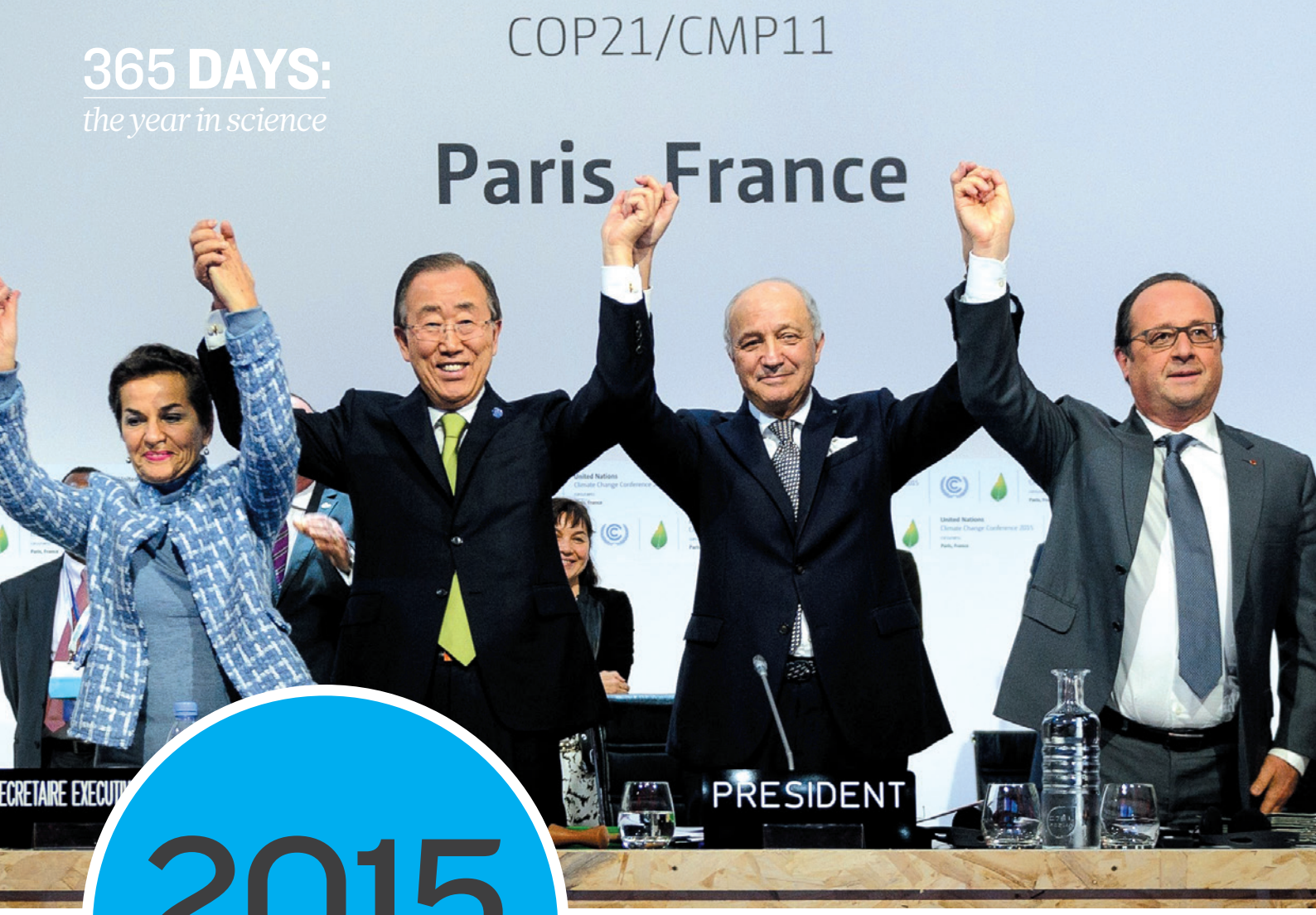

ARNAUD BOISSOU/COP21/ANADOLU/GETTY

2015 IN REVIEW

From climate change to gene-editing ethics, researchers tackled many thorny issues this year. They also made important discoveries — including ice mountains on Pluto, evidence of quantum weirdness and details about the molecular machines inside cells.

ROAD TO PARIS The world got serious this year about climate change. With the United Nations climate summit in Paris looming in December, both industrialized and developing nations pledged for the first time to control or reduce their greenhouse-gas emissions.

