The EU affects science from the collaborative opportunities that the bloc creates to the billions of euros that it distributes for research and innovation.

VIKTOR DRACHEV/AFP/GETTY

EUROPEAN UNION

Boon or burden: what has the EU ever done for science?

More than 500 million people and 28 nations make up the European Union. It will lose one of its richest, most populous members, if the United Kingdom votes to leave on 23 June. Ahead of a possible 'Brexit', Nature *examines five core ways that the EU shapes the course of research.*

SCIENTIST SUPERHIGHWAY

Science doesn't respect national boundaries, so it helps if scientists don't have to either — and EU rules and programmes encourage researchers to hit the road.

EU citizens have the right to live and work in any country in the bloc, and the European Commission's Marie Skłodowska-Curie actions pay for 9,000 scientists each year to move to or within the EU. The actions fill a gap left by national funders, which are often reluctant to fund researchers outside their country, says Caroline Whelan, a senior scientific officer at Science Europe, the Brussels-based organization of national research councils. The EU Erasmus exchange programme has transplanted more than 3.3 million students, and 470,000 teaching and administrative staff, since 1987.

Although there is little information on how such programmes affect scientists' overall mobility, they boost opportunities for collaboration. And because Marie Skłodowska-Curie fellows often return to their home country, they redistribute skills and knowledge. "This is fantastic for Eastern Europe and other less-well developed countries to build research capacity," says Lidia Borrell-Damian, director for research and innovation at the European University Association in Brussels.

A 2011–13 study found that 31% of EU academics had worked outside their country of residence in the previous decade. And leading scientists say that hiring from abroad helps them to respond to local skills shortages. The survey also found that 80% of those who had worked internationally saw a positive effect on their research skills, and 60% thought that mobility had strongly increased their research output (see go.nature.com/28wvqta).

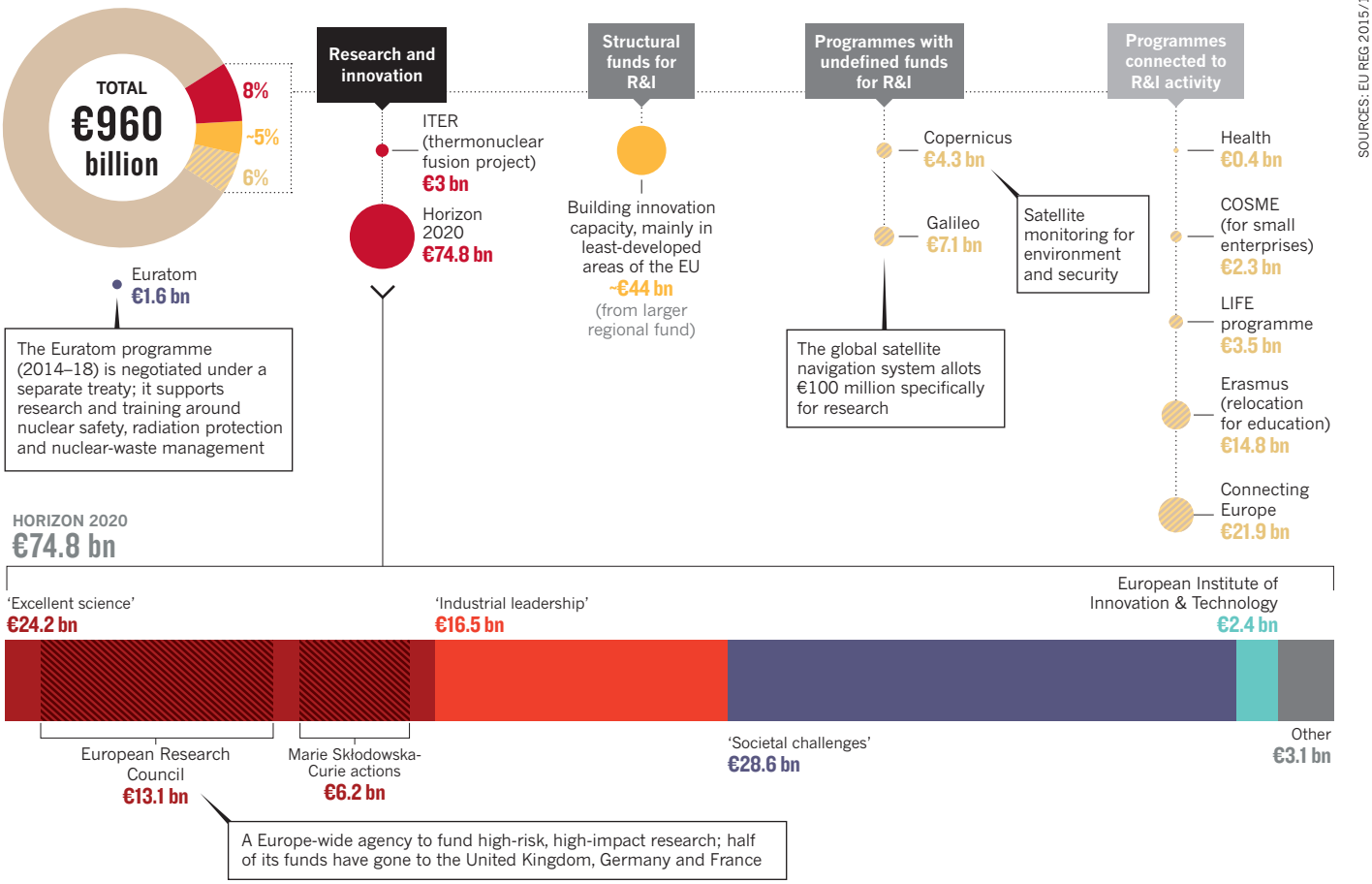
But the experiences were not all positive: more academics said that their job options had decreased as a result of moving than said that opportunities had increased, for example.

