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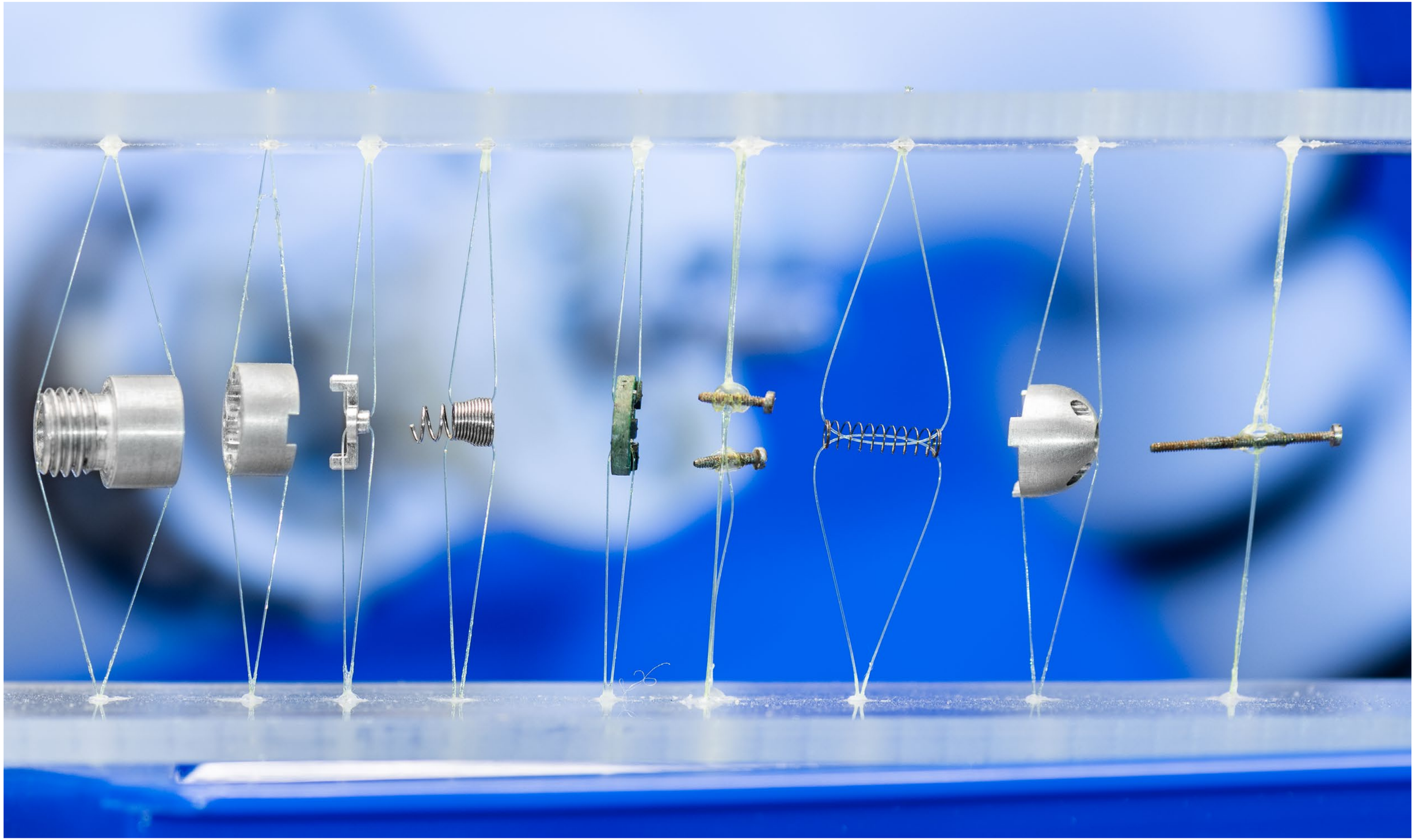
WERNER SIEMENS FOUNDATION

Our mission

2019 report

Bedretto Underground Lab—research into deep geothermal energy under near-authentic conditions