As the number of pledges grew during the year — to 184 by the time of the conference — so did optimism that the Paris talks would be a historic turning point in efforts to curb global warming (see page 460). The meeting, which took place under heightened security because of the Paris terrorist attacks in November, yielded a landmark agreement on 12 December that was approved by 195 countries. It commits most countries to reduce emissions and keep warming to 'well below' 2 °C. Nations will assess their progress in 2018 and must revisit their climate pledges every five years starting in 2020.

Climate negotiators were treated to some surprising good news in early December, when researchers at the Global Carbon Project reported that global carbon emissions could drop by 0.6% in 2015.

China and the United States, the world's biggest carbon emitters, helped to build momentum in the run-up to Paris. China announced that it would launch an emissions cap-and-trade system. And after years of indecision, US President Barack Obama made the symbolic move of saying no to the Keystone XL pipeline that would have transported oil from Canada to US refineries.

Even Pope Francis weighed in. He released an encyclical on the environment in June and gave speeches during his visit to North America in September that warned of the dangers of climate change and the urgent need to curb it. Two surveys of people in the United States that were conducted after the Pope's visit suggested that he helped to boost the acceptance of climate change as an important problem.

But nations' climate pledges will probably not keep warming to within 2 °C above pre-industrial levels, and past that point, many scientists think that the world will see warming-related ecological and economic disruptions. The average global surface temperature is now already 1 °C above pre-industrial levels, and 2015 will probably be the warmest year on record.

PLUTO *ET AL.* In Solar System exploration, dwarf planets ruled. The tiny worlds of Pluto and Ceres — the latter in the heart of the asteroid belt between Mars and Jupiter — received their first-ever spacecraft visits in

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Leaders at the UN climate meeting in Paris celebrated the adoption of a historic global warming agreement on 12 December.

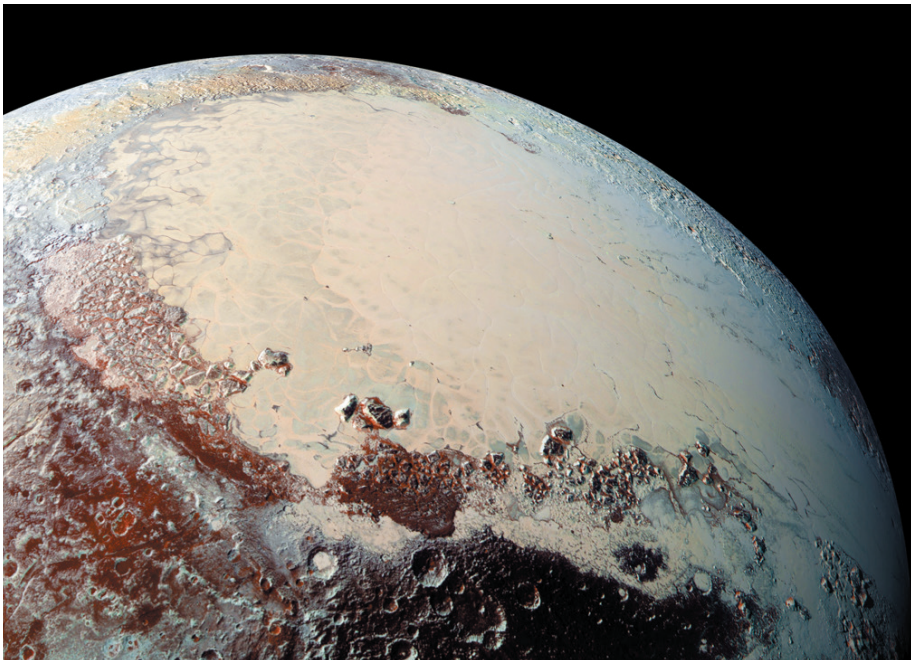
2015, producing many breathtaking images.

Pluto grabbed the spotlight when the New Horizons spacecraft flew past it on 14 July. The world revealed itself as a geological wonderland of ice mountains, nitrogen glaciers and smooth, frigid plains. The sheer complexity of Pluto's surface astounded planetary scientists, including principal investigator Alan Stern (see page 462), and raised major questions about what could be fuelling the geological activity that created it.

