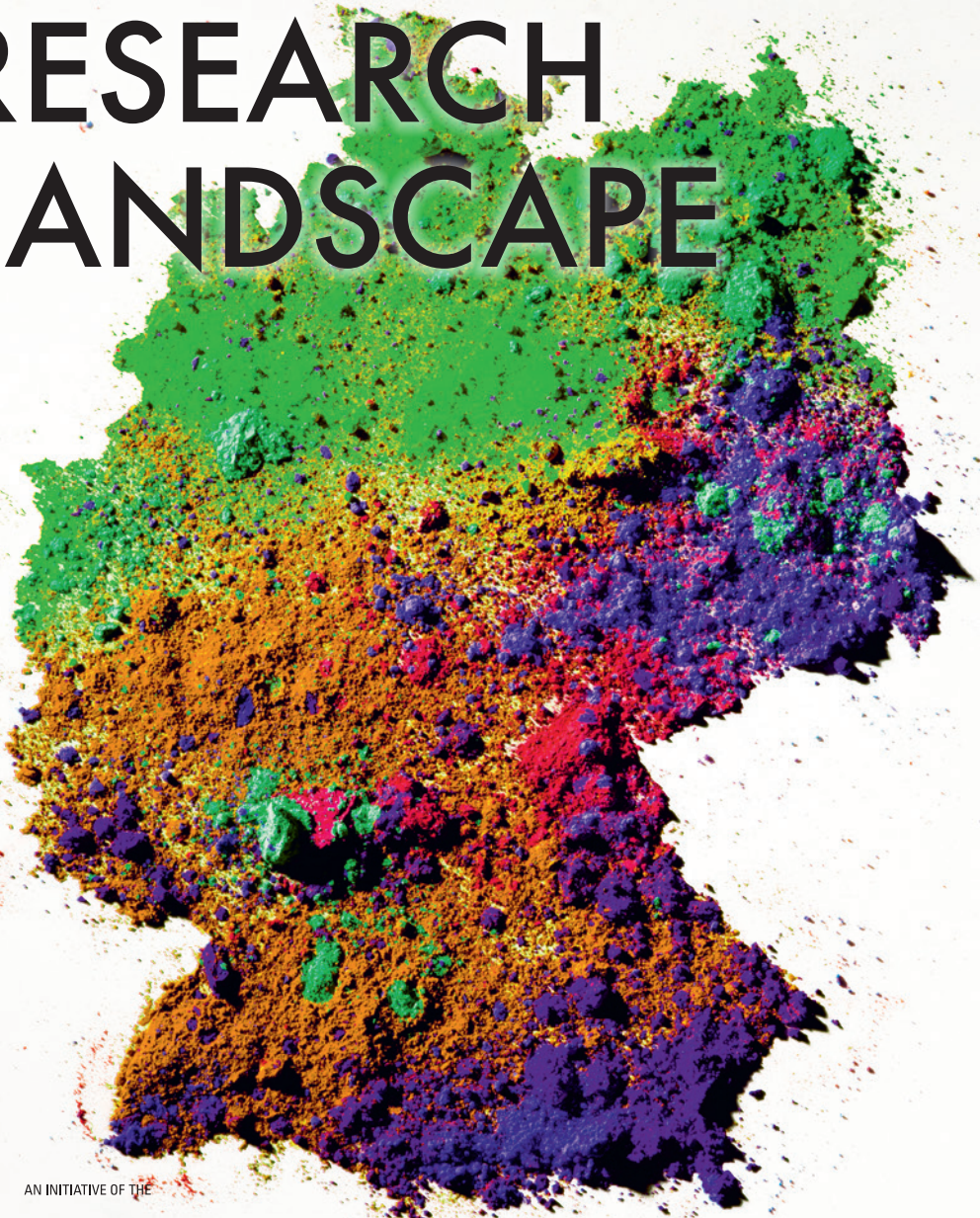
THE GERMAN RESEARCH LANDSCAPE



AN INITIATIVE OF THE

Federal Ministry
of Education
and Research

Research in
Germany

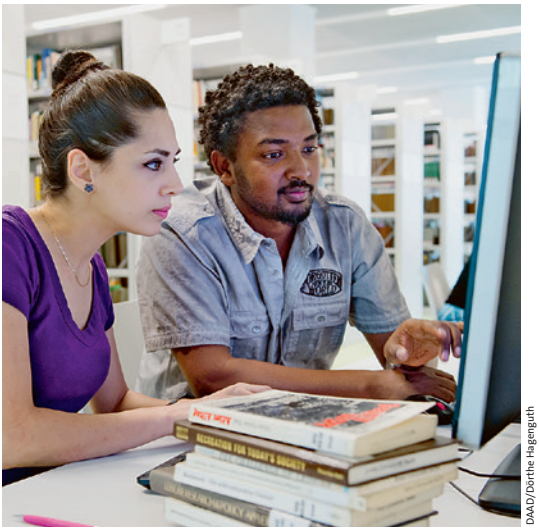
Land of Ideas

DISCOVER THE LAND OF IDEAS

From the fuel cell to one of the world's first Covid-19 vaccines – German inventions have changed people's lives. What is more, it is research and development (R&D) that keeps a successful economy going. However, we are currently facing many global challenges such as climate change, poverty and health issues. As a country, Germany is one of the world's top investors in R&D.

"The German research landscape" shows who is behind this: universities and research institutes, federal and state institutions and companies committed to research. Together, these partners form a research infrastructure of international significance. Germany offers academics from all over the world first-class working conditions, while international research institutions and businesses can find partners for collaboration and options for networking. Enjoy discovering the German research landscape!

DAAD/Volker Lannert



DAAD/Dorthe Hagenguth

DAAD/Jan Zappner

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RESEARCH IN GERMANY

Outstanding, innovative, open-minded – research in Germany has a superb reputation all over the world. It is a research community shaped by universities, research institutions and extensive research by industry. The research covers a broad range of different fields, with a special focus on future-oriented topics. Germany is one of the countries worldwide that invest the most in research and development.

J. Hosan/GSI Helmholtzzentrum für Schwerionenforschung GmbH

Key technologies for tomorrow: at the detector laboratory of the GSI Helmholtzzentrum für Schwerionenforschung, cameras are developed and produced for the centre's research work.

FACTS AND FIGURES

More than 1,000 public and publicly funded institutions for science, research and development

Over **400 research and innovation networks** and clusters

708,000 staff in R&D, including 434,000 researchers

More than **45,000 patent registrations worldwide** (5th place)

Expenditure on R&D: **104.7 billion euros**, or **3.1%** of GDP (2018)

Who researches what?

Almost 105 billion euros – that is the massive sum invested in research and development (R&D) in Germany. The funding partly goes to projects in universities, non-university research institutions and government research labs. Industry accounts for the largest share of R&D.

RECORD INVESTMENTS IN RESEARCH

The German private sector is the main investor when it comes to looking for new methods, products and applications. In fact, it contributes more than two thirds of total R&D funding in Germany. 2018 saw a record 72 billion euros invested. The German automotive industry is the most important client. More than a third of the money invested in R&D by industry goes into vehicle manufacturing. In terms of R&D intensity – that is to say the proportion of turnover spent on internal R&D expenditure – the pharmaceutical sector leads the field. For example, German firms played a leading role in the development of coronavirus vaccines, benefiting from massive support in the form of public funding. The vaccine developed by Mainz-based biotech company BioNTech and its US partner Pfizer was the first coronavirus vaccine to be approved in the USA and the European Union.

BROAD RANGE OF RESEARCH

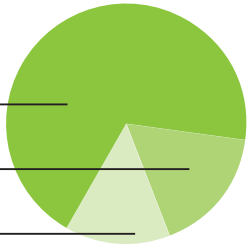
Higher education institutions are further important players in German research. They spend more than 18 billion euros to this end, conducting research across the entire spectrum of science. Basic research plays as important a role as application-oriented research. This also applies to collaborative projects with companies and non-university research institutes.

INTERDISCIPLINARY AND INTERNATIONAL

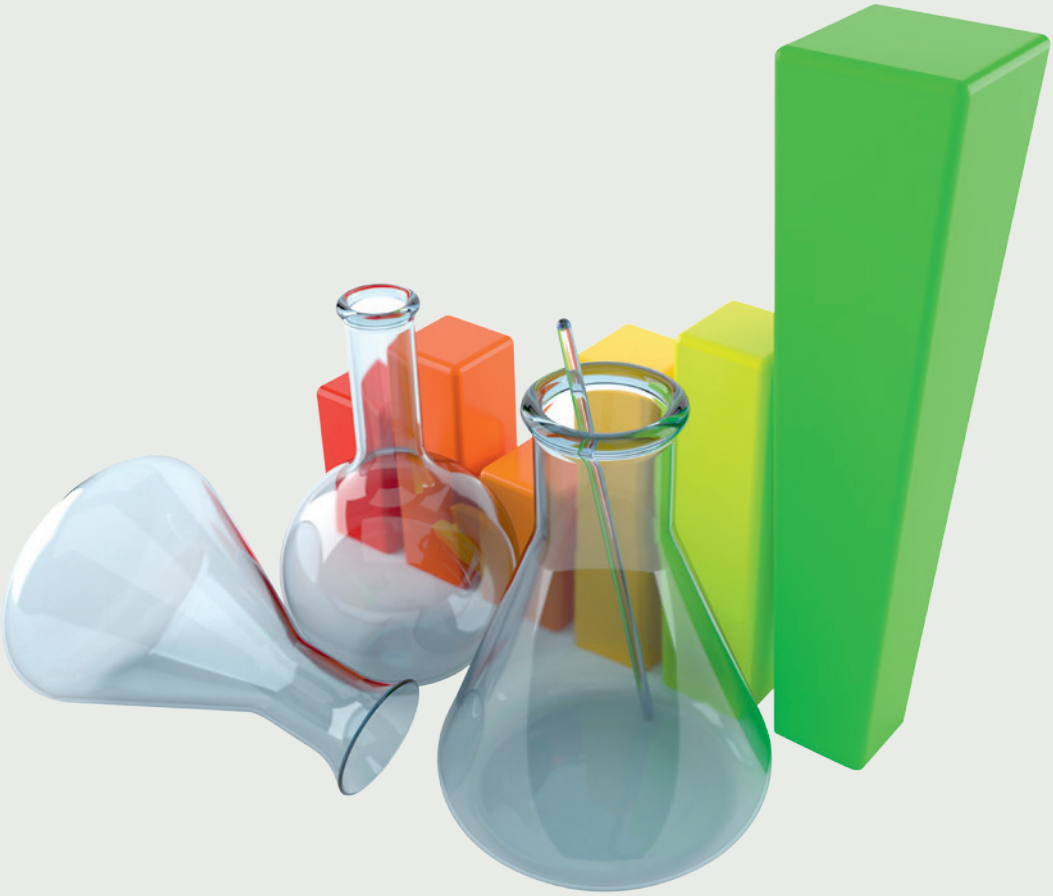
Non-university research institutes are a particular feature of R&D in Germany. These largely belong to the four major, internationally renowned research organisations, namely the Max Planck Society, the Fraunhofer-Gesellschaft, the Helmholtz Association and the Leibniz Association. Their R&D activities range from basic research to application-oriented research in all fields and disciplines. The organisations tend to conduct interdisciplinary research with an international focus and often in collaboration with academic or private-sector partners. Like the large **science academies**, which also count as non-university research institutes, the big four are registered as non-profit organisations and receive government funding.

Together with the **federal and state (Länder) research institutions** and other research facilities – such as archives, libraries and specialist information centres – publicly financed non-university research organisations commit more than 14 billion euros annually to R&D.

R&D
Internal expenditure by sector in %



2018; deviation in the sum due to rounding; source: Destatis 2021



ALMOST 105,000,000,000 EUROS

is invested by Germany in research and development

2018; source: Destatis

Talaj/istockphoto

Nina Lueth/laif

Finding solutions for tomorrow's world

The key objectives of government research policies are:

- to find solutions to global challenges
- to develop future competencies
- to establish an open innovation and venture culture

A series of research policy instruments is designed to help achieve this. One of the most important is **the cross-departmental High-Tech Strategy 2025**. "HTS 2025" will see Germany step up its investment in research and development to 3.5 percent of GDP by 2025. The goal is to move Germany further down the path to becoming the global innovation leader. This will be done by finding creative answers to the urgent challenges of today, be it a question of sustainable urban planning, climate action and eco-friendly energy sources, personalised medicine or the digital society. The idea is to speed up the process of turning scientific insights into applications.

For this to happen, science and industry, and this includes small and medium-sized enterprises (SMEs), must work closely together. Such collaborations are explicitly supported for example in the fields of electromobility or digital manufacturing. And when it comes to the big picture, things do not stop at national borders. Global challenges call for international efforts. Which is why the High-Tech Strategy 2025 focuses on European and international collaboration.

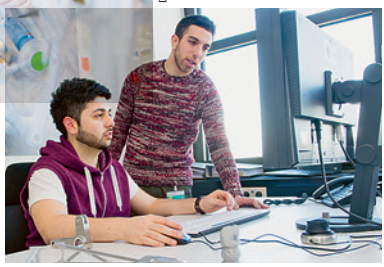
INTERNATIONAL ORIENTATION

More than 43,000 scientists from abroad **receive funding in Germany**

Cooperation agreements on scientific-technological **collaboration with more than 50 different countries**

Around **14,700 stays abroad are funded** each year for German academics

1.2 billion euros is the sum spent by the Federal Government on R&D to support international scientific organisations and inter-government research institutes



DAAD/Volker Lannert (2)

Close cooperation between the private sector and scientists is explicitly supported.

INTERNATIONAL NETWORKS

This is the focus of the Federal Government's **internationalisation strategy**. It seeks not only to strengthen scientific excellence through worldwide collaboration and forge strong international links between science and industry. The strategy is also intended to better master global challenges such as climate change, healthcare and food supplies – together with European and international partners. And it is a success: in 2018 alone, the Federal Ministry of Education and Research funded around 2,300 research projects involving international partners. There is above all strong cooperation with the **European Research Area**. More synergies, more coherence and more bridges built – these are the central objectives.

