turn their attention to tying the definition of the second to more-precise clocks, and potentially add more units to the system. "It's like at the end of the Harry Potter series. Good triumphs, but everything's just trashed," says David Newell, a physicist at NIST. In the SI, he adds, "there's still a whole load of mess that still needs to be cleaned up".

FOCUS ON THE CONSTANT

Measurements must always be made against a reference, and standard references ensure that units are comparable and consistent across the world — from measuring milligrams of drugs to the timing of Global Positioning Systems. The idea of basing all units on constants of nature has been around since the late nineteenth century. But it has taken almost 150 years for scientists to measure the values with enough accuracy to do so.

Metrologists working on electricity have refined experiments that count the flow of individual electrons, allowing them to use the charge on a single such particle to determine the ampere — replacing a definition that is based on a hypothetical experiment involving two infinitely long wires, which in reality can only be approximated. The kelvin will soon be defined by the Boltzmann constant, which links energy and temperature, rather than in reference to conditions at a specific temperature of water, known as the triple point.

Meanwhile, the mole — long measured as the number of atoms in 0.012 kilograms of carbon-12 — will soon equal the number of particles specified by Avogadro's number.

In the case of the kilogram, redefinition meant measuring with exquisite precision Planck's constant, a number that defines the size of packets of energy at the quantum scale. One method, known as a Kibble balance, derives Planck's constant by weighing a known mass against an electromagnetic force. Another counts the atoms in two spheres of silicon-28 to derive a value for Avogadro's number, which is converted to Planck's constant.

Teams applying the two different methods only reached values that were accurate and in close enough agreement in 2015. "The fact that they agree to a few parts in 10 million is absolutely extraordinary, as they are definitions based on completely different areas of physics," says Terry Quinn, former head of the International Bureau of Weights and Measures (BIPM).

> *"It's like the end of the Harry Potter series. Good triumphs, but everything's just trashed."*

Because physical artefacts are vulnerable to being lost or damaged, the change makes the mass definition more reliable. Although Le Grand K has, by definition, always weighed exactly 1 kilogram, its mass has changed slightly relative to copies. It has been impossible to say whether Le Grand K loses or gains atoms, but future studies should now reveal that. A beauty of the system is that any experiment — once international comparisons have shown it to be accurate — can be used to determine the unit, says Estefanía de Mirandés, a metrologist at the BIPM. This not only makes the system more democratic, it also 'future-proofs' the definitions, so that they can be used with more-precise experiments in the future, she says, potentially unlocking new technologies. Already, it allows measurements of very large and very small masses with much greater precision than today, she explains.

The second is currently described in relation to the frequency of microwave light absorbed and emitted by caesium-133 atoms. These atoms are now surpassed by 'optical clocks', which use different atoms that interact with higher-frequency visible light and seem to be able to keep time with less error: just 1 second over the age of the Universe. To update the definition of the second in 2026, as many metrologists hope will happen, the community will need to develop methods to compare optical clocks around the world and decide which atom, or atoms, to use as the standard.

Another bugbear that metrologists might try to resolve is finding a smoother way to include dimensionless quantities — such as the radian, the ratio of the length of an arc of a circle to its radius — in the SI system. "In some communities, there's a huge push for that," says de Mirandés.

For the BIPM, which was founded in 1875 to host the physical kilogram and metre standards, the SI revolution is bittersweet. Speakers at the meeting cheerfully quipped that there is no need to go to Paris any more. The BIPM now hopes to forge a role making comparisons between worldwide realizations of units, to ensure their accuracy, says de Mirandés. "It's the end of a period, but also the start of a new one." ■

POLITICS

Brexit divorce deal divides politicians and scientists

Draft treaty confirms Britain will leave European nuclear body — but uncertainties remain.

BY ELIZABETH GIBNEY & HOLLY ELSE

After two years of negotiations, the first real glimmers of what Brexit might involve have emerged. On 14 November, the Cabinet, the UK government's senior decision-making body, backed a draft agreement that defines the terms of the country's withdrawal from the European Union.

For science, many of the specifics that will be most relevant are still to be thrashed out. The 585-page exit treaty, if approved, largely confirms previous commitments made by the UK government, and mostly outlines what will happen during the transition period that begins after Britain leaves the bloc on 29 March 2019 and finishes at the end of 2020.

The text offers details on the future of nuclear regulation in the United Kingdom — but it has little to say on immigration or how access to valuable EU research funds might change. These details are likely to form part of a later agreement that will define the future UK–EU relationship, and which will be negotiated only after March 2019.

An outline of the structure of this relationship, sketched out in a short accompanying document, hints at the possibility of visa-free travel for short visits to and from EU countries after Brexit — encouraging news for researchers who are used to travelling for collaborations and conferences.

WHAT'S IN THE EXIT DEAL?