Ceres made a much more gradual appearance beginning in March, when its gravitational pull tugged NASA's Dawn spacecraft into orbit. The dark, water-rich body turns out to hold a number of its own mysteries, including a pyramid-shaped mountain, bright spots of reflective salt and an enigmatic haze that fills some of its craters in the morning sunlight.

The European Space Agency's Rosetta craft continued its spectacular orbit around Comet 67P/Churyumov–Gerasimenko. Its Philae lander, presumed lost after a bumpy landing in November 2014, phoned home in June before falling silent, perhaps permanently, the following month. Researchers analysing Rosetta data reported this year that oxygen is streaming out of the comet, and that its rubber-duck shape was probably a result of a low-speed collision between two smaller comets.

NASA's MAVEN (Mars Atmosphere and Volatile Evolution) mission delivered its first detailed measurements of how the solar wind strips away Mars's atmosphere over time, leading to the mostly airless world that Mars is today. And 11 years after arriving at the Saturn system, NASA's Cassini spacecraft confirmed that the buried ocean beneath the surface of the moon Enceladus stretches around the entire globe — making it a tempting place to hunt for extraterrestrial life.



NASA/JPL/SRI

NASA's New Horizons spacecraft sent back spectacular images of Pluto's rich terrain.

GENE EDITS TO ORDER

Rarely has a method roared onto the scene as quickly as the accurate, easy-to-use yet controversial CRISPR–Cas9 genome-editing system. In April, scientists in China reported use of the technique to edit non-viable human embryos (see page 461), which spurred researchers and bioethicists to debate in editorials and meetings whether the technology should ever be used in human embryos, even for basic research. The debate culminated in the International Summit on Human Gene Editing in early December in Washington DC, which brought together nearly 500 ethicists, scientists and legal experts from more than 20 countries. The organizers wrapped up the event with a statement: the tools are not yet ready to be used to edit the genomes of human embryos intended for pregnancy. But they did not call for an outright ban of this work for basic research.

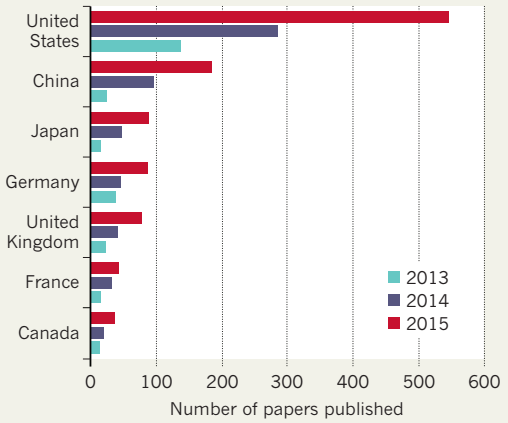
Over the past three years, CRISPR has become the tool of choice for scientists seeking to enhance animals and crops, and to cure human disease (see 'CRISPR craze'). In October, researchers set a record by editing the genomes of pig embryos in 62 places at once — a move that could help to revitalize the field of xenotransplantation. The genetic tinkering could lower the risk of exposure to potentially dangerous pig viruses when people receive human-like organs grown in swine. Dogs, goats and sheep have also had their DNA modified with the low-cost technology.

CRISPR could target human diseases as well. With that aim in mind, in August, Google and other investors pumped US$120 million into the genome-editing start-up Editas Medicine in Cambridge, Massachusetts. The firm plans to use CRISPR in clinical trials in 2017 to correct a genetic mutation in some people who are visually impaired.

Other, more mature genome-editing technologies are already entering the clinic. In November, researchers in the United Kingdom announced that they had used a different system — enzymes called TALENs — to edit human immune cells and transplant them into a one-year-old with leukaemia, possibly saving her life. And in December, scientists from Sangamo Biosciences in Richmond, California, announced that in 2016 they will begin a human trial to test DNA-snipping zinc-finger nucleases that correct a gene defect for haemophilia. ▶

CRISPR CRAZE

Research using the CRISPR gene-editing system is ramping up, as seen by the rise in the number of CRISPR-related publications.



SOURCE: SCOPUS; IMAGE: BGI

A technician from Chinese genomics institute BGI holds a 'micropig', whose genome was edited using TALEN enzymes.