The goals are also in line with the European Framework Programme **Horizon Europe**. The world's largest funding programme for research and innovation, it supports projects that cover the entire development chain – from basic research through to preparing products ready for market. Funding is available for higher education institutions, research institutes and companies – especially small and medium-sized enterprises. Germany contributes to the financing and benefits from the funding for research projects.

Strong public funding

Germany is one of the leading countries for research and science. This is thanks, not least, to the distinct system of **government research funding**, which finances infrastructure and institutions, but also supports outstanding academics. Together with the private sector, government is the biggest source of funding for research in Germany. Almost 30 percent of investments in R&D are financed from tax money. Thus Germany is among those nations worldwide whose governments invest the most in R&D – both in absolute terms and as a percentage of GDP.

WHAT IS FUNDED?

In Germany, the Federal Government and the 16 German states (Länder) share responsibility for funding education, science and research. There are several instruments for this:

- **Institutional funding:** This focuses first and foremost on basic equipment as well as on staff salaries and materials budgets for the research organisations and universities. Investments in new buildings or new purchases of research equipment or infrastructure likewise come under this category. More than 40 percent of Federal Government research support is spent on institutional funding.

- **Project funding:** This type of financing relates to specific, fixed-term projects and is allocated via special funding programmes. Project funding is provided to drive improvements in study programmes and teaching, for example. It also supports joint research projects between academics, researchers and SMEs in particular, or goes towards projects with international participation.

- **Departmental research funding:** Policymakers and public administrations need scientific support and advice themselves. Commissioned research is required to facilitate this. Primarily, of course, it is the government's own research institutions which the federal ministries or state (Länder) authorities contract for research assignments; however, other research institutions can also be commissioned with R&D projects.

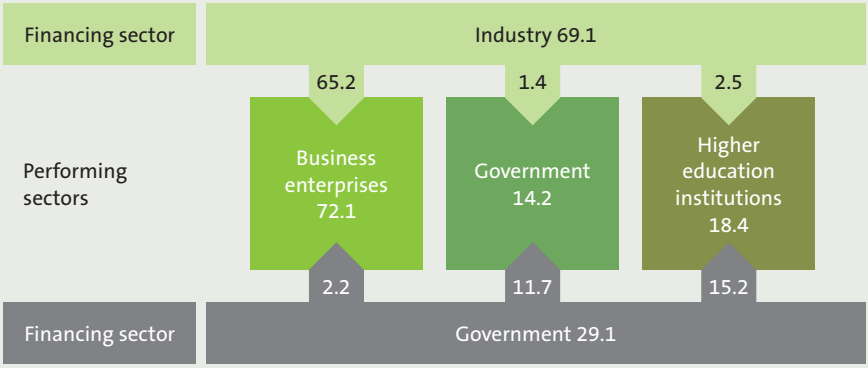
- **R&D tax incentives:** R&D tax incentives are another instrument for direct project funding. Companies of any size can apply for a tax incentive for R&D projects; this is based on expenditure for R&D personnel and for commissioned research.

- **Federal Agency for Disruptive Innovation – SPRIN-D:** The Federal Agency SPRIN-D aims to discover highly innovative research projects with disruptive potential, support their development and help them break into a market. The newly established Federal Agency is initially planned for a period of ten years, during which time a budget of around one billion euros has been earmarked.

SUPPORTING ACADEMICS

Direct government funding is not available for individual researchers. Instead, they can seek support from research funding organisations (which primarily draw on public-sector finance) such as the Deutsche Forschungsgemeinschaft (DFG), the German Academic Exchange Service (DAAD) or the Alexander von Humboldt Foundation. These organisations have specially tailored programmes for international academics, for international collaborations or for the support of (joint) research projects.

GROSS DOMESTIC EXPENDITURE ON R&D IN 2018 in billion euros



Funding is also provided by private non-profit organisations (0.4 billion euros) and foreign institutions (6.1 billion euros). Total funds: 104.7 billion euros.

Source: OECD 2020, deviations in the sums due to rounding

Andreas Heddergott/TU München

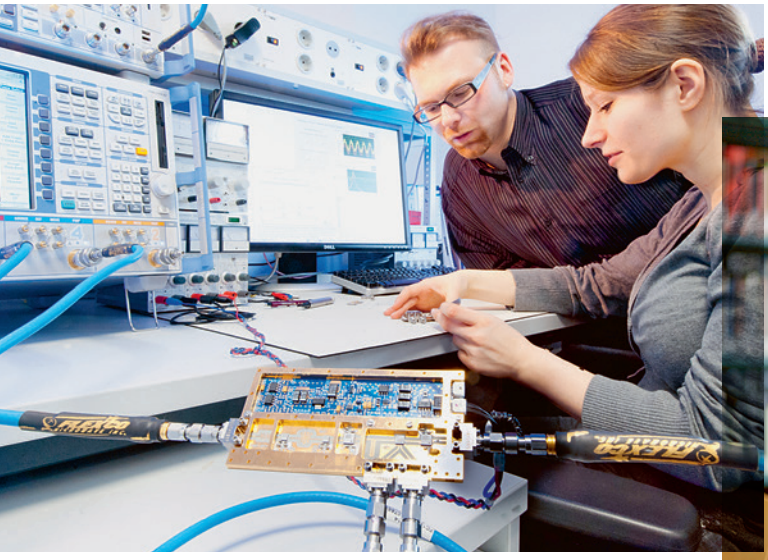
German Centres for Research and Innovation (DWIH)

The Covid-19 pandemic is proving to be one of the greatest challenges that the modern world has ever faced. Its impact has been felt on all areas of life – personal and professional, social and political, economic and academic. Since it is a global crisis, it requires a global response. Through a web-talk series, the DWIH New Delhi and its supporters are seeking to utilise perspectives from India and Germany with a view to understanding several aspects that have had an impact on the society.

The DWIH New Delhi is one of five German Centres for Research and Innovation which, alongside New Delhi, are located in Moscow, New York, Tokyo and São Paulo. They all see themselves as platforms for exchanging information about the German research and innovation world, and they showcase the research achievements of German academia and German companies that carry out research. In addition, they provide international academics, entrepreneurs or academic organisations with advice and support in the initiation of collaborations, information about funding options and points of contact in Germany. And naturally, the German Centres for Research and Innovation also offer a wealth of information about the multifaceted world of research in Germany.

www.dwih-netzwerk.de

DAAD/Sigrid Gombert



DAAD/Volker Lannert, DAAD/Christian Lord Otto

Global reach: German universities are not only active in international collaborations; many also offer opportunities to study abroad.

Ambassadors of German research abroad

German research and science make thorough use of international exchange and cooperation. And it's accessible – around the globe. For example, the **German Centres for Research and Innovation** form a network that brings international academics into contact with German research and helps form new hubs.

With representative offices in 14 countries, **German universities** have expanded their international visibility. What's more, over 37,000 agreements between German universities and partner institutions are in place worldwide. Many universities also offer opportunities to study abroad or are involved in setting up universities that follow the German model.

German universities are also regular guests at all important educational fairs abroad. During the coronavirus pandemic, MOOCs , web seminars, digital meetings and conferences, and virtual fairs have been used to replace or complement these formats.

The four big internationally renowned **non-university research organisations** – the Max Planck Society, the Fraunhofer-Gesellschaft, the Helmholtz Association and the Leibniz Association – are all represented worldwide with representative offices, affiliated international research centres or international platforms such as the Max Planck Centers.

The **Humboldt Foundation** and the research funding organisation **DFG** also have offices abroad. The **DAAD** maintains its own network of regional offices and information centres (ICs) in more than 60 countries, and has posted around 500 "Lektors" and language assistants to universities worldwide.

UNIVERSITIES

They are among the best in the world and are attracting an ever greater number of students from abroad. German higher education institutions, and not only those in the big cities, prioritise first-rate research and teaching and emphasise their international character.

Sigrid Gombert/Getty Images

Independent work: the "unity of research and teaching" plays an important role at German higher education institutions.

FACTS AND FIGURES

420 higher education institutions

738,000 staff in total, including 407,000 academic staff

2.9 million students in total

Expenditure on R&D:
18.4 billion euros (2018)

www.hrk.de

TU Dresden/Fakultät Informatik

Heidelberg University is the oldest university in Germany – and at the same time a vibrant hub of science: teaching started in three faculties way back in 1386. Today, the university has 12 faculties with over 28,000 students and 6,000 academics active in teaching and research. Heidelberg is one of Germany's most successful universities. There are currently three Nobel Prize laureates among its professors – in total, no fewer than 11 professors from the university have received this highest of scholarly honours.

TRADITION AND DIVERSITY

Not much younger, and just as successful, is Ludwig-Maximilians-Universität München (LMU). Dating back more than 500 years, it sees itself as a genuinely holistic educational institution that seeks to develop interdisciplinary solutions to the increasingly complex challenges of the future. From the start, it was one of the top universities in the Germany-wide excellence competition, and together with the Technical University of Munich (TUM) runs four clusters of excellence.

LMU and TUM in Munich, as well as Heidelberg University, all rank among Germany's internationally renowned **top universities**. Their successes are based on the long tradition of values which make academic quality possible in the first place: namely the **unity of research and teaching** and the guarantee of **scientific freedom**, both being qualities that shape the face of German universities and make them so special. The scholar Wilhelm von Humboldt (1767–1835) restructured education in Germany at the beginning of the 19th century and founded today's Humboldt-Universität zu Berlin in line with his ideas. As Humboldt himself stated, it became "the mother of all modern universities".

Getty Images/Graham Lucas Commons, Arnold Morasche/laif

Modern architecture, innovative curricula: as a university of technology, TU Dresden covers a broad scientific spectrum, whereas Leipzig University offers a range of humanities disciplines.

Open to new ideas: an important principle is the freedom of academic thought.

"Diversity and open-mindedness in higher education are the key prerequisites for academic work and cooperation."

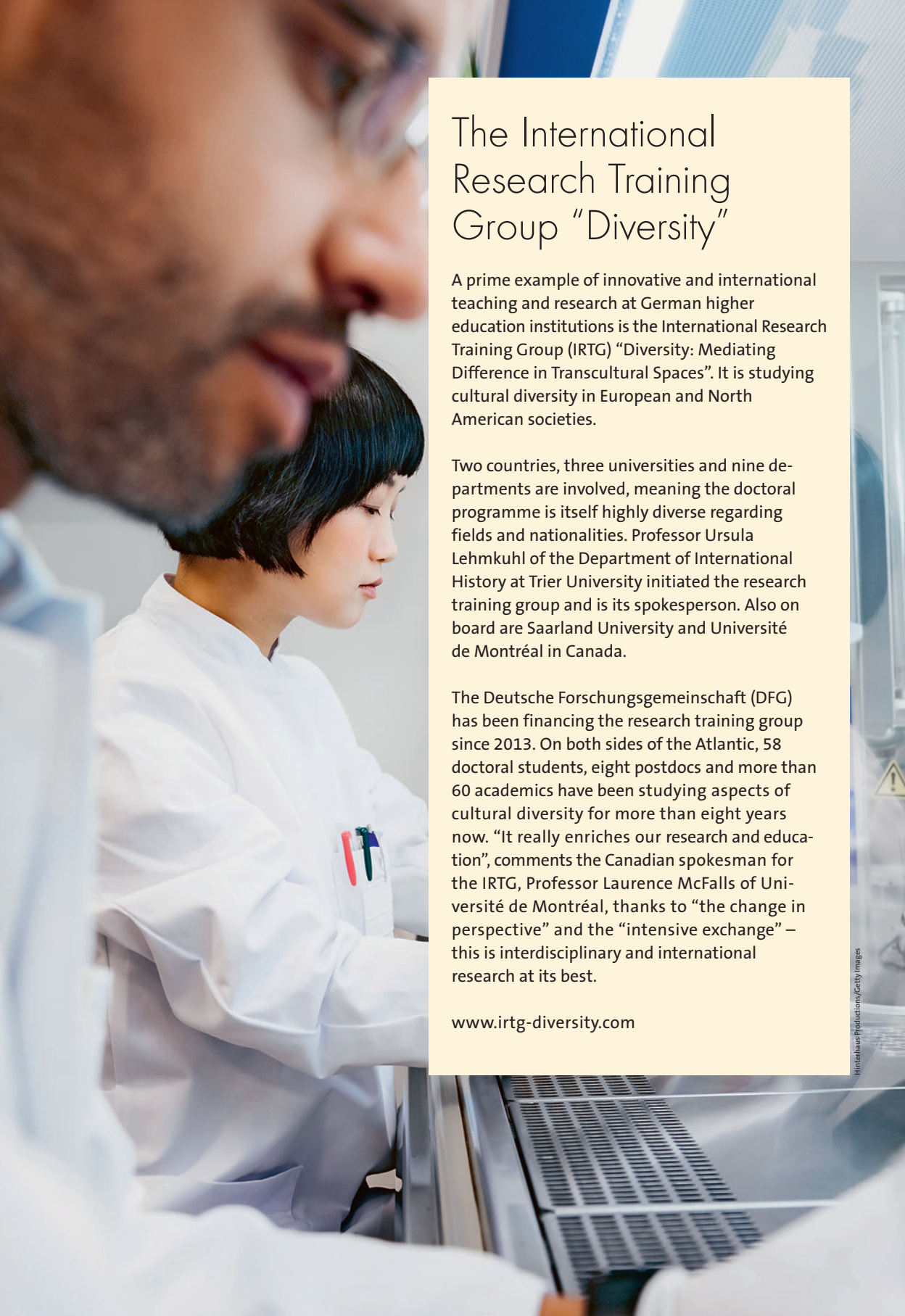
PROFESSOR KONRAD WOLF, Science Minister of Rhineland-Palatinate

Excellent conditions: high-level interdisciplinary and international research is conducted at the technical universities.

Mareen Fischinger/Getty Images, Technik Informatik/HAW Hamburg

TECHNICAL UNIVERSITIES

These also include the **technical universities** and colleges. Germany's 19 technical universities focus on engineering disciplines, the spectrum ranging from architecture to industrial engineering. The leading technical universities are grouped under the label **TU9** and include RWTH Aachen University. One of the German universities of excellence, this internationally renowned university, together with numerous regional partners, runs two of the seven future clusters that are funded nationwide, namely the NeuroSys and Hydrogen clusters. The major technical universities are outstanding research institutes: five of the nine universities are universities of excellence, and 145 of the renowned European ERC Grants have been awarded so far to TU9 scientists.