Another downside of mobility is that much of the flow goes just one way, says Maria Helena Nazaré, a physicist and former rector of the University of Aveiro in Portugal. "I think that's already creating problems." Countries such as the United Kingdom, the Netherlands and Sweden tend to be net attractors for the Marie Skłodowska-Curie actions, whereas Spain, Greece and Italy lose talent. Nazaré also notes that transferring pension and benefits between countries can be tough.

Still, the commission is committed to further greasing the wheels. Funding aimed at encouraging mobility has soared in the past two decades to €6.2 billion (US$6.9 billion) in 2014–20 — and the commission is tackling the pensions issue. It is also growing its EURAXESS portal, an EU-wide website that lists jobs and support for moving researchers, and has revamped its 'scientific visa' package for non-EU researchers. Notably, the United Kingdom has opted out of the visa, together with Denmark. ▶

EU SPENDING

The European Union has dedicated more than €120 billion (almost 13%) of its 2014–20 budget to research and innovation (R&I). A host of other EU-funded programmes also support or are connected to R&I activities, but don't define the amount of their investment.



SOURCES: EU REG 2015/1017; EPRS

UNIQUE SCIENCE

Scientists like to complain loudly about some aspects of the commission's 'Framework' funding programmes, which are dedicated to research and innovation (see 'EU spending').

To access a vast pot of cash geared to meeting 'Societal Challenges' — which amounts to an estimated €28.6 billion of the €74.8 billion available under Horizon 2020, the Framework programme for 2014–20 — they must meld themselves into large multinational collaborations, and adjust their research to fit EU strategic goals. But these constraints have fostered many valuable projects.

"I am a big fan of these programmes," says Nadia Rosenthal, scientific director of the Jackson Laboratory in Bar Harbor, Maine, who has collaborated with several EU consortia on mouse-genetics projects, which she says generated world-class science. "The coordination of talents they can achieve would be very hard to pull off in the United States — or in the UK alone, if it were not connected to Europe."

Take research into the health effects of low-dose radiation, which people may encounter during a CT scan or if they live within a few tens of kilometres of the site of the Fukushima disaster in Japan. So small are the risks — if they exist at all — that such research is low on most funding agencies' list of priorities.