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VACCINE VICTORIES Edward Jenner, who tested the first vaccine more than 200 years ago, would have been proud of the progress in 2015. After being fast-tracked into human trials this April, the rVSV-ZEBOV Ebola vaccine was found to offer near-total protection to people who received it soon after exposure to the disease, according to preliminary analysis of an ongoing clinical trial in Guinea. The vaccine consists of a weakened livestock virus that has been engineered to produce an Ebola protein, and it was the result of an accelerated development programme that experts say could be emulated to combat other emerging diseases.

But rVSV-ZEBOV arrived too late to have much impact on the Ebola epidemic, which has killed more than 11,000 people across West Africa. The disease is on the wane, but it made a surprising comeback in Liberia recently; after twice saying that it had rid itself of the virus, the country announced three new cases in November, including one death.

Nearly 30 years in the making, the world's first malaria vaccine won a lukewarm endorsement from a global vaccine advisory group in October. Researchers reported in April that the vaccine achieved a modest 30% protection rate in a clinical trial involving more than 15,000 children in Africa. The panel recommended pilot tests of the vaccine, called RTS,S, in up to 1 million children before it is widely distributed.

Polio vaccines brought the debilitating disease nearer than ever to global eradication: this year, just 66 wild-poliovirus cases were recorded as of 9 December. In July, Nigeria — one of three countries, along with Pakistan and Afghanistan, that have never interrupted the spread of the virus — celebrated a full year without a new wild-poliovirus infection for the first time, prompting the World Health Organization to remove the country from its list of polio-endemic nations in September. This paves the way for Africa to be declared polio-free as early as 2017.

Finally, Mexico approved the first ever vaccine against dengue virus. The vaccine's maker, Paris-based Sanofi, now hopes to secure approval in other countries in Latin America and Asia.

5,154

A RECORD NUMBER OF AUTHORS ON A PAPER WAS SET THIS YEAR.

QUANTUM SPOOKINESS Physicists celebrated the 100th anniversary of Albert Einstein's general theory of relativity in November with special conferences, books and collections of his papers. Einstein also made headlines in August when physicists presented the most convincing proof yet that two objects, such as subatomic particles, could be linked, or 'entangled'. This would allow one particle to influence the behaviour of another, even if the two are widely separated. Researchers showed that they could produce a robust entanglement between two electrons placed 1.3 kilometres from each other.

Einstein famously despised this phenomenon, which he called 'spooky action at a distance', because it seemingly broke the universal rule that nothing can travel faster than the speed of light. Despite Einstein's misgivings, the approach could one day be used to build a highly secure quantum Internet that is immune to hackers.

ARTIFICIAL EARTHQUAKES Oil and gas exploration and other human activities are thought to have triggered earthquakes worldwide, from Switzerland to India and China, but nowhere have scientists scrambled to understand and respond to the quakes as much as in Oklahoma. The state began recording an increase in seismicity in 2009, and this year experienced the most yet — it now has more quakes of magnitude 3 and above each year than California.

In April, officials finally acknowledged the probable role of the energy industry. The Oklahoma Geological Survey announced that oil and gas wells that pump wastewater deep into the ground are probably to blame: the injection of tens of millions of litres of liquid shifts fault stresses and increases the likelihood of quakes.

In response, the Oklahoma Corporation Commission, which regulates oil and gas exploration, cut back on the number of wastewater disposal wells allowed in the areas with the most seismic activity — a remarkable move given how powerful the energy industry is in state politics.

RESEARCH RELIABILITY RATED Debate about how to boost the reproducibility of research results shifted from handwringing to analysis and action in 2015.

Researchers in an array of fields struggle to independently reproduce published results for many reasons, ranging from poorly described methods to flawed data analysis.

In December, the US-based Reproducibility Project: Cancer Biology announced that it had scaled back its attempts to reproduce high-profile papers in cancer biology, from 50 papers to 37, because of the excessive cost and time required.

Efforts to quantify the problem bore fruit this year. In April, another Reproducibility Project team showed that some two-thirds of attempts to replicate published psychology studies ended in failure (see page 466). And a controversial analysis estimated that US$28 billion a year is spent on biomedical studies that are not reproducible, often because of poor documentation and flawed materials.

Funders have responded. Key biomedical institutes in the United Kingdom, including the Wellcome Trust, released a report this year sketching out strategies to improve reproducibility, such as standardizing experimental practices. The US National Institutes of Health (NIH) released reproducibility guidelines in October. These asked grant reviewers to look for

A three-week-old baby in Guinea was one of the last patients in the Ebola outbreak.