The International Research Training Group "Diversity"

A prime example of innovative and international teaching and research at German higher education institutions is the International Research Training Group (IRTG) "Diversity: Mediating Difference in Transcultural Spaces". It is studying cultural diversity in European and North American societies.

Two countries, three universities and nine departments are involved, meaning the doctoral programme is itself highly diverse regarding fields and nationalities. Professor Ursula Lehmkuhl of the Department of International History at Trier University initiated the research training group and is its spokesperson. Also on board are Saarland University and Université de Montréal in Canada.

The Deutsche Forschungsgemeinschaft (DFG) has been financing the research training group since 2013. On both sides of the Atlantic, 58 doctoral students, eight postdocs and more than 60 academics have been studying aspects of cultural diversity for more than eight years now. "It really enriches our research and education", comments the Canadian spokesman for the IRTG, Professor Laurence McFalls of Université de Montréal, thanks to "the change in perspective" and the "intensive exchange" – this is interdisciplinary and international research at its best.

www.irtg-diversity.com

Hinterhaus Productions/Getty Images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Strong practical links: teaching at German universities of applied sciences focuses on potential applications.

DIVERSE AND BROAD-RANGING

420 institutions of higher education are the vibrant face of higher education in Germany:

120 **universities**

203 universities of **applied sciences**

57 **film, art and music** colleges

34 colleges of **administration**

6 universities of other type

www.higher-education-compass.de

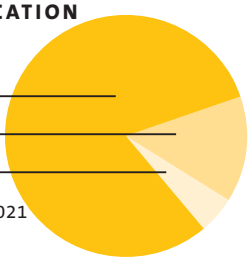
UNIVERSITIES OF APPLIED SCIENCES

Since the 1970s, **the universities of applied sciences** have been enriching German higher education. Originally set up as purely teaching facilities with a practical and applied focus, they are nowadays taking responsibility for important research and expanding their teaching range accordingly. They now cater to over one million students. At universities, basic research and applied sciences tend to take centre stage, and classes usually focus on research. By contrast, research at universities of applied sciences normally concentrates on applying teaching in practice.

RESEARCH BENEFITS TEACHING

This can also be seen from one of the newest academic institutions in Germany, Hochschule Emden/Leer. Founded in 2009, this university of applied sciences scores high with an interdisciplinary curriculum, an international approach and strong links to the region. It sees itself as an intermediary between science and business, and has its own technology transfer office. Research focuses on topics such as energy efficiency in manufacturing, health management and industrial informatics. Hochschule Emden/Leer cooperates with other universities and companies in the region. It is not only teaching that benefits from the research and the link to practical applications, so too do the students who wish to start up their own businesses (see also page 23).

SOURCES OF R&D FUNDING IN HIGHER EDUCATION



2018; source: OECD 2021

Application-focused and regionally rooted

The combination of **practical science and application-focused teaching** is pretty much unique in the world. The German **universities of applied sciences (FH/UAS)** are the country's former state schools of engineering, higher vocational schools and academies. They offer degree courses in subjects ranging from engineering and the natural sciences to economics, law, design and healthcare.

When first established in the late 1960s, practical training of skilled professionals was initially their focus. Since the mid-1980s, however, the universities of applied sciences have also been engaged in **applied research and development**.

These institutions have long been partnering universities to offer joint doctoral degree programmes. Nowadays, a number of research-oriented universities of applied sciences also have the **right to confer PhDs** in certain subjects themselves.

The principle followed by universities of applied sciences has proven successful: because they are **regionally rooted** and offer application-focused research and practical qualifications, the UAS are particularly well suited to responding flexibly to specific societal and business needs at the local level, working together with companies, associations, municipalities or social welfare institutions.

Applied research and research-based qualifications for young researchers are therefore the focus of special **funding programmes** at the federal and state levels. The programme **Research at Universities of Applied Sciences** takes centre stage. It currently makes 70 million euros per year available in funding to provide targeted support for UAS. This has financed more than 1,500 research projects since 2008.

Professors at universities of applied sciences need practical and teaching experience in addition to their scientific qualifications. The UAS are provided with additional funding to allow them to ecruit the best candidates: for example, the **FH-Personal** funding programme supports the establishment of specialist professorships or tandem programmes with companies or other partners for staff development.

Approx.

52,000

INTERNATIONAL ACADEMICS teach and research at German higher education institutions

37,600

AGREEMENTS between German universities and partner institutions in around 150 different countries

More than

5,600

INTERNATIONAL PHD STUDENTS successfully complete their doctorates in Germany every year

412,000

STUDENTS FROM ABROAD are enrolled in Germany

35

GERMAN UNIVERSITIES are involved in European higher education networks

2019, 2020, 2021; source: Destatis, BMBF, HRK

dpa/Schuetze/Rodemann, DAAD/Norbert Hüttermann

Analogue and digital: modern teaching follows both paths. The picture shows the library at Martin Luther University Halle-Wittenberg.

Attractive courses: Germany is the most popular study destination for international students after the USA, Great Britain and Australia.

INTERNATIONAL FOCUS

Science needs freedom and exchange across borders. No country can solve global issues such as climate change, combating poverty or sustainable energy supplies on its own. Which is why internationalisation is a key aspect at German universities, too. Important steps have already been taken: about 300 German universities collaborate with international academic institutions in 150 countries on more than 37,000 different projects.

German study programmes abroad play a special role here. One example of such cooperation is the German University of Technology (GUtech) in Oman, one of more than 80 German transnational education projects. It was founded in 2007 with support from RWTH Aachen University, on whose curriculum its study programme is modelled. With great success: companies in the region are eager to hire GUtech graduates because of their research-based, practical education and their high level of independence.

German universities are also involved in the **European University Networks** (EUN). This is a European Union initiative to support university partnerships all over Europe. These alliances of universities from at least three EU countries undertake to set up a **European inter-university campus**. The idea is for transdisciplinary and transnational teams of students, researchers and external stakeholders to tackle topics that are important for Europe, such as climate action, democracy, health, big data or migration.

OPEN FOR INTERNATIONAL TALENT

An increasing number of international academics are teaching and conducting research in Germany. One in eight academics at German higher education institutions, approx. 52,000 in all, come from abroad. And Germany is **one of the most popular destinations** for international students. Around 412,000 international students are enrolled at German universities. At the same time, roughly 135,000 Germans study abroad, which again fosters international exchange.

Learning together: at German universities, teamwork plays an important role, even across disciplinary boundaries.

DAAD/Dorthe Hagenguth, dpa/Arne Dedert

INVESTING IN INNOVATION

German universities have been very successful in extending their international profile, boosting innovative research and offering attractive study programmes. This is not least the result of massive investments by the Federal Government and the states (Länder). For example, the billions invested by the **Excellence Initiative** have had a tangible impact: graduate schools, clusters of excellence and future projects have enriched the university landscape, given research a real boost and created outstanding education facilities for young researchers.

Now, this successful programme is being continued in the form of the **Excellence Strategy.** It is again **investing in cutting-edge university research** while supporting clusters and universities of excellence, with annual funding totalling 533 million euros.

Small and medium-sized universities as well as universities of applied sciences also receive support. With their strong regional roots, they are innovation engines for their respective state. The federal/state initiative **Innovative Hochschule** will commit up to 550 million euros until 2027 to promote the research-driven transfer of ideas, knowledge and technology (see also page 23).

As a rule, complex research areas which involve high research risks and hold great potential for groundbreaking innovation require the collaboration of several partners. The **Research Campus** funding initiative therefore supports long-term projects involving **collaboration between science and industry**. The topics range from new methods for diagnosing infectious diseases to innovative manufacturing technologies. Each of the nine selected research campuses can expect to receive up to 2 million euros in funding each year.

Fostering talents from around the world

PROFESSOR MICHAEL HOCH,
Rector of the University of Bonn

Professor Hoch, the University of Bonn is the most successful university in Germany's nationwide excellence competition. What is your formula for success?
It is thanks to the extraordinary achievements of our academic and administrative staff. We have succeeded in bringing them together, in all their diversity, to work towards a common strategic objective. This gives rise to incredible innovative strength.

Nearly one in seven of the students at your university comes from abroad. What makes the University of Bonn so attractive to this target group?
Many of our departments are world-class. Our outstanding academics attract students and researchers from all over the world. As indeed does the international city of Bonn, which is a centre of science, culture and business, not to mention a United Nations base and home to numerous federal authorities in the west of Germany.

How do you hope the University of Bonn will develop over the coming ten years?
I hope that our curiosity-driven research will become an even more powerful international innovative engine to drive major global transformation processes. And that we continue to attract and provide excellent support to young talents from around the world.

Barbara Frommann/Uni Bonn, DAAD/Norbert Hüttermann

NON-UNIVERSITY RESEARCH

Independent basic research, applied science with a high degree of innovation and experiments with unique large-scale equipment: non-university research institutes in Germany offer ideal conditions for top-level research and enjoy international standing.

J. Hosan/GSI Helmholtzzentrum für Schwerionenforschung GmbH

Progress requires research: non-university research in Germany makes an important contribution to our future.

MAX-PLANCK-GESELLSCHAFT

Insight must precede application: the desire to get to the bottom of things drives the Max Planck Society, Germany's generator of Nobel Prize winners.

They go by the names of Gravity, Sinfoni and Naco, and they are very talented. Gravity for example can measure the changing positions of a star with great precision so as to determine the trajectory of its orbit. All three are extremely sensitive instruments for infrared observations, based at the Very Large Telescope (VLT) of the European Southern Observatory (ESO) in the Atacama Desert in northern Chile. Gravity, Sinfoni and Naco allowed the astrophysicist Professor Reinhard Genzel, together with colleagues from around the world, to track a star named S2 when it passed our galaxy's black hole in May 2018.

Genzel and his team spent many years preparing for this event. And for the first time they were able to measure something that Einstein had predicted: the light of a star is stretched to longer wavelengths by the very strong gravitational field of the black hole. This effect is known as gravitational redshift.

Genzel and his group have been researching black holes for decades and have made many groundbreaking findings in galactic and extragalactic astrophysics. This led to Genzel receiving the Nobel Prize in Physics in 2020 "for the discovery of a supermassive compact object at the centre of our galaxy". Genzel is one of the directors at the Max Planck Institute (MPI) for Extraterrestrial Physics in Garching near Munich. The institute is one of the Max Planck Society's 86 research institutes that work independently.

FACTS AND FIGURES

MAX PLANCK GESELLSCHAFT

86 research institutes (including 5 institutes abroad)

Roughly **24,000 staff** (approx. 6,900 scientists and 2,200 guest scientists)

More than **every second scientist** comes **from outside Germany**

Over 3,000 research projects in more than 120 countries

Annual budget: approx. **2.5 billion euros** (2019)

www.mpg.de

picture alliance/Zoonar

Invisible giants: black holes are among the greatest mysteries of the universe. The astrophysicist Reinhard Genzel proved that there is a black hole at the centre of the Milky Way that swallows up even stars and communication waves.

20

NOBEL PRIZE WINNERS

Since 1948, the year when the Max Planck Society was established, 20 scientists from its ranks have received the greatest honour for scientists: the Nobel Prize.

dpa/Peter Kneffel, p. 32: Heritage Auctions

Professor Reinhard Genzel is one of the directors at the Max Planck Institute for Extraterrestrial Physics in Garching. In 2020, he was awarded the Nobel Prize in Physics for his research on black holes.

They focus on basic research, often taking an interdisciplinary approach, in the following fields:

- life sciences
- natural sciences
- humanities and social sciences

TOP SCIENTISTS

What distinguishes the Max Planck Institutes is that they are established in line with Harnack's principle. This is named after Alfred Harnack, the first president of the Kaiser Wilhelm Society which was established in 1911 and was the precursor to the Max Planck Society. The aim is to recruit the world's best and most creative scientists to the society. The Max Planck Institutes are then set up according to their research interests and needs. **At the heart of this principle is absolute freedom of research.**

Heads of institutes enjoy the best possible working conditions and are given a free hand in choosing their staff, subject matter and cooperation partners. Nowadays, the institutes are no longer always established around individual researchers and more value is placed on interdisciplinarity and international collaboration than was the case 100 years ago.

Yet the same principle still applies to choosing outstanding researchers with a focus on the best minds, and they are given free rein in how they use resources.

THE MISSION

Max Planck Institutes are committed to basic research. They research the inside of elementary particles and the origins of the universe. They study the molecular building blocks of life, investigating ecosystems and the specific conditions underlying them, explore the changes resulting

from global migration and compare international legal systems. Whatever their particular focus, the Max Planck Institutes always devote themselves to fields of research that are particularly innovative.

The range of work covered by the Max Planck Society continues to grow, with new institutes being established and existing ones being rededicated in order to find the answers to the scientific questions of tomorrow. The Max Planck Society has the scope to be able to react quickly to new scientific developments.

INTERNATIONAL ORIENTATION

In view of such research conditions it is no wonder that the Max Planck Institutes attract so many top international players. **More than half of their scientists come from abroad**, as do nearly 40 percent of the institute directors. Over 90 percent of scholarship holders and almost 60 percent of visiting scientists have non-German citizenship.

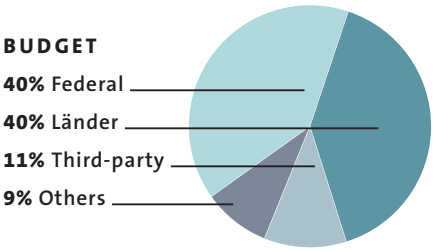
Yet it is not only the teams that are international. Max Planck Institutes are part of international networks; their scientists exchange ideas with colleagues all over the world and they are involved in more than 3,000 projects with some 6,000 international partners in 120 countries.

THE NEXT GENERATION

The efforts made by the institutes to encourage the upcoming generation also have an international focus. Every second doctoral student at more than 60 International Max Planck Research Schools (IMPRS) comes from abroad. The research schools are established by one or several Max Planck Institutes. They collaborate closely with universities and other research institutions which also have an international focus. Here next-generation scientists can enjoy first-class

"I chose the IMPRS because it offers a unique opportunity for developing my scientific and personal skills: I collaborate in a dynamic international team while learning state-of-the-art techniques."