Palaeobiotechnology—using ancient DNA for modern cures

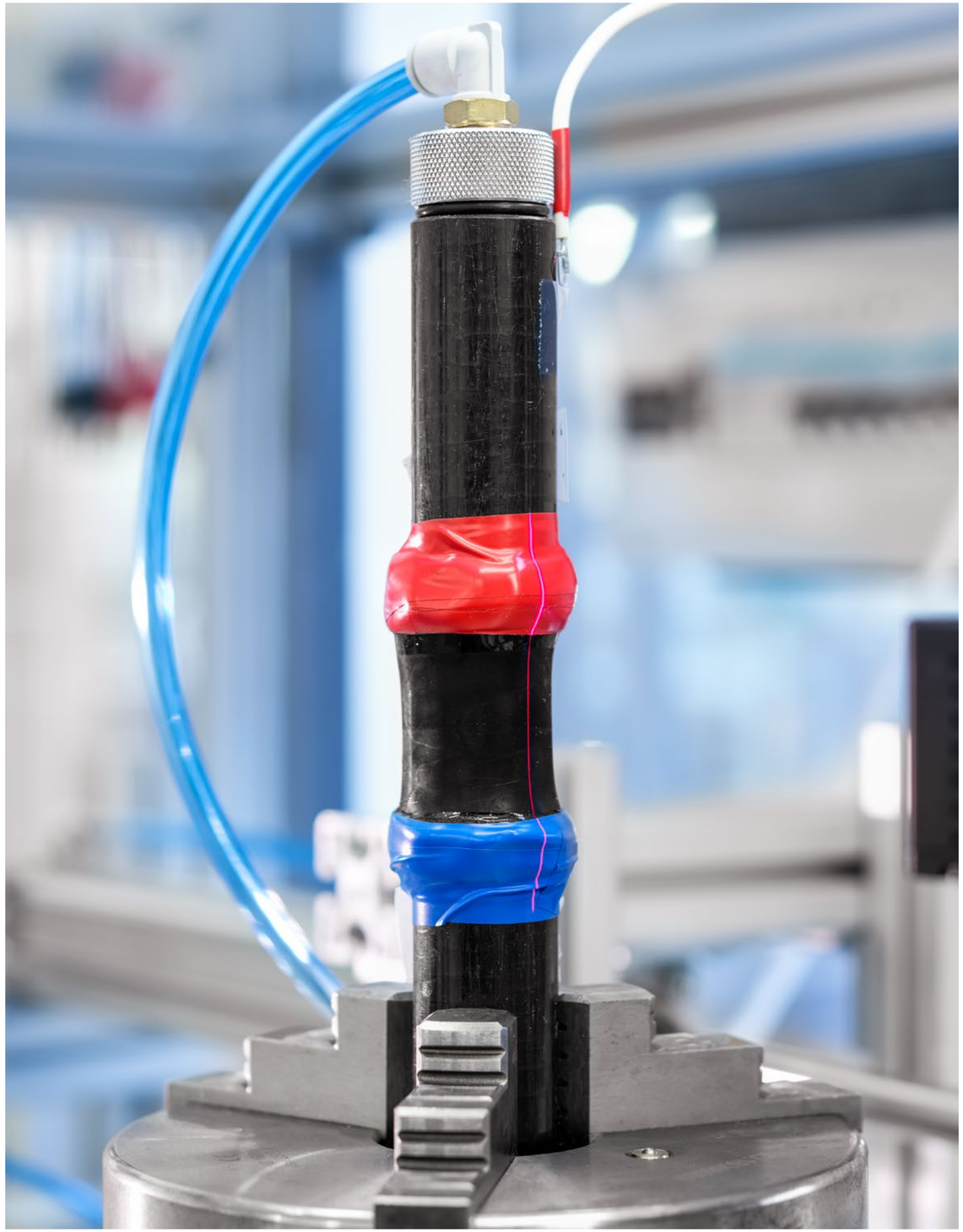


Minimally invasive bone surgery using laser technology

Palaeobiotechnology—using ancient DNA for modern cures

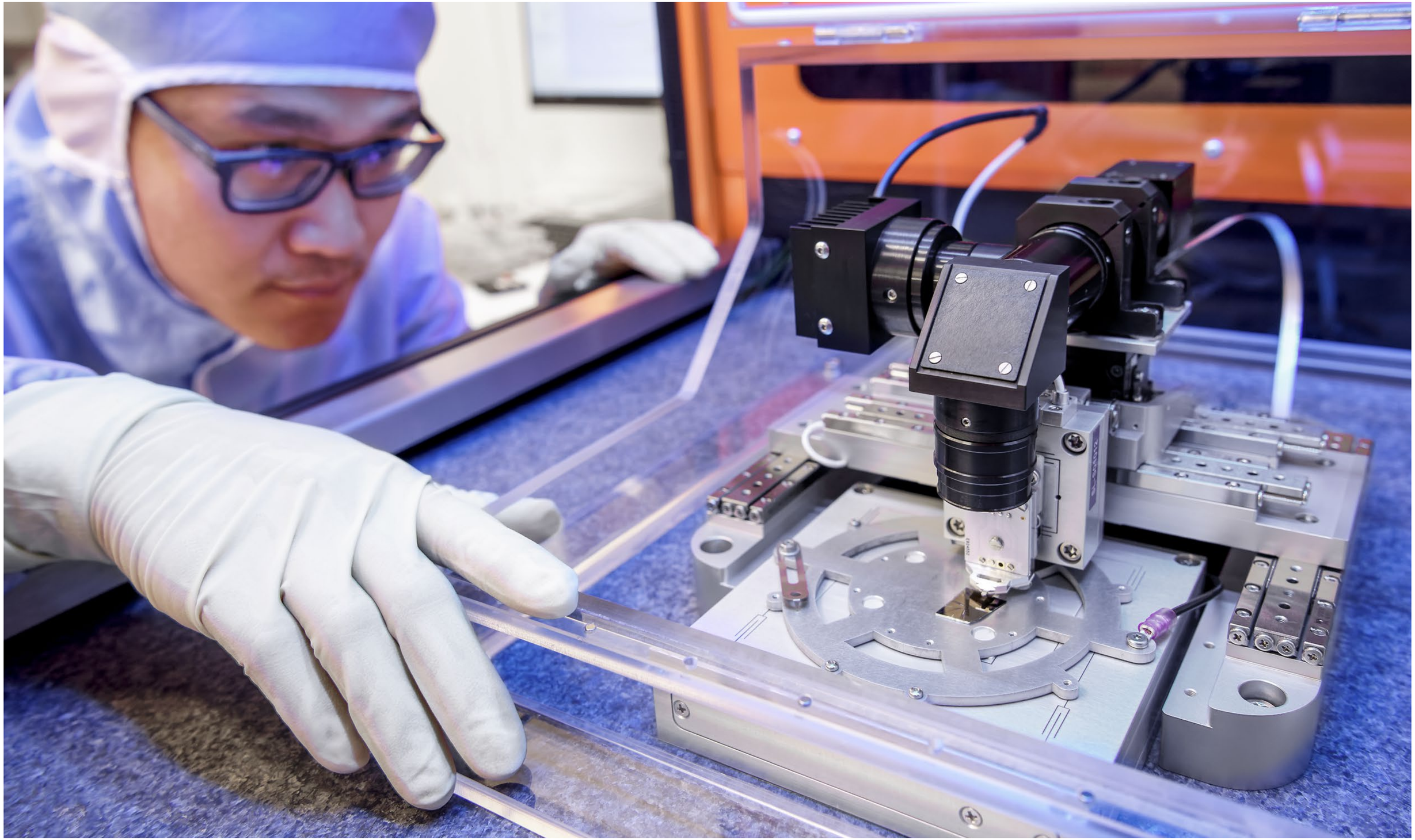
Supporting girls with a flair for technology

Bedretto Underground Lab—research into deep geothermal energy under near-authentic conditions



Developing artificial muscles

Sailing research lab *Eugene Seibold*—marine science and climate research



Single-atom switch—an innovative microchip that functions at the atomic level

Promoting innovation in technology and the natural sciences

The Werner Siemens Foundation supports groundbreaking projects in the fields of technology and the natural sciences. The selected projects in research and education are generally conducted at universities and higher education institutions in Germany and Switzerland; key requirements include upholding the highest standards and contributing to solving major problems of our time. The Foundation provides generous seed funding to innovative projects with the goal that, after a few years, the projects can be run independently and the results find industrial application. The Werner Siemens Foundation also promotes education and training projects and fosters young talent, particularly in the fields of mathematics, informatics, natural sciences, technology, medicine and pharmaceutical science.

Foreword

For the third year in a row, the report of the Werner Siemens Foundation is brightening what is otherwise an often grey January. Engaging articles and handsome photographs introduce the projects our Foundation was proud to support in 2019. When awarding funding, the Werner Siemens Foundation once again took particular care to select innovative projects that have the potential to solve central problems of our time.

This pioneering spirit is readily apparent among researchers in the field of deep geothermal energy: they want to ensure that roughly seven percent of Switzerland's electricity is generated by safe geothermal power plants by the year 2050. If Switzerland's ambitious energy transition is realised, the Werner Siemens Foundation will share in the success: our Foundation was not only the first organisation to provide major funding to deep geothermal energy research—in 2019, we also contributed another generous sum to the extraordinary Bedretto Underground Lab, located within Switzerland's Saint Gotthard Massif. This commitment then inspired other organisations to follow suit and provide funding. What the Bedretto Underground Lab holds in store is presented on page 23.

Another highly innovative and creative approach is being pursued in Project Palaeobiotechnology, where researchers want to develop new antibiotic drugs capable of fighting multiresistant bacteria. Without wanting to give away too many secrets, we offer just one hint: prehistoric teeth feature largely in the project. More on page 41.

The third new project to receive funding from the Werner Siemens Foundation in 2019 deals with our eroding trust in online communication and transactions. Recent reports of stolen data and spying scandals have made clear that exchanging sensitive data online must become more secure. IT specialists at ETH Zurich and the University of Bonn are now developing a completely novel kind of security architecture to ensure safe online transactions (page 63).

But rest assured: we can guarantee the safety of our new online tool for submitting project proposals to the Werner Siemens Foundation. Still today, we are one of the very few Swiss foundations to offer and manage the application process online. The echo after the tool's first year in operation was uniformly positive, the consensus in the Board of Trustees being that "the tool has greatly simplified the entire selection procedure". Managing the timeframe for when funds are transferred as well as evaluating and archiving all project proposals is now much more efficient.