SAMUEL ARANDA/NYT/REDUX/EYEVINE

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flaws in experimental design that might introduce bias and requested that grant applicants describe how they will authenticate reagents. Some scientific societies pushed back this year on another set of NIH guidelines from 2014 that required authors to describe their experiments more fully. The societies said that the rules would make the preparation and reviewing of papers too burdensome. Publishers are also getting involved: around a dozen journals this year began asking their authors to use unique identifiers for their reagents as part of a push by the Resource Identification Initiative.

SPOTLIGHT ON SEXISM The discussion about sexism grew more public this year, driven by several incidents that highlighted how chauvinism still permeates science. In April, evolutionary geneticist Fiona Ingleby of the University of Sussex in Brighton, UK, revealed on Twitter that *PLoS ONE* had rejected a paper that she wrote with a female colleague, after a reviewer said that adding "one or two" male co-authors would improve the analysis. The journal removed the reviewer from its database and asked the academic editor handling the paper to step down from its editorial board.

In June, Nobel-prizewinning biologist Tim Hunt drew widespread criticism when he spoke of his "trouble with girls" in laboratories. "You fall in love with them, they fall in love with you, and when you criticize them, they cry," he said at an international science-journalism conference in Seoul. Hunt, who two days later resigned from his post as an honorary professor at University College London, said that he had meant to be light-hearted and that he had been "hung out to dry", but the university did not reinstate him.

1,377

THE NUMBER OF PHYSICISTS WHO SHARED THE US$3-MILLION BREAKTHROUGH PRIZE IN FUNDAMENTAL PHYSICS, WHICH WAS AWARDED IN NOVEMBER FOR RESEARCH ON NEUTRINOS.

PETE SOUZA/WHITE HOUSE

US President Barack Obama announced the Precision Medicine Initiative in January.

October brought the biggest story of all: the revelation that renowned exoplanet hunter Geoffrey Marcy had sexually harassed multiple students over at least a decade. Marcy resigned from his post at the University of California, Berkeley, amid public outrage from colleagues at the university and in astronomy more widely (see page 464). The case has prompted soul-searching among scientific societies, and several are developing or re-evaluating policies intended to prevent sexual harassment at meetings and other events.

MOLECULAR FREEZE-FRAME Structural biologists uncovered unprecedented detail on life's molecular machinery this year, thanks to advances in a technique called cryo-electron microscopy (cryo-EM). Researchers can determine structures of cellular proteins by flash-freezing them, then photographing them at near-atomic resolution using an electron microscope. Cryo-EM has usurped X-ray crystallography in the past three years because it doesn't require proteins to be crystallized first, allowing researchers to analyse many more molecules.

Using the technique, biologists have mapped well over 100 molecular structures in detail this year, including the proteasome, which recycles damaged or unwanted proteins, and the spliceosome, which chops out pieces of messenger RNA before the sequence is translated into protein. This year also saw the sharpest cryo-EM structure so far — that of a bacterial enzyme involved in sugar breakdown — and researchers hope to bring this level of detail to medically important molecules.

MAKING MEDICINE PRECISE Tailoring treatments to individual patients has long been a goal in biomedicine, but US President Barack Obama gave this effort a big boost with his announcement in January of the Precision Medicine Initiative (PMI). As part of the US$215-million programme, which will award its first grants next year, the NIH and partner organizations will recruit one million people across the country, collecting genetic information, health records and even data from electronic health-monitoring devices. Researchers will use the information to look for links between disease risk and genetic and environmental factors.

The PMI inspired other governments to bet on giant longitudinal studies of their own. Soon after Obama's speech, California announced a $3-million initiative. And China is expected to launch its own large-scale project next year, which will take advantage of the country's considerable genomic-sequencing capacity.

Iceland showed this year what is possible with large numbers of human-genome sequences. In March, the Icelandic firm deCODE genetics in Reykjavik published four papers on its analysis of more than 2,600 full genomic sequences from Icelanders — the largest collection of human genomes from a single population. It described mutations linked to Alzheimer's disease and mutation rates in the Y chromosome. ■

Written by Monya Baker, Ewen Callaway, Davide Castelvecchi, Lauren Morello, Sara Reardon, Quirin Schiermeier & Alexandra Witze.

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