ANA PATRICIA BAÑOS QUINTANA is writing her doctoral thesis at the International Max Planck Research School "Chemical Communication in Ecological Systems", Jena



2019; source: Max Planck Society

A fantastic framework for our research project

DR MIRIAM LIEDVOGEL
Max Planck Research Group Leader
"Behavioural Genomics"

Dr Liedvogel, at the Max Planck Institute for Evolutionary Biology you investigate birds' migratory behaviour. What do you find so fascinating about it?
What I find particularly fascinating are young birds on their first long-distance migratory flight. They fly thousands of kilometres to a wintering site they have never been to before – without the help of their parents, but with remarkable accuracy! We want to understand which genes are responsible for letting the bird know how to find its wintering site and which signalling pathways play a role.

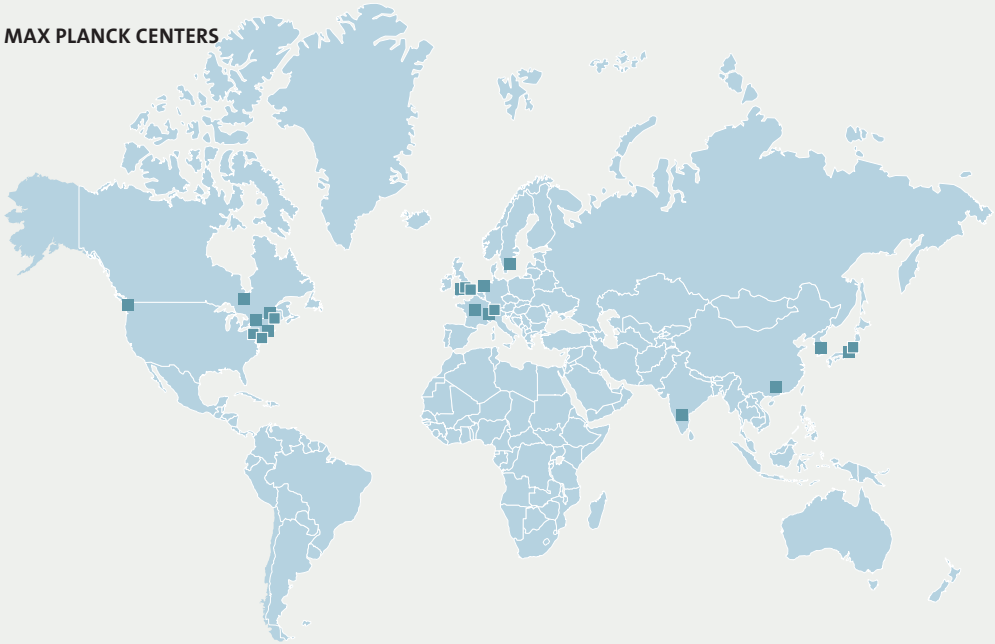
What makes a Max Planck Research Group a good place for your work?
It offers us a fantastic framework for our interdisciplinary project. That includes the infrastructure and expertise with which the institute supports us. Moreover, we have the greatest possible independence to pursue our specific research questions.

How important to you is international exchange?
Bird migration is a global phenomenon; national borders pose no barriers for birds. Breeding and wintering areas are often located on different continents, meaning that international cooperation is essential for our work, both in the field and in the lab.

private, Johann Schumacher/Getty Images

Language without speaking: scientists at the Max Planck Institute for Human Cognitive and Brain Sciences are exploring how the brain processes sign language.

MAX PLANCK CENTERS



The Max Planck Centers constitute a platform for international scientific collaborative programmes. They pool the expertise of the Max Planck Institutes involved and that of their international partners, enable the joint use of research facilities, support postdoc exchanges and host workshops.

MAX PLANCK INSTITUTES ABROAD

- Bibliotheca Hertziana in Rome, Italy
- Kunsthistorisches Institut in Florenz, Italy
- Max Planck Institute for Psycholinguistics in Nijmegen, Netherlands
- Max Planck Florida Institute for Neuroscience, USA
- Max Planck Institute Luxembourg for International, European and Regulatory Procedural Law, Luxembourg

conditions. The students are part of a group and have access to the relevant institutes' infrastructures. Around two thirds of the 3,600 doctoral students at a Max Planck Institute are enrolled at an IMPRS.

Particularly gifted young scientists with (international) experience as postdoctoral researchers can apply for a position as leader of a Max Planck Research Group. **Taking responsibility for such a group allows them to research independently**, manage a team and administer budgets. The Max Planck Society has set up about 180 Max Planck Research Groups. These open up excellent career opportunities and provide aspiring scientists with a chance to prove themselves.

FRAUNHOFER-GESELLSCHAFT

Dedicated to the future: when something needs to work, the researchers at the Fraunhofer Institutes are the people to call. After all, Fraunhofer is the largest organisation for application-oriented research in Europe.

Ute Grabowsky/Photothek via Getty Images

Specialists in high-tech: at Fraunhofer, the focus is primarily on innovations – although always taking the needs of the individual into account.

FACTS AND FIGURES

Fraunhofer

75 Fraunhofer Institutes and research facilities in Germany

Approx. **29,000 staff**, including more than **11,300 scientists** and scientific staff

More than **1,000 international researchers**

Research centres, representative offices and senior advisors in **Europe, North and South America, Asia, the Middle East and Africa**

Annual budget: approx. **2.8 billion euros** (2019)

www.fraunhofer.de

Researchers at the Fraunhofer Institutes look to the future in everything they do. Whether the subject is the tactile internet, smart manufacturing, cyber-security research or new technologies for the energy transition: they address the issues of today for the technologies of tomorrow with an eye to practical applications. **75 institutes and research centres** in Germany take this problem-oriented and application-based approach in the seven Fraunhofer Strategic Research Fields:

- bioeconomy
- digital healthcare
- artificial intelligence
- next generation computing
- quantum technologies
- resource efficiency and climate technologies
- hydrogen technologies

With around 29,000 employees and a research budget of 2.8 billion euros, the Fraunhofer-Gesellschaft is the **leading organisation for applied research in Europe**. It is named after the researcher, inventor and entrepreneur from Munich, Joseph von Fraunhofer (1787–1826). He carried out ground-breaking work in researching optics, and at the same time developed successful new products.

DAAD/Volker Lannert, p.41: t_kimura/Getty Images

Key technologies: the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR is one of the biggest radar research institutes in Europe.

THE TASK

Research for practical application was Joseph von Fraunhofer's guiding principle, and the Fraunhofer-Gesellschaft feels bound by this, too. The Fraunhofer Institutes work for clients in business as well as for the Federal Government and the German states (Länder). The aim is to make academic findings usable for customised products and applications. To this end, the Fraunhofer Institutes can draw on the expertise of international teams of experienced developers and creative minds, as well as on their own research departments.

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INVENTIONS A YEAR

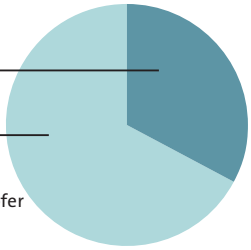
Fraunhofer is one of the top 20 patent applicants to the German Patent and Trade Mark Office and among the top applicants to the European Patent Office (rank 32). Small wonder that in 2019 Fraunhofer placed second among Reuters' ranking of The World's Most Innovative Research Institutions.

dpa/Daniel Karmann

"We know how": this is the principle according to which the researchers at the Fraunhofer-Gesellschaft work. They tackle their tasks with determination and an inquiring mind.

The Fraunhofer-Gesellschaft is primarily funded through commissioned research. Approx. 70 percent of the assignments come from industrial and service-sector companies, though publicly funded research projects are also covered. The basic funding is provided by the federal and state (Länder) governments.

BUDGET



2019; source: Fraunhofer

RESEARCH AIMED AT PRACTICAL APPLICATIONS

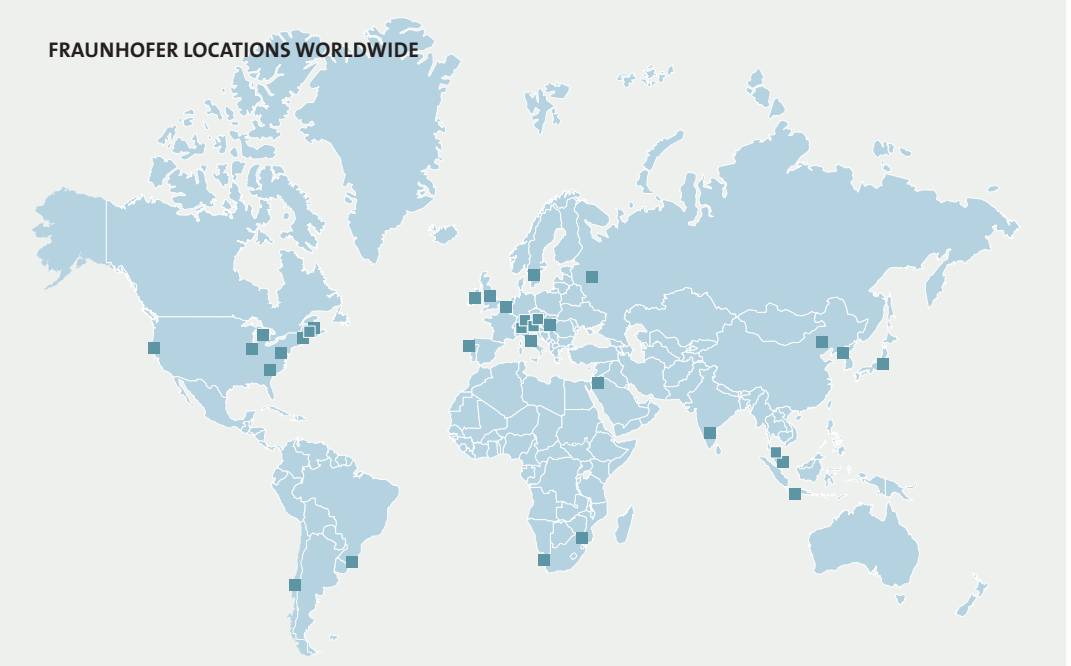
When science becomes practical, it translates into business. This works particularly well when Fraunhofer researchers found their own companies. The Fraunhofer Venture department supports this and is dedicated exclusively to company foundations, start-ups, investors and the participating Fraunhofer Institutes. In 2019 alone, Fraunhofer Venture supported 69 new spin-off projects, 26 of which came directly from within the ranks of the Fraunhofer-Gesellschaft. The focus here is on technology transfer to business.

Big data on the farm

Smartphones in the barns, high-tech on the fields: modern information technologies have long been making life easier for farmers. Many of the processes involved in cultivating crops or breeding cattle become more efficient as a result. However, the potential offered by digitisation in agriculture is far from exhausted: for example, how could farmers increase their productivity while at the same time operating sustainably? How could they raise the quality of the products and reduce their use of resources?

Researchers in the Fraunhofer lighthouse project "Cognitive Agriculture" (COGNAC for short) are searching for answers. Their goal is to set up a central, manufacturer-independent digital platform. "In this project, we are developing and testing novel concepts for an agricultural data space that allows confidential exchange and multivalent data use", explains Ralf Kalmar from the Fraunhofer Institute for Experimental Software Engineering IESE, one of eight participating Fraunhofer Institutes. The researchers use innovative robots, sensor systems and data services in their work. The data they generate are interlinked and analysed. This allows farmers to identify for example the ideal times for activities such as planting and harvesting. Big data on the farm – smart farming of the future.

www.cognitive-agriculture.de



FRAUNHOFER AFFILIATED PARTNERS, REPRESENTATIVE OFFICES AND SENIOR ADVISORS

North America
Boston, USA
Brookline, USA
College Park, USA
East Lansing, USA
Newark, USA
Plymouth, USA
San José, USA
Storrs, Connecticut, USA

South America
Santiago, Chile
São Paulo, Brazil

Africa
Pretoria, South Africa
Stellenbosch, South Africa

Middle East
Lavon, Israel

Asia
Ampang, Malaysia
Bangalore, India
Beijing, China
Jakarta, Indonesia
Seoul, South Korea
Singapore
Tokyo, Japan

Europe
Bolzano, Italy
Brussels, Belgium
Budapest, Hungary
Dublin, Ireland
Ercolano, Italy
Glasgow, United Kingdom
Gothenburg, Sweden
Graz, Austria
Moscow, Russia
Porto, Portugal
Vienna, Austria

INTERNATIONAL COLLABORATIONS

The Fraunhofer-Gesellschaft has affiliates in Europe as well as in North and South America and Singapore. At the centre of its European activities is its office in Brussels, which acts as an interface between Fraunhofer and the European institutions. Access to local markets abroad is provided through the Representative Offices and Senior Advisors, which are represented worldwide.

In addition, Fraunhofer is involved in numerous strategic collaborations with excellent international partners, such as at the Fraunhofer Project Center for Cybersecurity. A cooperative project established in 2019, it combines the competencies of Fraunhofer's Israeli partners at the Hebrew University of Jerusalem with the expertise of the Fraunhofer Institute for Secure Information Technology SIT. The centre, which is based in Jerusalem, is designed to serve as an R&D platform for companies and to form the heart of a network of excellence in the area of cybersecurity.

In 2019, Fraunhofer generated revenue of almost 300 million euros abroad.

A new era of communication

The age of digitisation entails some very considerable advantages. However, the data that is generated on a daily basis, which in some cases is highly sensitive, needs to be properly protected. Cybercrime is a problem all over the world.

Anyone wishing to protect their data in view of today's high-performance computers needs one thing in particular: highly secure communication systems. So-called quantum communication can play an important role in this. QuNET, an initiative funded by the Federal Ministry of Education and Research (BMBF), is researching and developing a modern IT infrastructure for Germany that is designed to achieve highly secure data transmission using quantum communication.

The main institutions taking part in QuNET are the Fraunhofer Institute for Applied Optics and Precision Engineering IOF, the Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, HHI, the Max Planck Institute for the Science of Light (MPL) and the German Aerospace Center (DLR-IKN). In the first phase, the partners already developed key modules for modern and secure communication systems, thereby paving the way for the hybrid, secure communication network of tomorrow.

> We protect the basic right to data security.

PROFESSOR ANDREAS TÜNNERMANN,
director of the Fraunhofer Institute for Applied Optics and Precision Engineering IOF and spokesperson of the QuNET steering committee

Sven Döring

Alfred-Wegener-Institut/Sebastian Grote

The research icebreaker Polarstern on a mission: scientists on board the excellently equipped polar research vessel are studying climate and climate change.