Responsibility for managing the online tool for project proposals rests in the capable hands of Erika Koller, who was appointed head of the Foundation's administrative office last year. Her story is the final article in the report: "Presenting Erika Koller".

And now we invite you to explore our 2019 report. For readers who would like to learn more about how the Foundation acquired its initial capital, we can recommend a book edited by the Foundation—*Nora Füssli* (Thomas Helms Verlag, Schwerin)—which recounts the life story of one of the Foundation's first and most generous benefactors.

Our very best wishes

Gerd von Brandenstein
Chairman of the Foundation Board
Werner Siemens Foundation

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What we support

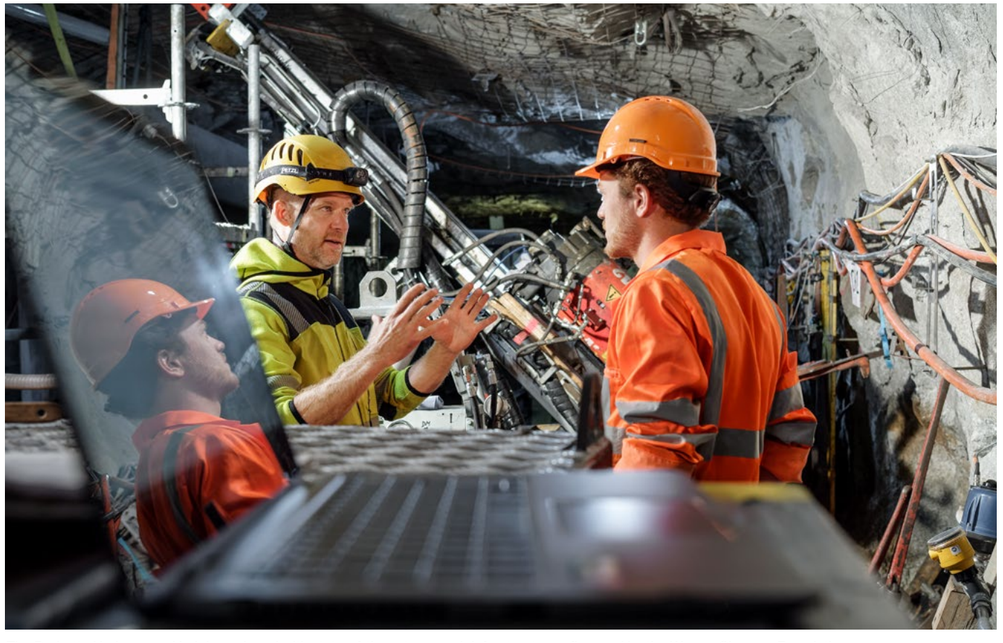
Bedretto Underground Lab

Deep geothermal energy research under near-authentic conditions

Granite. Hard, compact stone. But the eye schooled in geology can detect fine cracks—and these fissures are of great interest to researchers in the field of deep geothermal energy. In controlled experiments 1 000 metres below the Saint Gotthard Massif in the central Swiss Alps, geologists and physicists want to create even more of these fissures to observe how cold water flows through the cracks and is heated by the hot rock mass. Once transported back to the surface, the hot water can be used in turbines to generate electricity. That is how geothermal energy works, at least in theory. But can we really tap into the earth's heat without triggering earthquakes?

High hopes for geothermal energy

2019 was a momentous year for deep geothermal energy. Thanks to funding from the Werner Siemens Foundation, researchers from ETH Zurich were able to set up a unique underground laboratory in a former ventilation tunnel deep within the Saint Gotthard Massif of the central Swiss Alps. In the new Bedretto Underground Laboratory for Geoenergies, the team want to see whether—and how—they can tap into the heat of the earth without triggering dangerous earthquakes.



The Bedretto Underground Lab is equipped with state-of-the-art research infrastructure—financed by the Werner Siemens Foundation.

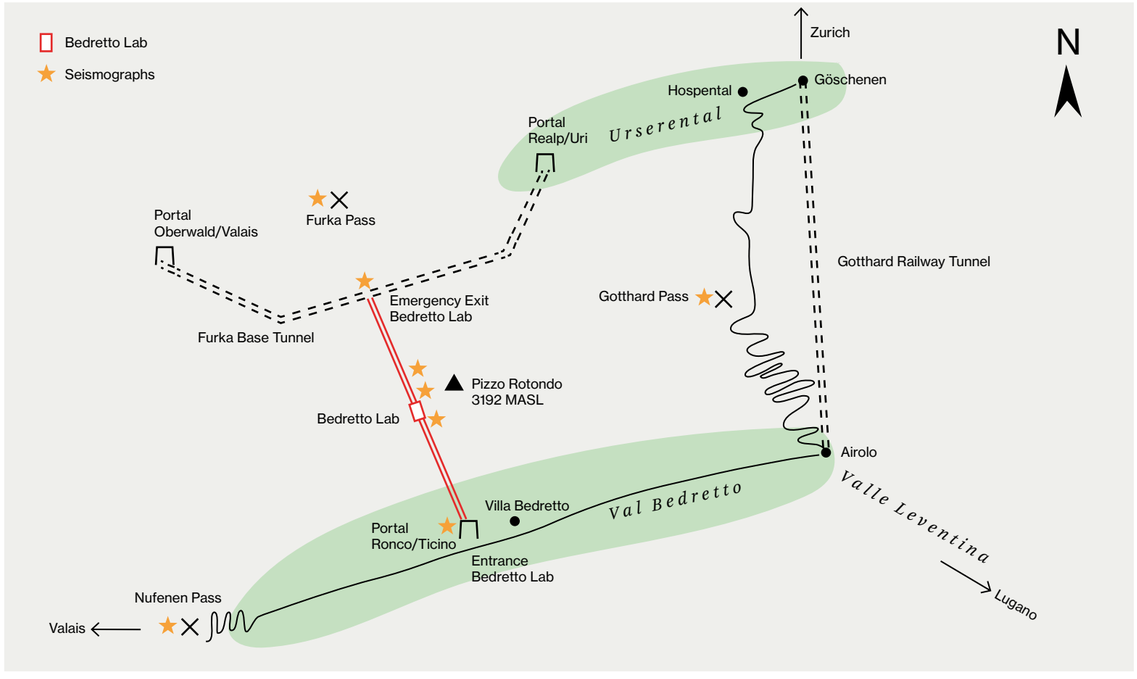
Until recently, all was quiet in Val Bedretto. Sun-hungry tourists from the north would motor past quickly, not giving the valley so much as a glance when passing through the Alps on their way south to Italy and the sea. But in 2019, Val Bedretto achieved international fame—at least among experts in geothermal energy, who, after exiting the Gotthard tunnel, began taking a sharp turn westwards and driving up the valley. Their destination is a former ventilation arm in the Furka Tunnel—part of the Matterhorn-Gotthard railwayline—that quite literally has the goods: it harbours a state-of-the-art underground lab for deep geothermal energy research—a world's first that was made possible thanks to funding from the Werner Siemens Foundation. In the near-authentic conditions in the Bedretto Underground Lab, leading research groups from throughout Europe want to observe how granite reacts to deep drilling and so-called stimulation treatments in which high-pressure water injections generate numerous fine cracks (called joints) in the granite (more information in the interview on page 32).