But the issue is of perennial concern to the public. And studying it requires collaboration between radiation-protection agencies and academics, as well as the use of large data sets, which can be gathered only by multiple collaborating nations.

These factors make low-dose-radiation studies perfect fodder for EU funding, says Thomas Jung, head of radiation protection and health at the German Federal Office of Radiation Protection in Munich, which has participated in the series of low-dose-radiation projects that the commission has supported since 2010.

Societal Challenges funding has also supported projects that others shy away from, such as transplanting cells derived from the brains of fetuses into the brains of people with Parkinson's disease. In 2003, researchers around the world abandoned this controversial line of research — which tries to replace the neurons whose loss causes the illness's symptoms — after many trial participants failed to benefit and no one could work out why. Then, in 2014, the commission-funded TRANSEURO trial began.

TRANSEURO aims to transplant neurons into 150 people with Parkinson's in the United Kingdom, Sweden, France and Germany using harmonized clinical protocols to help establish which conditions work best. The large collaboration, which joins 14 biomedical laboratories, clinics and companies, is essential, says TRANSEURO's coordinator, neurologist Roger Barker at the University of Cambridge, UK. "Without the EU, I doubt this would have happened."

Trust between companies is crucial to the Advanced Immunization Technologies (ADITEC) project, which aims to create a generic toolbox to speed up vaccine development. Under the confidentiality agreements of the consortium, which the commission has funded since 2011, companies are comfortable sharing the components of their proprietary vaccines. The project has already produced the first direct comparison of different companies' 'adjuvants', substances that strengthen immune responses (N. P. H. Knudsen *et al. Sci. Rep.* **6,** 19570; 2016). "We had always thought it would be impossible to compare them," says ADITEC coordinator Rino Rappuoli, chief scientist of GSK Vaccines in Siena, Italy.

LIFTED THE EAST

In late 2000, when NATO sponsored a meeting on science in Central and Eastern Europe, much of the region was a world apart from the EU. Years of communist thinking had nourished

the illusion that the mere existence of institutes and research facilities was more important than their actual performance.

Attitudes have changed, partly thanks to the EU, which absorbed the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia in 2004, then Bulgaria and Romania in 2007 and Croatia in 2013.

These countries have had a low rate of success in winning grants from the Framework programmes. But all of the former communist states are recipients of the commission's 'structural funds' — subsidies designed to reduce social and economic disparities, a goal of the EU. How the funds are used is decided locally, but of the €170 billion available for 'cohesion and regional development' in 2007–13, the commission pushed for €20 billion to be spent on research. In 2014–20, almost €44 billion is meant to be used for science and innovation in poorer regions.

The cash has been most effective when used to refurbish universities and provide labs with the equipment needed to train students and entice researchers to stay, says Peter Tindemans, secretary-general of science-advocacy group EuroScience in Strasbourg, France.

The funds have also financed the €850-million Extreme Light Infrastructure, a pan-European laser facility under construction at sites in the Czech Republic, Hungary and Romania. The facility is expected to attract leading talent from around the world to the region, but Tindemans cautions that improvements to the research environment must come first. "You can't jump-start scientific development solely with large infrastructures," he says.

FOSTERING EXCELLENCE

To win cash from EU funding programmes, researchers must often fit their work into broader societal or economic goals. But one corner of the European funding apparatus is all about science for science's sake.

Set up in 2007 to raise the quality of research across Europe, the European Research Council (ERC) awards generous grants that are open to any discipline, come with minimum bureaucracy and are judged solely on the quality of the application.

The ERC budget has grown from €7.5 billion in 2007–13 to €13.1 billion for 2014–20. At up to €2.5 million over 5 years per researcher, its grants are longer and larger than those of most national funders. The approach seems to work: 7% of ERC-generated papers come in the top 1% of the most highly cited articles by discipline, publication type and year.

Not everyone is happy with the 'excellence at all costs' approach. Since the ERC's inception, half of the grants it awarded under its three core schemes have gone to just three countries: the United Kingdom, Germany and France.