HELMHOLTZ ASSOCIATION

Investigating unknown worlds: ambitious goals require effective tools. The Helmholtz Association uses high-performance infrastructure and unique large-scale research equipment.

FACTS AND FIGURES

HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

18 independent research centres

Approx. **43,000 staff**, including roughly 25,000 scientists and scientific staff

8,000 PhD students, among them over 2,000 international doctoral students

More than **10,000 international researchers**

International collaborations all over the world; **research networks in Germany**, especially with universities

Annual budget: approx. **5 billion euros** (2020)

www.helmholtz.de

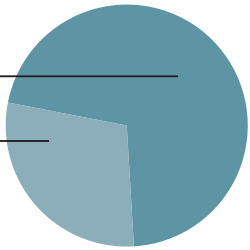
It was the biggest Arctic expedition of all time: the German research icebreaker Polarstern spent an entire year drifting through the frozen Arctic Ocean. Hundreds of scientists from 20 countries took part in the MOSAiC expedition. Their goal was to undertake a close-up study of the Arctic as a hotspot for global warming and obtain fundamental insights that would lead to a better understanding of anthropogenic climate change. MOSAiC was coordinated by the **Alfred Wegener Institute**, Helmholtz Centre for Polar and Marine Research (AWI).

AWI is one of **18 independent research centres** that have joined forces under the umbrella of the Helmholtz Association of German Research Centres. With approx. 43,000 employees and an annual budget of around 5 billion euros, the Helmholtz Association is the largest scientific organisation in Germany. The association is named after the great German polymath and naturalist Hermann von Helmholtz (1821–1894).

HZDR/Frank Bierstedt

Hope for patients: researchers at the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) have developed an immunotherapy to treat radiation-resistant tumours.

BUDGET



2020; source: Helmholtz Association

The research centres within the Helmholtz Association focus on natural sciences, biology and medicine, and work in six fields of research:

- energy
- earth and the environment
- health
- aeronautics, space and transport
- information
- matter

THE TASK

Helmholtz works on **long-term research goals**. Its core objective is to preserve and improve the basis for human life. The researchers in the association help to decode the complex systems that define and shape humanity and the environment. And they develop answers to the major, pressing issues facing society, science and the economy: What will the energy supply of tomorrow look like? How can resources be used sustainably? What therapies can be found for previously incurable diseases?

WORKING WITH LARGE-SCALE EQUIPMENT

The autonomous research institutes specialise in developing, building and operating complex **research infrastructures**. The large-scale equipment they use includes accelerator systems, telescopes, research ships and high-performance computers, which Helmholtz makes available to scientists all over the world. And the interest from the international research community is immense: in 2020 alone, more than 10,000 researchers from abroad, among them almost 3,500 visiting scientists, were able to exchange ideas and make use of the infrastructures of the Helmholtz Centres.

We observe electrons at work

PROFESSOR FRANCESCA CALEGARI
Head of the Attosecond Science division at DESY, Deutsches Elektronen-Synchrotron

Professor Calegari, what is attosecond physics and why are you interested in these short timescales?
An attosecond is one quintillionth of a second – that is 18 zeros behind the decimal point. One attosecond to a second is like a second to the age of the universe. Attosecond physics means we can observe electrons at work. Having access to this incredibly short timescale allows the origin of fundamental physical and chemical processes – activated by the light-matter interaction – to finally be revealed.

What do you aim to achieve with your research?
I am interested in investigating ultrafast processes in biorelevant molecules. With the help of attosecond laser pulses, we have been able to image in real-time the ultrafast electronic motion occurring in amino acids – the basic building blocks of proteins – after interaction with light. In the long term, we're hoping not only to observe the electrons but also to guide them, with the aim of controlling the outcomes of a biochemical reaction. This research has potential outcomes in medicine and pharmaceutical applications.

What is special about working at a Helmholtz Centre?
DESY offers an extremely attractive, interdisciplinary research environment. I can collaborate here with groups from a range of fields and use different light sources for my experiments, such as FLASH and the European XFEL. I can investigate biorelevant molecules from various points of view.

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JUNIOR RESEARCH GROUPS

Strategic talent management plays an important role for the Helmholtz Association. With its junior research groups, the association promotes the early independence of young postdocs.

DAAD/Volker Lannert, p. 50: DustyPixel/Getty Images

Attractive conditions for talents: the Helmholtz Association makes targeted offerings to early career researchers.

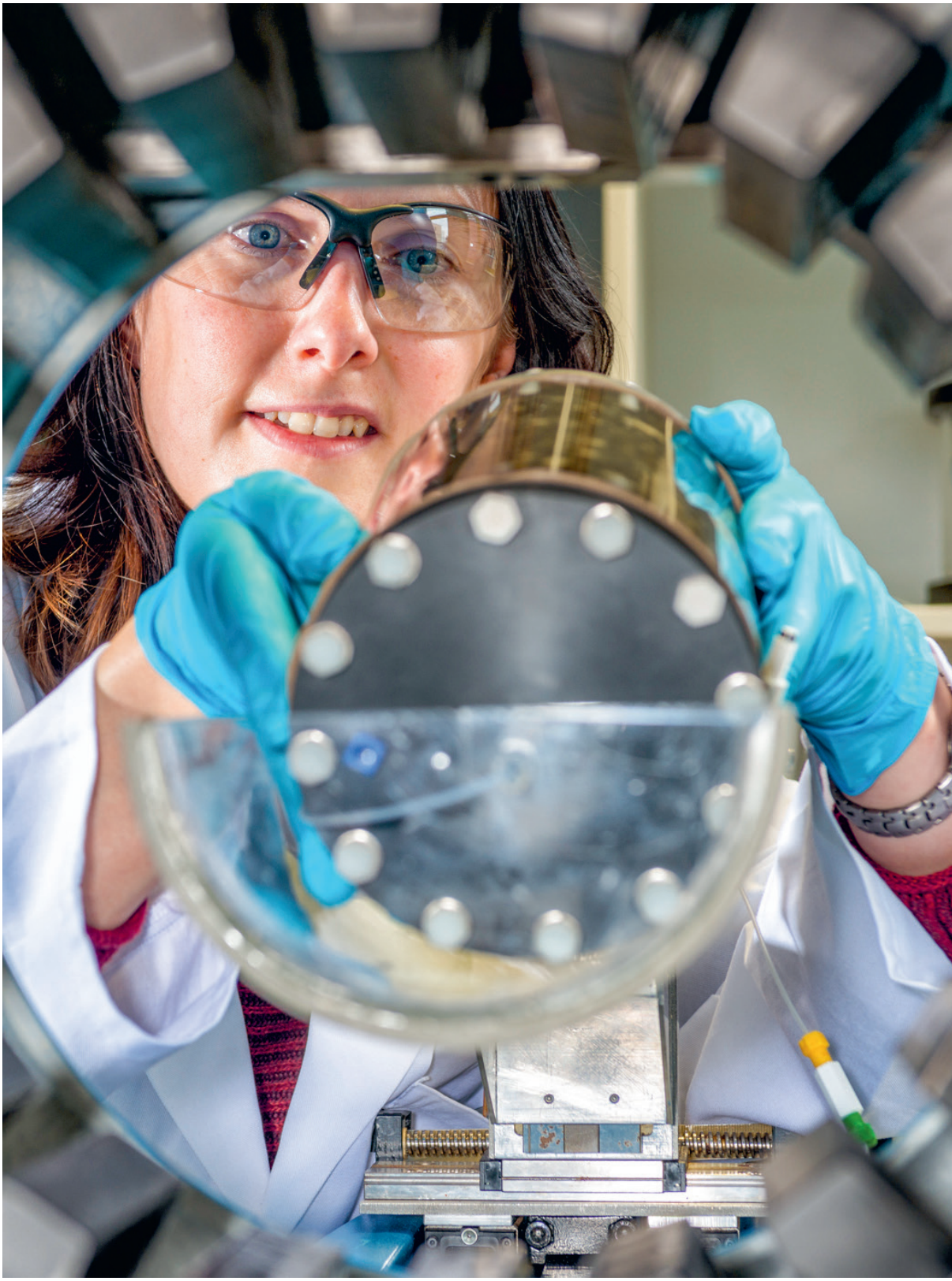
OPPORTUNITIES FOR YOUNG SCIENTISTS

The utmost priority is given to fostering up-and-coming scientific talent. The association's talent management team gives particularly strong support to PhD students, postdoctoral researchers and future managers. Helmholtz offers its early career researchers attractive qualification opportunities:

- 21 Helmholtz Research Schools and 13 Helmholtz Graduate Schools
- a postdoc programme for support immediately after the doctorate
- approx. 200 junior research groups for top (international) talents

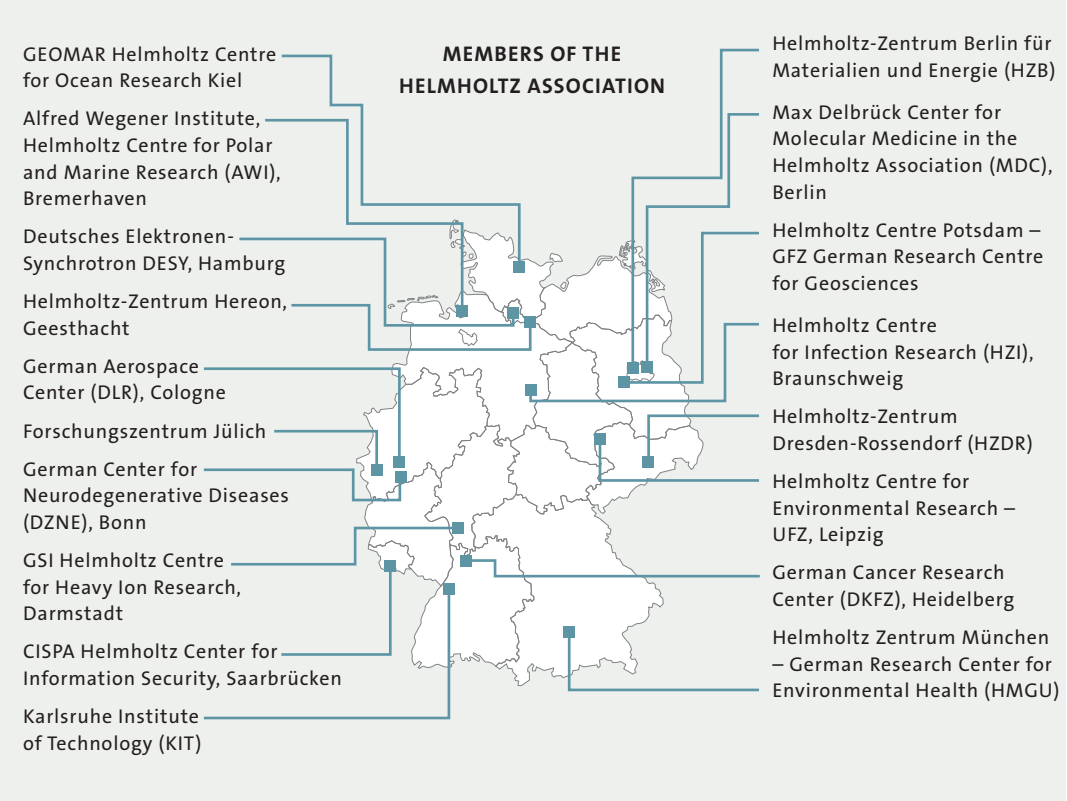
HELMHOLTZ INTERNATIONAL RESEARCH SCHOOLS

For young international scientists, the nine **Helmholtz International Research Schools** offer a structured doctoral programme run jointly by the Helmholtz Centres, partners from abroad and German university partners. Up to 25 doctoral candidates work together here as they focus on specific research topics. This gives them the opportunity to gain vital experience in working with other researchers at the international level. The PhD students receive outstanding specialist training that not only lays the foundations for a future career but is also character-forming.



HZDR/Oliver Killig

Racetrack for particles: the petawatt laser PENELOPE, a medical particle accelerator, is set up at the ELBE – Center for High-Power Radiation Sources at the Helmholtz-Zentrum Dresden-Rossendorf.



TRANSLATION INTO PRACTICE

The work of Germany's largest scientific organisation goes further than researching the fundamental elements of the major challenges of the day. The Helmholtz Association also aims to apply and implement the findings and solutions in practice, and thus, more specifically, to translate research into usable products and services. In order to achieve this, Helmholtz issues for example licences, facilitates the use of research infrastructure and also fosters collaboration and commissioned research right through to establishing start-ups.

In 2020 alone, there were **18 spin-offs from the Helmholtz Centres**, with scientists founding their own companies based on a technology they developed. In total, the association can proudly look back on more than 250 successful company foundations since 2005.

LEIBNIZ ASSOCIATION

Theoria cum praxi: the desire to use science for the benefit and good of humankind was formulated by Gottfried Wilhelm Leibniz back in 1700. The research organisation that bears his name demonstrates every day just how relevant this principle still is, even today.