Underworld paradise

It was Domenico Giardini who had the idea to convert the former ventilation arm into an underground lab. Giardini, professor of seismology and geodynamics at ETH Zurich and a respected expert in deep geothermal energy, had previously conducted research in the Grimsel rock laboratory, but the Bedretto Underground Lab is in a league of its own. The facility is located a good 2 200 metres in the interior of the mountain, with Piz Rotondo, the highest mountain in the Saint Gotthard Massif, towering some 1 000 metres over the tunnel—an underworld heaven for deep geothermal energy researchers. The purpose of the Bedretto Underground Lab is, however, not to conduct research for the sake of research: rather, the tests are designed to provide clear answers to concrete questions regarding the feasibility of deep geothermal energy in Switzerland and other regions. Specifically, the researchers want to find out whether the risk of triggering earthquakes through drilling and stimulation is too high.

Switzerland's energy strategy

Switzerland is one of several European countries that plan to phase out nuclear energy and replace fossil fuels (natural gas and oil) with renewable energies. In 2007, the Swiss federal government set out an initial set of guidelines for achieving the national energy transition; the goal of reducing CO_2 emissions was then formalised in the federal CO_2 act in 2011. In 2019, the Federal Council and the chambers of parliament initiated deliberations on a comprehensive revision of the CO_2 act with the aim of further tightening the targeted levels for CO_2 emissions. With reference to the legal provisions for increasing the energy supply from CO_2-neutral technologies and renewable energy sources, a team of energy experts—including Domenico Giardini—developed the idea to tap into a single renewable energy source that would, in future, cover most of the energy demand in Switzerland. This source could then be supplemented by alternative energy technologies like water, solar and wind, which are susceptible to seasonal fluctuations. A key requirement of the chosen renewable energy source is its capacity to provide electricity throughout the year, especially



Location of the Bedretto Underground Lab in southern Switzerland

Before an experiment begins, the hydraulic conditions (pressure and flow rates) in the borehole are measured.

Domenico Giardini, architect and head of the Bedretto Underground Lab: “I think that by 2050, every Swiss canton could and should be operating a geothermal energy power plant.”

in the cold winter months—and deep geothermal energy would be up to the task. After all, below the earth’s surface, the temperature is stable all year round, roughly 60 degrees Celsius at a depth of two kilometres. If we could tap into this heat, we could use it to generate electricity, even in winter.

Which renewable energy source?

It would be possible to argue that water, and thus hydropower, is plentiful in Switzerland and has proved reliable for decades—and that it would therefore be a better choice than deep geothermal energy. But Domenico Giardini counters: “Hydropower is currently the most important domestic energy source and it has the largest storage capacities. But it would require a massive amount of additional infrastructure to further expand its capabilities. Moreover, hydropower relies on a sufficient supply of water, which, however, is affected by climate change and water consumption, not to mention various other economic and socio-political factors.” Indeed, the construction of dams often faces stiff opposition, and the only current project is a new dam at the Susten Pass, where the Trift Glacier melted and formed a new lake. How many new dams would have to be built to ensure that hydropower could deliver the basic energy supply is illustrated by the following calculation: every year, nuclear power stations in Switzerland produce some 25 million megawatt-hours of electricity, which corresponds to roughly 40 percent of Switzerland’s energy needs. If all nuclear power plants were replaced by hydropower plants, at least 170 new dams would have to be built, all of which would need to have the dimensions of the projected Trift dam. Highly unrealistic, says Giardini, adding that in its Energy Strategy 2050, “the federal government is reckoning at the most with a 10 percent increase in electricity generated by hydropower plants”.

Solar power is currently also not able to deliver the basic energy supply, as it is only generated during the day, mainly in summer, and when the skies are clear. Seen on an annual basis, that would be only 15 percent of the time. Finally, wind power is an even less likely candidate due to the low acceptance of wind farms in the population; moreover, only a few regions (the Jura region, for example) are windy enough.

The right mix

“The sustainable energy sources we currently use—water, solar, wind and hot thermal water—can’t meet our energy needs in winter,” is how Giardini sums up the problem. “But that’s not to say we shouldn’t use them. What we need is a good mix to guarantee a year-round energy supply.” And this is where deep geothermal energy has a clear advantage: having no seasonal or weather-related limitations, it would be well-suited to deliver the basic energy supply—if the associated risks can be borne. In any event, the Swiss federal energy strategy forecasts that deep geothermal energy will furnish roughly seven percent of Switzerland’s electricity by 2050.

In order to answer the open questions on Switzerland’s energy transition, the Federal Office of Energy resolved to increase funding for energy research in general, and for deep geothermal energy in particular. The government created eight competence centres for energy research and named Domenico Giardini head of the Swiss Competence Center for Energy Research – Supply of Electricity. His suggestion

The Bedretto Underground Lab is halfway down a disused railway tunnel. The first task was installing ventilation (left) as well as electrical and communications systems (right).

to convert the former ventilation shaft in Val Bedretto into an underground lab for researching deep geothermal energy met with broad acceptance—but who would cover the rather prohibitive costs? Giardini says, “The Werner Siemens Foundation was the first organisation to believe in the Bedretto Underground Lab and to offer substantial funding. This confidence inspired other interested organisations and large financial backers like ETH Zurich and the Federal Office of Energy to commit to the project.”

Since October of 2019, the European Union has also been on board. The EU has a particular interest in the Bedretto Lab, as researchers from various countries collaborate and consolidate their knowledge. These synergies can also be applied in different contexts, for example, to better predict earthquakes in Italy and other earthquake-prone European countries. For this reason, the European Research Council (ERC) has awarded Domenico Giardini a six-year grant in the amount of 14 million euros.

Massive undertaking

In the meantime, the Bedretto Underground Lab has become a huge undertaking in which all relevant federal offices, private industrial companies and key research groups from Switzerland and abroad work together to determine what role deep geothermal energy can play in the national energy supply. The industry partners were involved in planning from the outset, as they supplied the technology and equipment, which they also plan to test in the lab. Researchers in the field of deep geothermal energy from throughout Europe were also invited to join the project; of these, the Finnish industrial and research partners are of particular importance, as their successful procedures will be tested in the Bedretto Underground Lab.

Leading researcher Martin O. Saar

One of the leading researchers in the underground lab is Martin O. Saar, professor of geothermal energy and geofluids at ETH Zurich and Werner Siemens Foundation Endowed Chair. Saar and his research group are analysing the behaviour of granite before and after water is injected into the rock (stress measurements). With the help of markers (called tracers), they can also observe where the water flows and how hot the rock is at a given location. Nevertheless, Domenico Giardini stresses that we need a deeper understanding of how drilling and stimulation treatments actually impact the rock: “Later, when we’re drilling four to five kilometres underground to build a geothermal energy power station, we’ll have reached a level where there’s enormous pressure, meaning we’ll be disturbing the natural tectonic motions in the interior of the mountain.” An additional problem is that the researchers cannot predict the long-term effects of the large quantities of water that will be injected into the rock and transported back to the surface.