Hammered out in fraught negotiations with EU officials, the withdrawal agreement would allow EU citizens currently living in Britain, and their families, to claim permanent residence. This should ease fears expressed by many EU nationals resident in the country, including many scientists, that they would have to leave their jobs after Brexit.

The agreement also confirms that Britain will leave the European Atomic Energy Community, Euratom, when it pulls out of the EU.

UK Prime Minister Theresa May is seeking parliamentary support for the draft Brexit deal.

TOLGA AKMEN/AFP/GETTY

It fleshes out commitments made in a joint statement last December that Britain will be responsible for international nuclear safeguards in its own territory, in line with the existing regime overseen by Euratom.

But the document doesn't address a key concern for some researchers: whether Britain can retain membership of the nuclear-fusion experiment, ITER, in France, which it currently has through Euratom.

Nor does it indicate whether the UK-based test bed for this project — the Joint European Torus near Oxford, which is largely EU-funded — will receive any cash after its current contract expires at the end of this year.

The agreement confirms that, during the transition period, UK scientists will remain eligible for grants under the Horizon 2020 research-funding programme until the programme ends.

And in statements following the deal's announcement, UK Prime Minister Theresa May offered some information on the possible shape of Britain's post-Brexit immigration system. She confirmed that 'free movement' between the United Kingdom and the bloc — something that researchers say has fuelled scientific collaboration — would end, and suggested that Britain would shift to a skills-based immigration system that would not offer priority to EU citizens over those from the rest of the world.

POLITICAL BACKLASH

For research, the deal "looks pretty good if we have to proceed with Brexit", says Alastair Buchan, a pro-vice-chancellor of the University of Oxford.

However, Nobel-prizewinning geneticist Paul Nurse says that the agreement is disappointing for UK scientists. He welcomes the certainty it offers EU citizens living in the United Kingdom, but laments the lack of information about whether highly skilled EU scientists will be able to work in the country in the future.

The agreement has divided politicians, and turmoil in Parliament has cast doubt on whether it will pass the next step of approval required by the United Kingdom — a vote in Parliament, slated for December. The potential resulting ructions would increase the prospect of Britain crashing out of the EU without any kind of agreement on a future relationship — a situation widely feared by the science community.

"The threat of a chaotic no-deal Brexit cannot be considered an option."

"The threat of a chaotic no-deal Brexit cannot be considered an option," says Venki Ramakrishnan, president of the Royal Society in London.

At an emergency summit of the European Council to be held on 25 November, the leaders of the 27 other EU countries are expected to formalize the agreement.

If May's support holds, and the deal is approved by Parliament, it must then go before the European Parliament and garner the approval of a majority of member states.

If Parliament rejects the deal, Britain and the EU could go back to the negotiating table, but would have only until the departure date to agree on new terms. ■ SEE EDITORIAL P.443

NEUROSCIENCE

'Mini brains' show human-like activity

Electrical patterns resemble those in premature babies.

BY SARA REARDON

'Mini brains' grown in a dish have spontaneously produced human-like brain waves for the first time — and the electrical patterns look similar to those seen in premature babies.

The advance could help scientists to study early brain development, and many are excited about the promise of these 'organoids'. But it also raises ethical concerns about creating miniature organs that could develop consciousness.

Researchers led by neuroscientist Alysson Muotri of the University of California, San Diego, coaxed human stem cells to form tissue from the cortex — a brain region that controls cognition and interprets sensory information. The group presented the work at the Society for Neuroscience meeting in San Diego this month.

Muotri and his colleagues grew hundreds of brain organoids in culture and continuously recorded electrical patterns, or electroencephalogram (EEG) activity, across the surface of the mini brains. The scientists were surprised by the EEG patterns that they observed.

In mature brains, neurons form synchronized networks that fire with predictable rhythms. But the organoids displayed EEG patterns that resembled the chaotic bursts of synchronized electrical activity seen in the brains of premature babies born at 25–39 weeks post-conception. Muotri is quick to caution, however, that the organoids aren't close to being human brains.

The work is preliminary, says Hongjun Song, a developmental neuroscientist at the University of Pennsylvania in Philadelphia. But the similarities to preterm-infant EEG patterns suggest that the organoids could eventually be useful for studying brain-development disorders, such as epilepsy or autism, he adds.

But not everyone agrees. Just because the organoids' brain waves look like those in premature babies doesn't mean they're doing the same thing, says Sampsa Vanhatalo, a neurophysiologist at the University of Helsinki.

And the ethical questions that this project raises about whether organoids could develop consciousness will be difficult to resolve, says neuroscientist Christof Koch of the Allen Institute for Brain Science in Seattle, Washington. Researchers don't even agree on how to measure consciousness in adults, or when it appears in infants, he says. ■