FACTS AND FIGURES

Leibniz Association

96 independent institutes

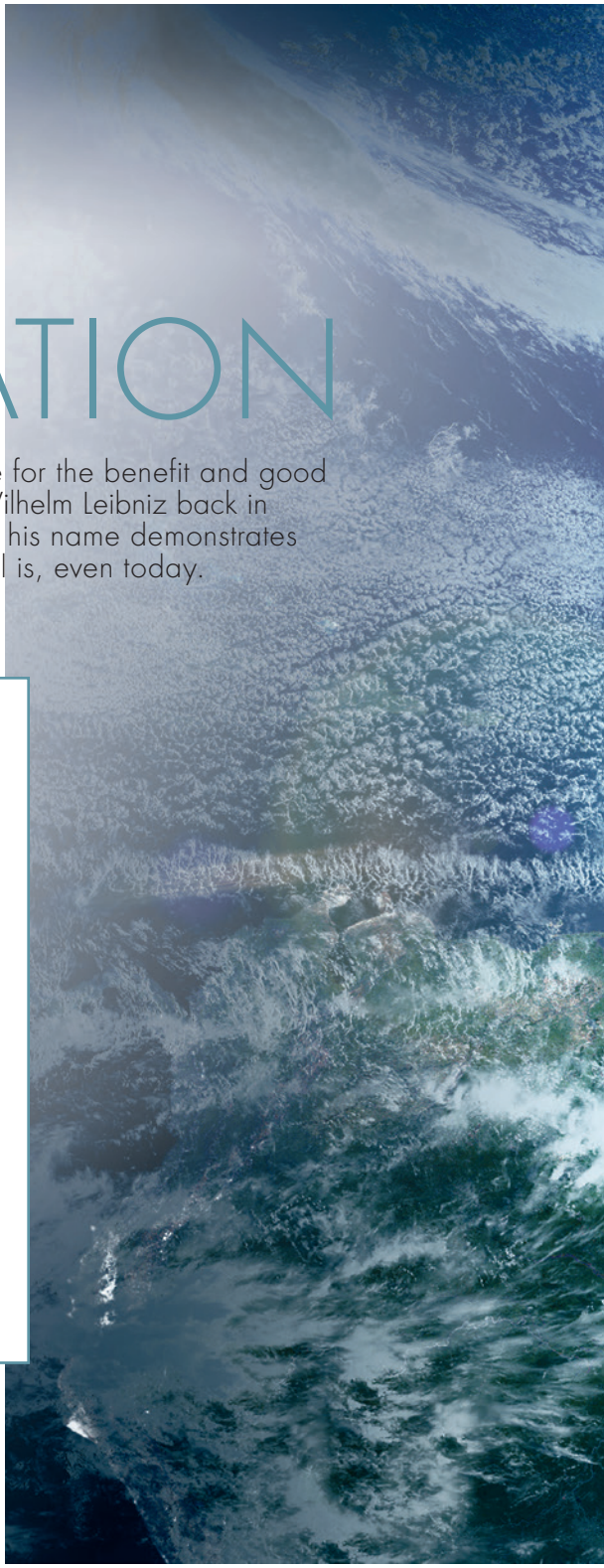
Approx. **20,000 staff** (including 10,000 researchers)

Roughly **2,400 international researchers**

Approx. **4,000 doctoral students**

Annual budget: more than **1.9 billion euros** (2019)

www.leibniz-association.eu



Planetary boundaries: a team of researchers at the Potsdam Institute for Climate Impact Research is investigating changes in various areas of our Earth system.

Shutterstock/Denis Tabler

What are the limits to our planet's resilience? This weighty question has relevance for the whole of humankind. The **Potsdam Institute for Climate Impact Research** (PIK) is searching for an answer in the "Potsdam Earth Model Planetary Boundary Simulator" project. For the first time, it is exploring how the various so-called "planetary boundaries" (such as climate change, acidification of the oceans and loss of biodiversity) affect one another and which feedbacks arise between the atmosphere, the terrestrial and marine biosphere, oceans and ice sheets. Studying all relevant components jointly is intended to paint a picture of the overall state of the Earth system and to simulate the changes it is undergoing. The researchers hope that this will give them insights in particular into the effects that global change is having on forest ecosystems and which consequences the weakening of the Gulf Stream will have for the marine biosphere.

THE BRIEF

PIK is not only one of the world's leading think tanks in the field of environmental policy, but also one of a total of **96 independent research institutes** run by the Leibniz Association. Like PIK, they are all guided by the same principles of quality and social relevance that were advanced by Leibniz more than 300 years ago. The scope of their research ranges from the natural sciences, engineering and environmental sciences to economics, space science, social sciences and the humanities.

Shot by Scott/Getty Images, p. 57: Nana_studio/Stock Adobe

A broad field: Leibniz Association scientists pursue research in fields such as biodiversity – as well as in peace studies, contemporary history and education.

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RESEARCH STATIONS ABROAD

From Senegal and Peru to Norway – Leibniz Association research stations are to be found all over the world.

The entire world of economics

Nowhere in the world is there as much literature on economics as there is here at the ZBW – Leibniz Information Centre for Economics. The world's largest research infrastructure for literature on economics, the ZBW operates nationally – both online and offline. Its library houses more than 4.4 million books and some 24,000 current magazines. 2.3 million documents are available online. These are complemented by 206,000 articles and working papers, all of them freely accessible.

This wealth of literature is of particular benefit to economists. Yet not only the online services and the open-access repository, but also the specialist portal EconBiz containing over ten million data records can be accessed free of charge by anybody interested throughout the world.

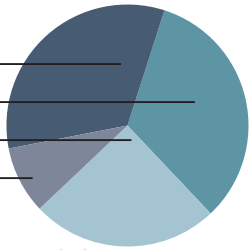
In the 21st century the librarian's world is undergoing a period of radical change such as has never been seen before. It is the ZBW's intention to become actively involved in this process. The organisation is for example conducting research into application and publication processes on the Internet and investigating new search paradigms for revealing previously unknown links between digital documents. Open science plays an important role for the ZBW. The centre conducts intensive research in this area, too, developing new technologies that enable access and remove barriers.

www.zbw.eu

DAAD/Christian Lord Otto, p. 58: Stefan Vorbeck

A tight-knit international network: the Leibniz Association engages in global collaboration – with around 25% of its scientists coming from abroad.

BUDGET



2020; source: Leibniz Association

The focus of the Leibniz Association is on **knowledge transfer**. It advises and informs representatives of politics, science, business and the general public. The institutions in the Leibniz Association are concerned with **basic research, applied research and research-based infrastructures**. It is this wide range of subjects and research approaches that makes the Leibniz model so very appealing – to top international researchers, too.

Leibniz boasts four kinds of research infrastructures:

- **information infrastructures** such as archives and libraries to manage information of all kinds
- **e-Infrastructures** such as data and cloud infrastructures, high-performance and supercomputers and grid computing infrastructures
- **large-scale equipment** and research platforms such as GREGOR, the largest solar telescope in Europe, in Tenerife
- **social research infrastructures**, i.e. conference and meeting centres where scientists can exchange information in their own specialist areas and initiate new projects

THE ROADMAP

The **Leibniz Roadmap for Research Infrastructures** is the Leibniz Association's way of planning the future. To ensure that excellent research will still be possible in 10 to 15 years' time, the research infrastructures need to be assessed and expanded. The roadmap contains concepts for research infrastructures which the Leibniz Association has prioritised as part of an internal process. To qualify, the relevant concepts should allow for excellent scientific work and be socially relevant, of significant importance to the scientific community and user-oriented.

Nine projects designed to complement and enrich the research infrastructures of the future were chosen. Four of the Leibniz concepts were selected for the list of the national Roadmap for Research Infrastructures; three others have been included in the roadmap of the European Strategy Forum on Research Infrastructures (ESFRI). One thing that has already been decided is to set up the Leibniz Center for Photonics in Infection Research (LPI). It was one of three new national research infrastructures to be selected, and is to go into operation in 2024. Its goal is to fight infectious diseases with the help of innovative photonics-based diagnostics and therapeutic methods.

THE NEXT GENERATION OF SCIENTISTS

Training the next generation of scientists is an important aspect of the Leibniz Association's mission. There are some 4,000 doctoral students working at the institutes. In addition, the Leibniz Association is committed to structured graduate training. To this end, the Leibniz Institutes collaborate closely with universities. In total, Leibniz is involved in almost 170 graduate schools.

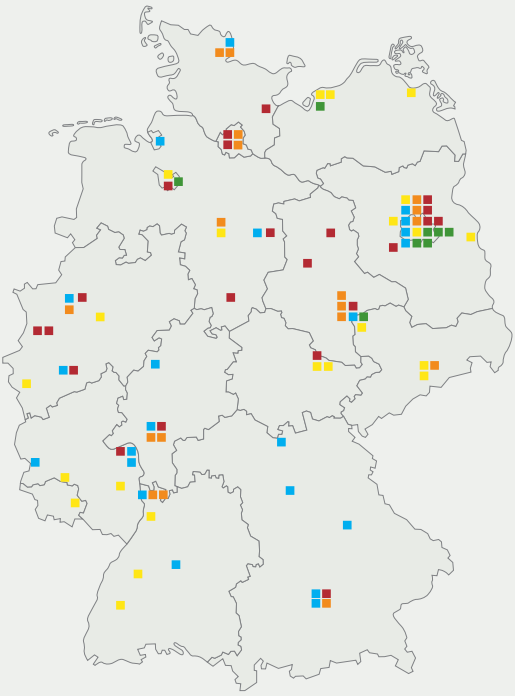
COOPERATION AND NETWORKING

Leibniz also collaborates closely with universities on research. There are more than 20 networks of Leibniz Institutes and university facilities working together on an interdisciplinary basis as the **Leibniz ScienceCampi**.

Various Leibniz Institutes are affiliated in twelve **Leibniz Research Alliances** and concentrate on subjects of great scientific and social relevance. For instance, scientists at eight Leibniz Institutes have teamed up to form the Leibniz Research Alliance "Nanosafety" with a view to understanding the effect of nanoparticles and developing safe nanomaterials.

The institutes also cooperate as part of **Leibniz Research Networks** on focal topics or key technologies such as green nutrition and citizen science. These networks see themselves as a central point of contact for their fields of research not only within the Leibniz Association, but also for the worlds of politics, media and business and for their sponsors.

LEIBNIZ INSTITUTES STAND FOR A BROAD SPECTRUM OF SCIENCE



- Humanities and educational research
- Economics and social sciences, spatial research
- Life sciences
- Mathematics, natural sciences and engineering
- Environmental research

dpa/Alexander Heinl

One of eight research museums in the Leibniz Association: the Senckenberg Museum in Frankfurt am Main is one of Germany's largest museums of natural history.

DAAD/Jan Zappner

Excellent teams: more than 2,000 academics conduct research under the umbrella of the Union of the German Academies of Sciences and Humanities.

ACADEMIES

Bring all the most intelligent people together in one and the same place. That was Plato's idea over 2,400 years ago, when he identified the grove of Akademos as the ideal place for his philosophers' school. And to this day it is at the core of the idea of a community of thinkers – the academy.

Germany's first scholarly society was founded as long ago as 1652. The **Deutsche Akademie der Naturforscher Leopoldina** is thus the oldest scientific and medical academy in the world. It has been the German National Academy of Sciences since 2008. Yet there are many other academies in Germany, too. They include the **Union of the German Academies of Sciences and Humanities**, which is an association of eight state (Länder) academies. Then there is the National Academy of Science and Engineering, **acatech**, which represents the technical sciences, at home and abroad. And since the beginning of the new millennium **Die Junge Akademie** has represented new scholarly talent.

The key tasks of the academies are to coordinate long-term basic research projects, to advise policymakers and the public on issues relating to our futures, and to support interdisciplinary dialogue by organising symposia and events.

FACTS AND FIGURES

UNION
DER DEUTSCHEN AKADEMIEN
DER WISSENSCHAFTEN

8 academies in the Union with more than 2,000 scientists and scholars

Approx. **900 staff** on the Academies Programme

Annual budget of the Academies Programme: **70.8 million euros** (2021)

www.akademienunion.de

Union of the German Academies of Sciences and Humanities

Eight academies have joined forces to form this union. They represent more than 2,000 member scientists who are among the best in their

We document our cultural heritage

PROFESSOR HANNS HATT
President of the Union of the German Academies of Sciences and Humanities

Professor Hatt, what does it mean to be President of the Union of the German Academies of Sciences and Humanities?
It is a great honour to represent the eight venerable academies of sciences and humanities. More than 2,000 outstanding scholars from a variety of fields are members of these institutions. Our goal is also to further strengthen cooperation between the academies.

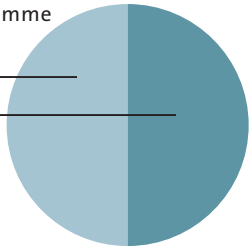
What is special about the Academies Programme?
The Academies Programme is unique worldwide. It includes more than 130 long-term basic research projects in the humanities. They are dedicated to retrieving, preserving and interpreting documents of culture heritage worldwide. In this way, it makes a key contribution to documenting cultural heritage and showing how it is relevant to society today.

What does the Union intend to achieve in the next few years?
It is the task of academics to advise society and policymakers on major challenges, such as migration, climate change and energy. It is imperative that expertise in the social sciences and humanities become more strongly involved in this process. And such expertise is especially well represented at our academies.

DAAD/Jan Zappner

Focusing on cultural heritage: the Union coordinates Germany's largest research programme in the humanities and social sciences.

BUDGET
Academies Programme



2021; source:
Union of Academies

respective fields. In particular, they conduct **basic research in the humanities and social sciences**, projects that require endurance. Some of their traditions date well into the 18th century. The latest member of the Union is the Academy of Sciences and Humanities in Hamburg, which was founded by Hamburg civil society in 2004.

The collective research programme of the academies of sciences – the **Academies Programme** – ranges from the Goethe Dictionary and the edition of Alexander von Humboldt's manuscripts to basic research on the role of culture in early expansions of humans. It is the largest programme of research in the humanities in Germany and draws on funding of more than 70 million euros for a total of 132 research projects. The goal is to catalogue, secure and represent Germany's cultural heritage.

THE EIGHT ACADEMIES IN THE UNION ARE:

- Berlin-Brandenburg Academy of Sciences and Humanities (1992/1700)
- Göttingen Academy of Sciences and Humanities (1751)
- Bavarian Academy of Sciences and Humanities (1759)
- Saxon Academy of Sciences and Humanities in Leipzig (1846)
- Heidelberg Academy of Sciences and Humanities (1909)
- Academy of Sciences and Literature, Mainz (1949)
- North Rhine-Westphalian Academy of Sciences, Humanities and the Arts (1970)
- Academy of Sciences and Humanities in Hamburg (2004)

Leopoldina

"Exploring nature for the glory of God and the good of mankind" was the mission of Johann Lorenz Bausch, Johann Michael Fehr, Georg Balthasar Metzger and Georg Balthasar Wohlfahrt when, in 1652 in the Free Imperial City of Schweinfurt, they founded the Academia Naturae Curiosorum, one of the world's first scientific and medical academies. The Deutsche Akademie der Naturforscher Leopoldina sought to bring together the leading academic scholars of the day in order to debate scientific questions, insights and findings across the disciplines and for the benefit of society.