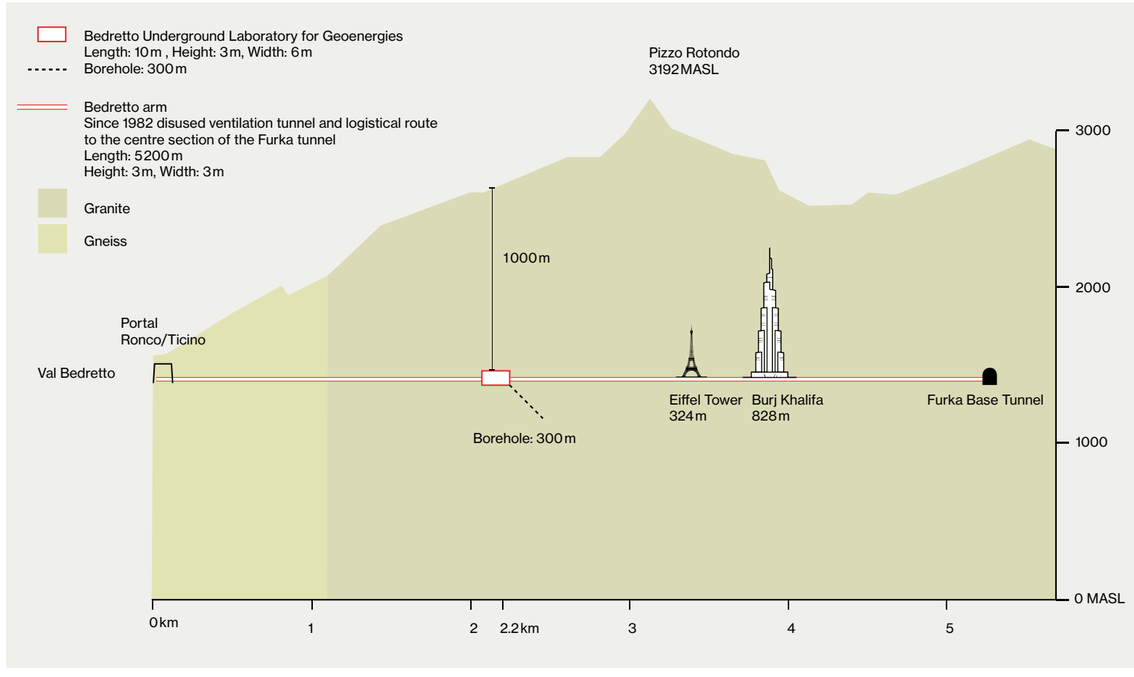
Safety is paramount

The researchers already have a wealth of knowledge, but the devil, as always, is in the detail. And it is precisely these details that the tests in the Bedretto Underground Lab must answer if deep geothermal energy is to form part of the Swiss Energy Strategy 2050. “If the tests in the Bedretto Underground Lab go wrong, the entire future of deep geothermal energy in Switzerland will be called into question,” says Giardini. “We have to demonstrate with absolute certainty that the risk of triggering dangerous earthquakes through drilling can be contained—only then will we receive permission to build deep geothermal energy power stations. The government authorities, the population, industrial partners and we researchers must have full confidence in the results.”

How does Domenico Giardini rate the probability of establishing deep geothermal energy in Switzerland? Surprisingly high. “We still need time before we’re able to use sustainable energy sources in all areas of life. But I think that by 2050, every Swiss canton could and should be operating a geothermal energy power station.”

In the belly of the mountain

The Bedretto Underground Lab is located in a former ventilation arm of the Furka Tunnel—part of Switzerland's Matterhorn-Gotthard railway line. The disused section of the tunnel is a little over five kilometres long, but not quite three metres in diameter, meaning that all research equipment—which was funded by the Werner Siemens Foundation—had to be squeezed through the narrow passageways. We talked to Marian Hertrich, geophysicist at ETH Zurich and manager of the Bedretto Underground Lab, about how he and the international research teams conduct their tests deep within the Saint Gotthard Massif.



The subterranean walk to work for the researchers in the Bedretto Underground Lab is 2.2 kilometres long.

Marian Hertrich, geophysicist at ETH Zurich, is manager of the Bedretto Underground Lab. He coordinates the various research groups and experiments.

The Bedretto Underground Lab officially opened in May of 2019, and the first tests were conducted shortly afterwards. What was your first project?

Marian Hertrich: We first had to determine what the "normal condition" of the tunnel is. We charted the tunnel walls to see what types of rock are located where, and what kinds of fissures—or joints, as we geologists call them—are already present. We measured the stress levels in the rock, and a specialised company made the large borehole for the stimulation treatments as well as the three boreholes for the measuring equipment. These preliminary experiments revealed key information about the elasticity and breakage patterns of the rock already before we began our actual work.

The Bedretto Lab is equipped with state-of-the-art instruments. How did you get them underground?

We used an electric construction trailer to transport eight truckloads of material into the tunnel: the drill casings, motors, pushrods, chains, packer systems, computers and more. It was a major logistic feat to fit everything into the narrow space.

The team began their work in August 2019, and the lab is located over two kilometres deep in the rock. Do the researchers always have to walk?

I like the walk, but the team can also ride in the electric construction trailer, although it creeps along at a snail's pace.

How suitable is the Bedretto Underground Lab as a testing site for deep geothermal energy?

It's well-suited, as the rock already has an ideal number of joints that we can drill through and use. At the same time, we also need enough unjointed rock areas for the stimulation treatments that generate new fissures—and the lab has plenty of these as well. We have a huge volume of rock to use for targeted stimulation treatments.

These stimulation treatments are of central importance in deep geothermal energy. Can you give a rough description of how they work?

We pump water at high pressure into the boreholes, which causes the granite to fracture into numerous joints. The conditions for the tests need to be as controlled as possible, meaning that the water shouldn't fracture the rock until it's at the end of the borehole. And because the rock breakage triggers movement below the ground, we also want to make sure that no perceptible—or worse: damaging—earth tremors are triggered.

How can you control these subterranean motions?

We use so-called packers to control the breakage. Packers are inflatable components, like balloons, on the long rods that we insert into the borehole. Then we inflate the packers a few millimetres until the borehole is hermetically sealed. There are 10 to 15 packers on each rod; that's how we divide the borehole into separate sections. Afterwards, when water gets pumped into the borehole, only the sections between packers are subject to the pressure—and not the entire borehole. This makes it possible for us to systematically create joints in the hot rock areas, section by section, controlled and in exact doses. The

volume of hot rock that the water runs through is called a reservoir.

Is there water in the reservoirs?

That depends on the kind of geothermal energy project. In the Bedretto Lab, the reservoir is made of jointed granite—it's a hot dry reservoir that heats the pumped-in water. To generate electricity using the earth's interior heat, deep geothermal energy power plants inject cold water into the hot reservoirs for heating. Then the heated water is brought to the surface and piped into turbines that generate electricity.

How deep is the borehole?

In our tests, we drill at a 45-degree angle, 300 metres into the granite. To make an ideal geothermal borehole, we would drill straight down, vertically, and then turn to make a horizontal borehole at the bottom. Unfortunately, we can't do that here in the Bedretto Lab because the drill casing is 5 metres long, but the tunnel isn't even three metres high. That's why we have to quasi simulate the final part of an ideal borehole: the horizontal turn at the end.

What kind of rock are you drilling?

It's Rotondo Granite, a very homogeneous granite mass with the same properties over several hundred metres.

Granite is, of course, hard. Is that a good or bad thing for your work?