But the ERC system lifts the quality of research beyond the projects that it funds. Either in an attempt to win more of its grants or simply inspired by the ERC, member states are redesigning national policies to make their science more competitive, says Jose Labastida, head of the ERC's scientific department. He cites Poland's National Science Centre, set up in 2011, as an example.

And 17 countries have run schemes that fund ERC runners-up — applicants who met the quality threshold but were unsuccessful — essentially reusing the agency's high-quality peer-review process. "The ERC has raised the scientific level all over Europe," says Catherine Cesarsky, an astronomer at the French Atomic Energy Commission near Paris.

RESEARCH MELTING POT

Science thrives on collaboration — and the EU has partnered with other agencies (see 'European, but not EU') and creates myriad opportunities for researchers to pool ideas and cooperate.

Most of the funding for the EU's Framework programmes is reserved for projects in which partnerships are formed by at least three organizations from different countries. The last programme, FP7, which ran from 2007 to 2013, spent €41.7 billion of its €50.5-billion budget on some 26,000 joint projects, generating more than 500,000 pairs of collaborative links between research organizations, according to the commission. The Framework programmes also fund mobility grants that foster collaboration.

In less-well-off countries, meanwhile, structural funds equip researchers to work with their counterparts in more scientifically developed nations, says Rémi Barré, an emeritus researcher at the National Conservatory of Arts and Crafts in Paris.

The gradual political, economic and research integration of the EU's member states has created an environment that is conducive to collaboration, according to geneticist Paul Nurse, head of the Crick Institute in London. Research is now embedded across the EU's activities, from the bloc's negotiation of the COP21 climate accord in December 2015 to its environmental-protection policies and regulatory bodies such as the London-based European Medicines Agency.

Contact between science ministers from different member states and researchers has become the norm, says Frank Gannon, former head of the intergovernmental European Molecular Biology Organization. By contrast, he recalls how fragmented European research was a few decades ago when he was a researcher in Ireland. "The sense of isolation of a researcher was massive." ■

Reporting by Alison Abbott, Declan Butler, Elizabeth Gibney, Quirin Schiermeier and Richard Van Noorden

EUROPEAN, BUT NOT EU

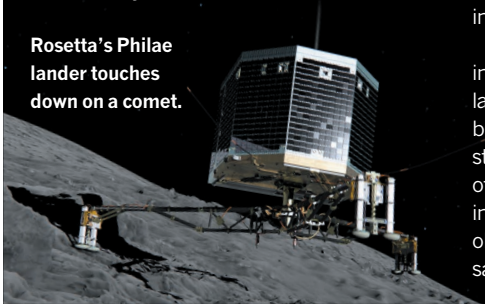
Although separate, CERN and ESA receive EU funds.

Before the EU began to have a major role in coordinating Europe-wide research in the 1990s, the task fell mainly to pan-European research organizations such as the CERN particle-physics laboratory.

Established by treaty in 1952 by 11 countries, CERN, near Geneva, Switzerland, was born in the same post-war spirit of peace as led to the formation of the EU. But the lab pre-dates the EU's main forerunner, the European Economic Community, which had no remit for research, by about five years. CERN now has 21 member states and is a major recipient of EU funds, including for a 2020 upgrade of its Large Hadron Collider, which scientists used to discover the Higgs boson.

Another organization that grew up alongside the EU is the European Space Agency (ESA). It arose from a 1975 merger between the European Space Research Organisation and the European Launch Development Organisation. Both were created in the 1960s to guarantee Europe independent access to space.

ESA has racked up a string of successes, including the Rosetta mission that put a lander on a comet in 2014. The EU is now the biggest single contributor to the 22-nation-strong agency, accounting for some 20% of its budget. ESA and the EU are partners in the multibillion-dollar Copernicus Earth observation system and in the Galileo global satellite navigation system.



ESA/GETTY

Rosetta's Philae lander touches down on a comet.

CLARIFICATION

The News Feature 'The material code' (*Nature* **533,** 22–25; 2016) did not make it clear that the director of the Materials Genome Project is Kristin Persson, and that she has an affiliation with the University of California, Berkeley.