That remains the case to this day. About 1,600 outstanding scientists from over 30 countries, among them 33 Nobel laureates, work according to this interdisciplinary and international tradition. Each of them was nominated for membership solely on account of his or her significant scholarly achievements. The Leopoldina is now located in Halle in Saxony-Anhalt. **It is the world's oldest continuously existing academy of the natural sciences.**

DIALOGUE OF THE ACADEMIES

Since 2008, the Leopoldina has been the German National Academy of Sciences. It is thus the voice of German science in the international dialogue between academies. The Leopoldina has a global network of international partners such as the Académie des sciences in France or the Indian National Science Academy. The Leopoldina not only represents German scientists on the international committees, but also shares its findings with policymakers and the public. Together with the science academies of the G7 and G20 member states, it advises the heads of state and government at their annual summit meetings, for example.

FACTS AND FIGURES

Approx. **1,600 members**, including more than 500 international scientists and scholars

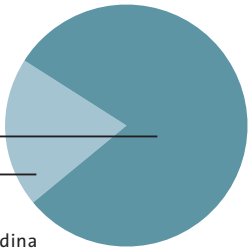
Approx. 100 staff

Close relations with science academies on all continents

Annual budget:
17.2 million euros (2019)

www.leopoldina.org

BUDGET



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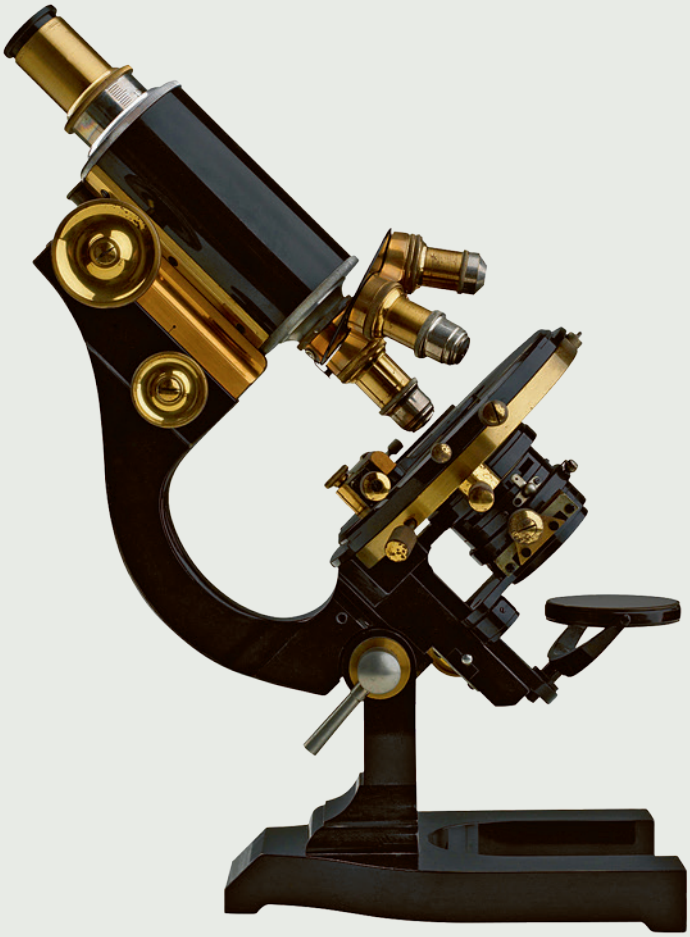


7,800

OUTSTANDING SCHOLARS

Since its foundation back in 1652, more than 7,800 outstanding scholars have been nominated members of the Leopoldina. Among them were 183 Nobel laureates and renowned personalities such as Marie Curie-Skłodowska, Charles Darwin, Albert Einstein, Johann Wolfgang von Goethe, Alexander von Humboldt and Max Planck.

Tetra Images/Getty Images

Die Junge Akademie

Die Junge Akademie, founded in 2000 by the Leopoldina and the Berlin-Brandenburg Academy of Sciences and Humanities, is the world's very first academy for early career researchers. The 50 young researchers from across all disciplines rotate: every year, ten new nominees replace ten members who withdraw. During their five-year membership of Die Junge Akademie, each member has access to a research budget of some 35,000 euros for joint projects. Taking their cue from Die Junge Akademie, there are now academies for young scientists in numerous countries. In fact, the **Global Young Academy** was founded in 2008, with Die Junge Akademie playing an advisory role in the process.

FACTS AND FIGURES

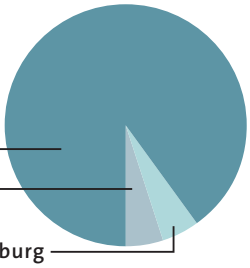
Die Junge Akademie

50 members, each with a research budget of 35,000 euros

5-year membership

More than 40 research groups since foundation

www.diejungeakademie.de



2021; source: Die Junge Akademie

acatech

acatech, the National Academy of Science and Engineering, sees itself as a "working academy". It has almost 600 members from academies, universities, research institutes and companies. They collaborate in 10 topic networks that address the research and technology-policy issues of tomorrow. **acatech views itself as a network that links science and business**. Scientists and experts from the business sector work closely together. Their objective: to provide independent, science-based consulting geared to public welfare for policymakers, businesses and the public. The topic networks at acatech are interdisciplinary in structure and have a practical focus. They address issues of future industrial applications, as well as economic, ecological and social opportunities and risks. The topics range from the reliability of complex socio-technological systems or the analysis of the development of the energy systems of tomorrow to questions of possible obstacles to innovation in nanotechnology.

FACTS AND FIGURES

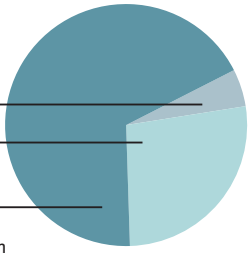
acatech
NATIONAL ACADEMY OF SCIENCE AND ENGINEERING

Almost 600 members

Approx. 40 research projects per year, collaboration with institutions and companies

Annual budget: approx. **13 million euros** (2020)

www.acatech.de



2021; source: acatech

DAAD/Jan Zappner

Forever changing: after completing five years each, ten members withdraw from Die Junge Akademie and are replaced by ten newly appointed young researchers. Total membership remains constant at 50.

GOVERNMENT RESEARCH INSTITUTIONS

Are tattoos dangerous? When does noise cause illness? What can be done so that fish swim upstream again? Scientists in government research institutions are exploring such issues that potentially affect us all. And the insights they gain often lead to recommendations for policymakers.

Biobased building materials: the concrete of the future may contain rice husks or coconut fibre.

Sandra Standbridge/Getty Images

FACTS AND FIGURES

More than **40 federal institutions** with R&D responsibilities

About **140 state** (Länder) **research institutes**

More than **25,000 staff** (among them 12,000 R&D personnel)

Internal expenditure: **3.1 billion euros** in total, for R&D: 1.5 billion euros (2019)

www.bundesregierung.de

The construction sector is booming – not only in Germany, but worldwide. However, this could have fatal consequences for our climate as large amounts of carbon dioxide are released during the production of cement, which is a key component of concrete. This is reason enough for researchers at the **Bundesanstalt für Materialforschung und -prüfung (BAM)** to work on finding ways to replace cement, at least partly, with renewable resources. Their research shows that the husks or skins of plants such as rice, cassava or coconut can be used as a substitute for the conventional chemical and mineral additives in concrete. In fact, the new concrete is in some cases stronger, as well as easier to process and mould. This would be ideal for use in Africa, where many cement plants are currently being built. What is more, large quantities of the raw materials from plant husks and their ashes are available there, without being used to date. This basic research, which is of interest not only to the construction industry in Africa, was helped by the BAM's cooperation with African scientists. This collaboration is now to be made permanent by creating a joint knowledge network with researchers in Africa and industry.

Germany is a globally significant player

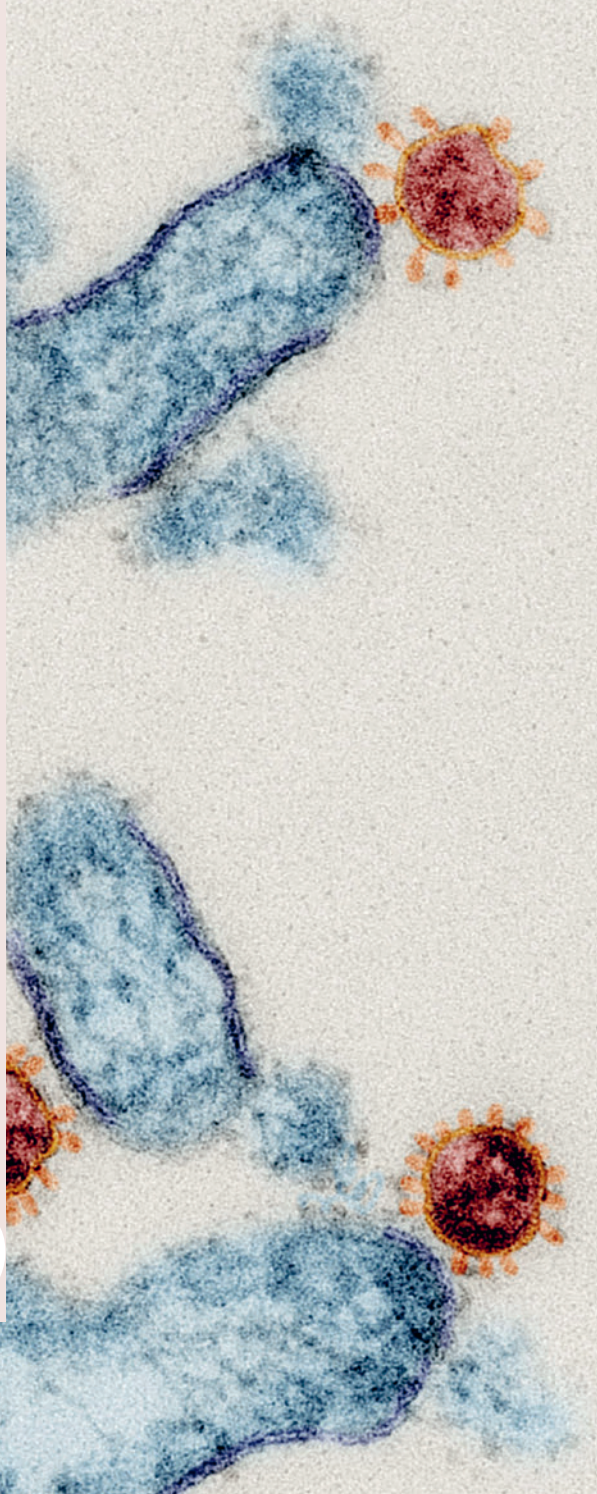
PROFESSOR KLAUS CICHUTEK,
President, Paul-Ehrlich-Institut (PEI), Federal Institute for Vaccines and Biomedicines

Professor Cichutek, the coronavirus has revealed how dangerous viruses still are today and how important vaccination research is. What makes Germany stand out as a location for research in this field?

Germany has traditionally played an important role in vaccine development and production. In addition, biotechnology has been widely promoted in Germany as a promising means of developing innovative therapies and diagnostics. This, combined with creative and risk-taking researchers, has made Germany a globally significant player in the field. During the pandemic, several companies in Germany played a key role in the rapid development of novel and highly effective vaccines.

What are the most important issues that the PEI will address in the medium term?

By establishing the German Pandemic Vaccines Center at the Paul-Ehrlich-Institut, we will lay the foundations for the development and supply of vaccines in future pandemics. In addition, we will continue to build on the synergism between translational academic research, medical product development by biotech and pharma industries, and the regulatory science provided by the Paul-Ehrlich-Institut. This is a mainstay of our response to the pandemic, as well as to many other clinical challenges we are facing.



RKI/Dr. Michael Laue, Thorsten Jansen

Robert Koch-Institut

Prime science: government research institutions devote themselves to topical issues that have an impact on the world.

COOPERATING WITH THE MINISTRIES

The most important job of the BAM is to help develop legal regulations, for example for defining safety standards and limit values, and to advise the German government, industry and national and international organisations on matters relating to materials technology and chemistry. The BAM is one of over **40 federal research institutions** that specifically pursue research on questions raised by policymakers and public authorities. About 5,000 scientists make forecasts that give early warning of pending problems, or they study the effects of ongoing initiatives. In this way they provide the scientific insights that the Federal Government needs in order to take well-founded decisions. The scientists concern themselves with current issues, such as:

- the impact of modern technologies
- health and nutrition
- mobility and urban development
- the environment, energy and climate protection
- changed working and living conditions
- the global economy

If for example there is an outbreak of measles or a dangerous virus like the coronavirus SARS-CoV-2 begins spreading, the Robert Koch Institute (RKI) in Berlin will continuously monitor the situation, evaluating all available information, assessing the risk for the population in Germany and advising the Federal Ministry of Health and the Federal Government. It provides health professionals with recommendations and gives an overview of its own research. If allergies to textiles or resistances to antibiotics are detected, it is the German Federal Institute for Risk Assessment (BfR) in Berlin that intervenes and warns the public.

RESEARCH AT THE STATE LEVEL

At the state (Länder) level, there are another 140 or more research institutions with over 6,000 staff members to support the respective state governments. Here again, about 1,300 scientists conduct research on all the relevant social and economic issues. The experts look for contemporary solutions in fields such as laser applications, totalitarianism studies, hydrogen and heat storage or artificial intelligence.

Adobe Stock/fotostudiocolor24

Competent and motivated: highly qualified personnel work at state research institutions.

The **German Research Center for Artificial Intelligence** (DFKI) for example seeks to develop innovative software. It is Germany's leading research centre in the field of innovative commercial software technology using artificial intelligence. The DFKI is a public-private partnership with the states of Bremen, Rhineland-Palatinate and Saarland and has numerous renowned German and international high-tech companies as shareholders. At present, approximately 660 highly qualified researchers, administrators and 440 graduate students from more than 65 countries are contributing to approximately 250 DFKI research projects – such as joint activities with the European Space Agency (ESA) to develop AI technologies for applications in civilian space travel.

VAST NETWORK

The **government research institutions' infrastructure** is in part among the best worldwide and open to external research groups, too. The goal is to boost interaction between everyone involved in the German research and innovation community – and shed light on issues of science policy from many different angles.