Drilling into granite is expensive and more complicated than drilling into softer sedimentary rock, but it also demonstrates good breakage qualities.

Will you be able to apply the results of the tests with Rotondo Granite to regions with different geological properties?

No, but our experiments are highly relevant for other deep geothermal energy projects in Switzerland and in other regions such as Scandinavia. In northern Switzerland, there's a lot of homogeneous granite several kilometres below the surface, and in Scandinavia, for instance, there are also large granite masses, so these regions will likely benefit from our findings. But deep geothermal energy projects in Munich or Vienna, for instance, are operating in limestone, which requires different procedures to transport heat from the rock up to the surface.

Who has made the most progress?

In regard to gaining a detailed understanding of the processes needed to make deep geothermal energy more efficient and also safer in the long term, Switzerland with the Bedretto Underground Lab and the Grimsel rock laboratory is definitely a contender.

Is there an independent authority that monitors the tests in the Bedretto Underground Lab?

Yes, impartial monitoring is very important in the project, and we invited the ETH Zurich Swiss Seismological Service to be on the team. The staff there follow our work closely and provide support in planning and conducting measurements. In addition, so that even the smallest earth tremors are registered, we installed three new seismographs in the general surroundings of the Bedretto Underground Lab: at the Furka, Nufenen and Gotthard passes. We also have seismographs in the tunnel's interior: one at the entrance, one at the end, and three directly in the underground lab. These data are monitored by the Swiss Seismological Service and the findings are published online for the general public to read.

The borehole in the granite (with metal closure, photograph above) used for the controlled experiments is a good 9 centimetres in diameter and about 300 metres deep. It was drilled at a 45-degree angle (photograph below).

The long rods with inflatable parts (packers) attached are lowered into the borehole.
The packers ensure that pressure is applied only to targeted rock areas to generate new joints.

Facts and figures

Project

In the Bedretto Underground Lab, international research groups are conducting closely monitored experiments in near-authentic conditions to determine whether geothermal energy can be safely harnessed. They want to better understand how deep rock layers react to drilling and stimulation treatments and find ways to better predict earthquakes.

Support

The Werner Siemens Foundation is supporting the further development of the Bedretto Underground Lab as well as the MISS flagship project (Mitigating induced seismicity for successful georesources applications) in which researchers seek ways to minimise the effects of induced earth tremors and thus create the conditions to safely use deep geothermal technologies.

Funding from the Werner Siemens Foundation

12 million Swiss francs

Project duration

2018 to 2024

Project leader

Prof. Dr Domenico Giardini, Professor of Seismology and Geodynamics, ETH Zurich

Financing institutions

ERC 2019 Synergy Grant of the European Research Council; EU Framework Programme for Research: Horizon 2020; multinational EU joint project: GEOTHERMICA; ETH Zurich; Werner Siemens Foundation; Swiss National Science Foundation; Federal Office of Energy, Switzerland; Innosuisse – Swiss Innovation Agency

Tunnel proprietor

Matterhorn-Gotthard Railway

Building commission

ETH Zurich; Swisscom

Lab operator

ETH Zurich; Department of Earth Sciences, ETH Zurich

Lab sponsors

ETH Zurich; Werner Siemens Foundation

Research partners

ZoDrEx; DESTRESS – Demonstration of soft stimulation treatments of geothermal reservoirs; Swiss Competence Center for Energy Research – Supply of Electricity; Validation of Technologies for Reservoir Engineering (VTRE); Swiss Seismological Service (SED), ETH Zurich; ETH Zurich; EPFL; University of Lausanne; University of Neuchâtel; Anger; Cetim; CSIC; IDAEA; És-Géothermie; Geo-Energie Suisse AG; GZB; Rhein-Westphalian Technical University Aachen (RWTH); Sirius E.S. GmbH; Welltec

Safety

Suva; SiBau Management GmbH; Swiss Seismological Service (SED), ETH Zurich

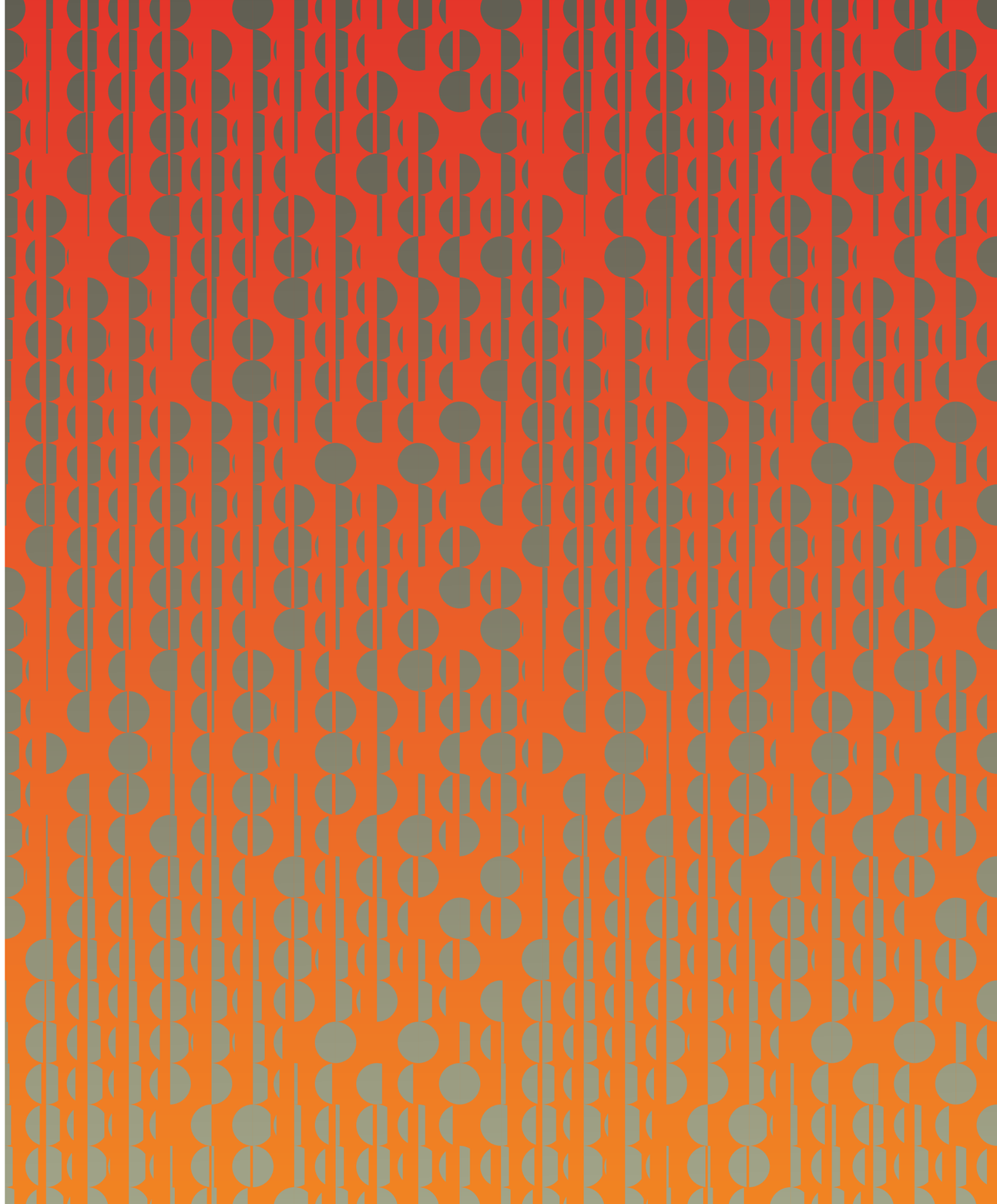
Construction

Baumeler Leitungsbau AG; Fretus AG; Azienda elettrica comunale Bedretto; awa PlanBau GmbH; Cava di estrazione di ghiaia di Bedretto

unique
promising
decisive

Innovation

With the Bedretto Underground Lab, the Werner Siemens Foundation is supporting deep geothermal energy research in real conditions—because tapping into the earth's heat holds potential for Switzerland's future energy supply. The researchers believe CO_2-neutral deep geothermal energy is a viable alternative to fossil fuels and could play a major role in the national Energy Transition 2050.



Ancient medicine

Palaeobiotechnology—harvesting prehistoric natural products with antibacterial properties

The Neanderthals had rather poor dental hygiene, which is why their teeth present such an unappetising picture. But they are a thing of beauty to an archaeologist and a biotechnologist in Jena. These two researchers know that microbes are preserved in ancient dental plaque. And they believe that some of these prehistoric bacteria may help us stay healthy in the future.

Moving forward into the past

Christina Warinner travelling into the past—conveniently located in the cleanroom at the Max Planck Institute for the Science of Human History. In the ultra-hygienic conditions of the lab, Warinner analyses natural products in ancient specimens.

Bacteria are increasingly becoming resistant to antibiotics—a worrisome development and a fundamental threat to global health. To solve the problem, chemist and biotechnologist Pierre Stallforth and archaeologist Christina Warinner have adopted a highly innovative approach: they are delving deep into human history in the search of substances able to combat the resistant bacteria of today. That Neanderthals never brushed their teeth has proven to be a blessing.

Alexander Fleming's chance discovery of penicillin in 1928 is one of the major milestones in the history of medicine. In his rather untidy lab, the Scottish bacteriologist noticed that a mould of the *genus penicillium* was preventing bacteria cultures from multiplying. In the coming decades, the various strains of antibiotics developed on the basis of Fleming's work would save millions of lives.

But this achievement is now in jeopardy. Over the years, medical staff and patients alike have grown careless in their use of the wonder drug, and the ever-adaptive bacteria have taken advantage of the situation by developing defence mechanisms against antibiotics. Bacterial resistance to life-saving medicines has consequently made treating infections like pneumonia and tuberculosis more difficult—or impossible in some cases. Current estimates place the number of worldwide deaths due to antibiotic resistance at 700 000 per year.

Seeking diversity

Another problematic aspect is that very few new strains of antibiotics have been developed in recent decades. Now, however, research efforts have gained momentum thanks to creative minds, unconventional ideas and innovative technologies. The Werner Siemens Foundation is funding the work of two such pioneering thinkers in Jena, Germany: chemist and biotechnologist Pierre Stallforth of the Leibniz Institute for Natural Product Research and Infection Biology, and archaeologist Christina Warinner of the Max Planck Institute for the Science of Human History. In the scope of "Project Palaeobiotechnology"—their joint research endeavour—the two scientists are seeking new antibiotic agents at an unlikely site: early human history.

The reason for their unusual approach is that bacteria have always defended themselves against enemies and rivals (for instance other bacteria) by producing antibiotic substances. Medical researchers have taken inspiration from this adaptability and, already today, three-quarters of all antibiotics are modelled on so-called natural products created by bacteria. Since the 1970s, however, only synthetic antibiotics having a similar, but not identical chemical structure have been produced—and this makes it easier for bacteria to develop microbial resistance.

The new recipe

Stallforth and Warinner are convinced that new antibiotic drug classes are necessary. The idea behind their decision to search in the ancient past is that they want to surprise resistant bacteria with substances that no longer occur in nature. And thanks to innovations in biotechnological methods, recreating these natural products is now possible. The recipe entails sifting through the DNA of prehistoric humans to find the genetic material responsible for producing these agents, then introducing the DNA sequences into present-day bacteria. The result: under laboratory conditions, the bacteria produce natural products identical to those in early history. In short, Warinner and Stallforth aim to transport useful substances from the past to the present in order to develop medicines for the future. The steps along the way are depicted in the photo essay on page 52.

The secrets harboured in dental plaque

The research methods of Warinner and Stallforth may call to mind the film Jurassic Park, where geneticists use DNA samples to awaken dinosaurs to new life. But Christina Warinner has little patience with the narrative: "Dinosaurs became extinct about 70 million years ago. It's highly unlikely that traces of their DNA can still be found." Pierre Stallforth agrees: "And if any traces are found, it wouldn't be possible to recreate incredibly complex life forms like dinosaurs." In comparison, their own plan is quite modest, yet all the more realistic for that. Warinner and Stallforth will travel "only" 100 000 years into the past, to the Palaeolithic era, where their focus is on tiny molecules of natural products.

And rather than taking a time machine, all they need for their journey is dental plaque—which has proven to be a veritable gold mine for archaeologists. In her research, Warinner has demonstrated that no other substance harbours more or better-preserved DNA than dental plaque, and she has earned international renown in the field of archaeogenetics for her analyses of ancient DNA. Over time, Warinner has collected hundreds of dental plaque samples from all over the world and from various epochs to use in her work.

Dental plaque functions as a type of time capsule that holds a petrified record of everything a human being had in his or her mouth: scraps of food, but also thousands of bacterial species. It is also very auspicious for research that Neanderthals and other early hominids had rather poor dental hygiene. Had they used toothbrushes, this

A bird's-eye view of the prehistoric time capsule – food scraps and different types of bacteria are preserved in petrified dental plaque that is up to 100 000 years old.

Chemist and biotechnologist Pierre Stallforth is head of Project Palaeobiotechnology. He and his team use nuclear magnetic resonance spectroscopy to identify potentially interesting ancient natural products.

abundant oral microbiome—the entire community of microorganisms in the mouth—would have been destroyed.

Novel challenge

Pierre Stallforth's part in the project is replicating ancient natural products having antibiotic properties. The biotechnologist and chemist is specialised in the analysis and synthesis of natural products; through his past research, he has already discovered promising candidates. His work is made possible thanks to new technologies like Next Generation Sequencing (NGS) for fast and precise DNA analysis in addition to new methods of genetic sequencing.

Nevertheless, recreating DNA from the past represents an entirely novel challenge for even the most forward-looking biotechnologists, and Pierre Stallforth and his team must first further develop existing technologies. Prehistoric DNA is preserved in fragments, so the researchers need to recognise and identify the traces of DNA, put them together correctly and then close gaps in the genetic sequence using bioinformatics methods.

Such complex projects rely on interdisciplinary expertise, which Stallforth has found at the Friedrich Schiller University Jena, where experts from the fields of archaeology, molecular biology, chemistry and biotechnology work together closely at the "Balance of the Microverse" Cluster of Excellence that explores microbial communities.