Deutscher Wetterdienst (DWD) for example relies not only on government research staff. Scientists from LMU Munich, FU Berlin and the universities of Hamburg, Frankfurt, Bonn and Cologne, as well as from the Max Planck Institute for Meteorology and the Max Planck Institute for Human Development, work at its Hans Ertel Centre for meteorological research. Their aim is to improve weather forecasting and climate monitoring. For example, they use laser beams to measure wind patterns, gusts and convective turbulent structures up to a height of several hundred metres above the ground. The researchers see themselves primarily as information providers: they study the weather to help DWD give more accurate weather warnings and to support the quality of decisions by policymakers, local authorities and business.

Strengthening bees

Bee populations are suffering from both climate change and the bee parasite varroa, in combination with attacks by viruses. There have been heavy losses. One measure to support honeybee biodiversity is the creation of Europe's first gene bank for honeybees, led by the Institute for Bee Research Hohen Neuendorf e. V. (LIB). The institute is headed by Professor Kaspar Bienefeld. In recent years, LIB and industry partners have made technical advances in the preservation of drone semen, allowing the gene bank to be set up. The aim is to collect genetic resources from over 200 colonies, in cooperation with national and international partners.

The LIB is itself the product of successful cooperation. The long-standing research establishment is funded by the states of Brandenburg, Saxony-Anhalt, Saxony, Thuringia and Berlin. Representatives of beekeeper associations and scientists are also represented in the non-profit organisation. With a strong practical focus, the institute addresses different aspects of bee research: breeding and preservation of bee populations, molecular microbiology, honey analysis and projects to protect wild bees and honey bees.

www.honigbiene.de

Länderinstitut für Bienenkunde Hohen Neuendorf

PRIVATE SECTOR

The private sector in Germany is one of the world leaders in research. It invests billions in research and development and relies on a global network of research facilities, all dedicated to finding solutions for products and processes for the industry of tomorrow.

FACTS AND FIGURES

More than **470,000 research staff**

Distribution of the internal research budget: 8% small enterprises (up to 249 employees), 4.5% medium-sized enterprises (250–499), 87.5% large enterprises (more than 499)

R&D internal expenditure: **72.1 billion euros or 2.2% of GDP** (2018)

www.stifterverband.de

Reaching for the sky: wind power is becoming increasingly important worldwide.

Getty Images/CharlieChesvick

Bayer AG

It's a good plan. And a gigantic one. One of the biggest offshore wind farms in the world is to be linked to an electrolyser and become the world's first system to produce coveted "green" hydrogen directly – that is to say without the turbine being connected to the grid. To achieve this, Munich energy company Siemens Energy and its Spain-based subsidiary Siemens Gamesa have joined forces. Over the next five years, 120 million euros are to be spent on developing an innovative solution that will illustrate how a cost-efficient and climate-neutral modular offshore wind-hydrogen system can be realised on a major scale. The project is part of the H_2Mare initiative and is being implemented as part of the ideas competition "Hydrogen Republic of Germany" run by the Federal Ministry of Education and Research.

Green hydrogen has a key role to play in tackling climate change: it is to help make the biggest emitters of greenhouse gases – such as the steel and aluminium sectors and the manufacturers of glass and cement – more climate-friendly. The research and development of solutions that will allow its production are therefore essential if we are to meet the central challenges of today: how can we become independent of mineral oil by using clean technologies? What will mobility look like tomorrow? Be it small start-ups, small and medium-sized enterprises (SMEs) or global players such as Volkswagen – the German private sector is deeply involved in research into practical and fundamental issues.

Innovation as the basis: research and development are key in the pharma industry.

Arthur Pease/Siemens AG

Image-generating processes in medicine: new technologies enable treatment methods that are more precise.

EN ROUTE TO INDUSTRY 4.0

Germany is one of the top five industrialised nations worldwide when it comes to the volume of private sector investments in research and development (R&D). **The sector accounts for more than two thirds of total R&D expenditure**, namely more than 72 billion euros in 2018. Companies in the following areas are particularly active:

- automotive and transport technologies
- data processing, electronic and optical products
- mechanical engineering
- engineering firms, software developers, scientific and technical development laboratories and research institutions

At present, researchers in many companies are addressing the topic of Industry 4.0: digitally networked systems connect production facilities using modern information and communication technologies. There is hardly any other development that German corporations have engaged with as intensively as digitisation. This is also true of the heavyweight in industrial research: the automotive industry, which accounts for slightly more than one in three euros spent on R&D. The electronics, chemical and pharmaceutical industries are also major investors in R&D.

Gorodenkoff Productions OU, Volkswagen AG

Seamlessly connected: the German company Bosch has teamed up with the US company Microsoft to develop the next generation of vehicle software.

Not only industrial corporations rely on research to advance: freelance, scientific and technological service providers invest more than classical pharmaceutical industries. A typical example of one such young company is HQS Quantum Simulations, a spin-off of the renowned Karlsruhe Institute of Technology (KIT). This deep-tech start-up develops ideas for making quantum computers suitable for use in medical or energy research.

LEADING IN THE WORLD

By international standards, German industry is right at the forefront of research and development. **One of the leading companies worldwide in the R&D investment tables is the carmaker Volkswagen**. It spent more than 14.3 billion euros on R&D in 2019 alone. In the same rankings, Daimler, BMW, Robert Bosch, Siemens and Bayer are all among the top 30 corporations worldwide. Many companies conduct research abroad and some even have their own global networks, such as German automotive component supplier Continental. It develops its products at 88 different locations worldwide.

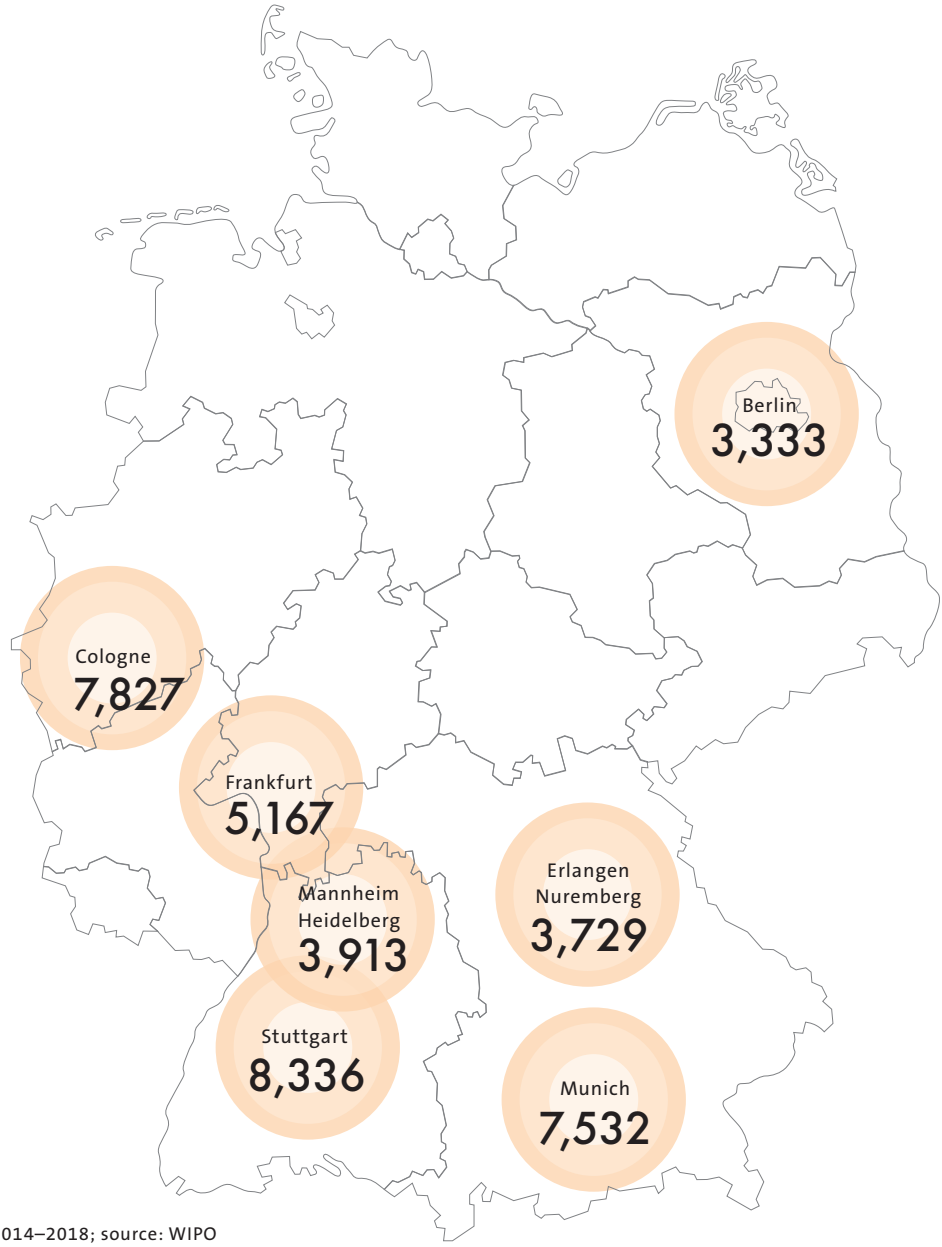
GERMAN COMPANIES WITH THE HIGHEST R&D EXPENDITURE
in million euros

Volkswagen	14,306
Daimler	9,630
BMW	6,419
Robert Bosch	6,229
Siemens	6,086
Bayer	5,628
SAP	4,283
Continental	3,597
Boehringer	3,462
Merck	2,268

2019; source:
EU R&D Scoreboard 2020

CLUSTERS OF INNOVATIVE ACTIVITY

Germany is one of the world's most innovative countries when it comes to international patent applications (in line with the Patent Cooperation Treaty, PCT): **seven metropolitan areas rank among the world's top 50 science and technology clusters** – only the USA is represented by more regions in this list.



2014–2018; source: WIPO

Many people have been involved

PROFESSOR UĞUR ŞAHIN,
Chief Executive Officer,
BioNTech SE

Professor Şahin, your company BioNTech developed one of the world's first Covid-19 vaccines to obtain market approval. What is your formula for success?
The progress we had already made in developing our mRNA technology made all the difference. We have a great team of many experts who facilitated the development, production and distribution processes. Many different aspects were tackled in parallel: while development of the vaccine was underway, we were busy expanding our production capacities at the same time. Many people have been involved in this project for all humankind.

You are cooperating with the US company Pfizer. Why is international cooperation so important?
A global problem cannot be solved by one company or one country working on its own. We knew that we would need a strong partner to test the vaccine worldwide and have it approved. Furthermore, we needed a partner with the infrastructure required to get the vaccine to as many people around the world as possible. Our contribution came in the form of the mRNA technology and our deep understanding of the immune system.

Which key research areas do you plan to focus on particularly over the coming ten years?
Above all on cancer research. Our goal is to replace existing treatment methods with novel approaches and to develop therapies for cancer types that to date have proven virtually untreatable. We want to improve the lives of patients. In addition, we are working on ways to treat autoimmune disorders such as MS and allergies.

Garodenkoff Productions OU, Bayer AG

Internationally successful: German companies are among the world top five in terms of patent, utility model and industrial design applications.

Big players: alongside the automobile and electronics sectors, the chemical and pharma industries are among the major investors in R&D.

Thanks to its strong research sector, Germany is also among the world top five in terms of patent, utility model and industrial design applications. The world's top applicants include Bosch, Siemens and BASF, not to mention family-owned Schaeffler and the automotive manufacturer BMW.

HIDDEN CHAMPIONS AND START-UPS

It is not only large corporations that conduct a lot of research. Almost 13 percent of the total spent on in-house R&D by businesses – i.e. 9 billion euros – is invested by SMEs. Above all the **mid-sized mechanical engineering, pharma and IT service companies** have a strong research focus. They include many hidden champions such as the family-owned PTV Group from Karlsruhe, whose innovative software is making mobility more efficient, safe and environmentally friendly. And not only in Germany: with 28 locations worldwide, PTV Group has customers in more than 120 countries.

IT also plays a key role among start-ups. More than one in four are digital newcomers, their business models centring for example on apps, online commerce or web design. And there are support programmes to help them lock into venture capital from private equity investors or funding programmes like the **High-Tech Gründerfonds (HTGF)**, Germany's biggest investor when it comes to early-phase financing of innovative and technology-oriented companies.

ABOUT THE INITIATIVE "RESEARCH IN GERMANY – LAND OF IDEAS"

WHAT IS "RESEARCH IN GERMANY"?
"Research in Germany" is an initiative of the Federal Ministry of Education and Research. It presents Germany as a country of research and innovation and creates a forum for international exchange and cooperation.

WHAT ARE THE GOALS OF "RESEARCH IN GERMANY"?
"Research in Germany" provides international researchers with information about funding and career opportunities in Germany. The initiative gives research and science organisations from all over the world the chance to establish contact with potential German partners in the fields of science, research and industry. The initiative presents itself online at www.research-in-germany.org, as well as at international conferences and fairs.

This and many other "Research in Germany" publications are available at
www.research-in-germany.org/downloads

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IMPRINT

Publisher Deutscher Akademischer Austauschdienst (DAAD)
German Academic Exchange Service
Kennedyallee 50, 53175 Bonn (Germany)
www.daad.de

Section International Research Marketing

Project coordination Dr Georg Krawietz (responsible), Susanne Findeisen, Janina Kimmel

Publishing house FAZIT Communication GmbH, Frankfurt am Main
Editorial team: Janet Schayan, Clara Krug (project management), Dr Sabine Giehle (text), Anke Stache (art direction), Chris Cave (translation), Zarka Ghaffar (production)

Printed by msk marketingservice köln GmbH
"The German research landscape" is printed on ecologically friendly enviropolar paper which is certified according to the FSC® standard and has been awarded the Blue Angel seal and the EU Flower seal.

RECYCLED
Paper made from recycled material
FSC
www.fsc.org
FSC® C011331

Climate neutral
Print product
ClimatePartner.com/53516-2102-1011

Print-run July 2021 – 5,000
(2nd, updated version)

Note The DAAD places special emphasis on using language that treats women and men equally. The grammatical male form is occasionally used alone in this publication purely as a means of improving legibility. Naturally, these terms are meant in a gender-neutral way.

Cover photo Colormos/Getty Images

This publication was funded by the Federal Ministry of Education and Research.

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WWW.RESEARCH-IN-GERMANY.ORG

AN INITIATIVE OF THE

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Research in
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