Learning from evolution

For Christina Warinner, all this is a dream come true: "Thanks to new technologies, we can see further and further into the past, and a whole new world is emerging." It is likely that Warinner, Stallforth and their research groups will also discover other natural products having a potentially wide range of applications: as alternative energy sources, pigments or industrial materials. The main goal, however, is increasing the diversity of antibiotics.

At the same time, Project Palaeobiotechnology will also help to shed light on the history of humankind. This includes fundamental questions regarding the evolutionary development of bacteria, their antibiotic natural products and their antibiotic resistance. But this much is clear: resistance predates the production of antibiotics in the lab. Already tens of thousands of years ago, bacteria found ways to defend themselves against the antimicrobial products of their enemies and competitors.

Warinner and Stallforth have no illusions: bacteria will always develop resistance to new antibiotics. "But once we understand how bacteria evolve to become resistant, we may have indications as to how antibiotics should be structured to prevent a resistance for as long as possible," Stallforth says. To better grasp the evolution of bacteria, natural products and resistance, the researchers plan to compare the ancient microbiome with that of the present day, in particular the microbiome gathered from traditional communities in Mongolia or Cameroon, where no processed food is eaten and where pharmaceutical antibiotics are uncommon.

Postponing resistance

Pierre Stallforth stresses that preventing resistance is mainly a political and public health issue. New antibiotics should be used only with great restraint, for instance as a drug of last resort or in combination with other medicines or therapies. Moreover, preventing antibiotic waste produced by the pharmaceutical industry from contaminating soils and water—a common problem in developing countries—is essential. "If we act with greater caution, we can postpone resistance for decades," Stallforth says.

The search for new antibiotic agents must nevertheless continue to move forward, and one aim of Project Palaeobiotechnology is to develop a procedure that will allow researchers to efficiently mine for large samples of natural products and test their antibiotic properties. The Werner Siemens Foundation is supporting this work with a 10-year grant; in order to have interesting agents for pharmaceutical companies by 2029, the researchers will already begin preclinical trials of promising natural products to discover whether the products are effective—and safe—in cell cultures and in animals.

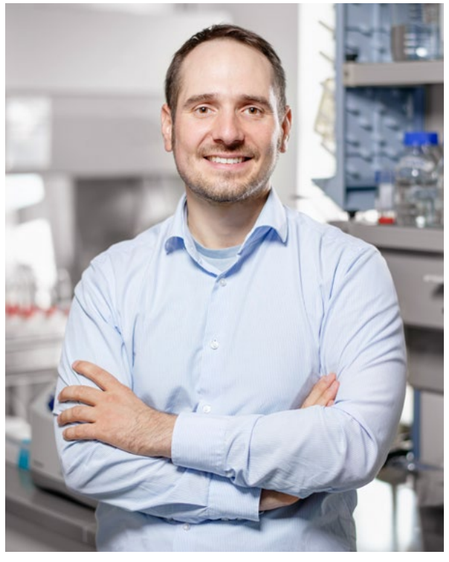
World première

The project is the first of its kind: never before have researchers sought new antibiotics in ancient fossils or attempted to replicate the natural products of extinct bacteria. As such, Christina Warinner and Pierre Stallforth are operating in a unique niche, one that promises to reveal a wide range of potential antibiotic agents. With the grant from the Werner Siemens Foundation, Warinner and Stallforth are joining forces to found and permanently establish the new discipline of palaeobiotechnology. One step towards achieving this goal is setting up a new interdisciplinary graduate school, where future archaeologists learn about biotechnological methods, and future biotechnologists acquire archaeological know-how. And embark on a journey back to the past—and into the future.

The microbe whisperer

Chemist and biotechnologist Pierre Stallforth wants to better understand how microbes interact with their environment. He also believes that using research findings for the benefit of humanity is a logical course of action—a philosophy that runs in the family.

Lab bacteria and the ancient natural products they produce are stored at minus 80 degrees centigrade.



Project leader Pierre Stallforth is setting up the world's first research unit for palaeobiotechnology thanks to funding from the Werner Siemens Foundation.

Although it sounds like a cliché, it is true: as a boy, Pierre Stallforth had a chemistry set and was certain that he would one day study chemistry. Stallforth's ambition was in no small part inspired by his childhood experiences in his father's surgery in Augsburg, Germany, where he would experiment with test tubes in the lab. Unlike many other chemistry-set fans, however, Pierre Stallforth pursued his dream and went on to study chemistry at Oxford University. During his doctoral studies at ETH Zurich, he then focused on developing a vaccine without proteins, a property that would keep the drug stable in high temperatures and thus have great advantages in countries where guaranteeing refrigerated transportation of medicines is difficult. His work was successful and his approach to developing a novel vaccine is now being pursued at a biotechnology company.

Communicative microbes

Pierre Stallforth is especially interested in uniting basic research with real-world applications. Following his post-doctoral training at Harvard Medical School in Boston, he returned to Germany in 2013 and began his position as group leader at the Leibniz Institute for Natural Product Research and Infection Biology in Jena. His specialisation is the complex interplay between microorganisms: how they communicate and cooperate with each other, and how they fight one another. Stallforth's research group has already demonstrated that natural products having antibiotic properties play a key role in fending off enemies and rivals.

Pierre Stallforth enjoys exploring new paths, and where other research groups limit their focus to single agents, he wants to understand how multiple substances interact with and within their environments. This is how he recently discovered a new combination of active agents for use against certain multiresistant germs; the combination is based on two antibiotic natural products—produced by the same bacterium—whose effectiveness increases markedly when linked. The new strategy is currently undergoing further testing at the Leibniz Institute.

New field of research

Stallforth is also pursuing unconventional goals in Project Palaeobiotechnology, which has been awarded a 10-year grant from the Werner Siemens Foundation, starting in 2020. The time and place for his new endeavour is ideal: technological capabilities have advanced rapidly, and he has found broad interdisciplinary expertise in Jena for the project he launched with Christina Warinner. "It was a happy stroke of fortune that I met Christina Warinner two years ago when we were working in a research cluster on microorganisms," Stallforth says. Their different perspectives on the same questions—how to better understand the function of genes in bacteria and how to use the variety of the natural products in ancient bacteria to produce new antibiotic medicines—are an ideal combination. After meeting, Stallforth and Warinner began work on their first joint project: analysing the DNA of a mediaeval skeleton. For Stallforth, the 10-year grant from the Werner Siemens Foundation is a unique opportunity: the collaboration with Warinner can continue in Jena and "thanks to the grant, we can establish the world's first research unit in the new field of palaeobiotechnology".

Archaeologist of the invisible

Bones and ancient tools from early human settlements have never captured the interest of archaeologist Christina Warinner—her passion is bacteria. She wants to demonstrate the crucial role microbes played in human evolution. And to explain why we should show them a little more respect.

Christina Warinner is an archaeologist specialised in the microbiome of early humans.

“Bacteria adapt and change over time, but their huge significance for humans remains the same,” says archaeologist Christina Warinner.

At home, Christina Warinner has two cats and a dog. “And millions of other pets,” she says with a laugh. Because her research is so closely tied to the innumerable bacteria that inhabit our bodies, she has begun seeing them as a kind of house pet. “We really don’t appreciate what these bacteria do for us,” says the archaeologist. “Of course, some microbes make us ill, but for tens of thousands of years, they have also been helping humans stay healthy.” Nevertheless, the field of medicine has only just begun to research the microbiome—the entire community of microorganisms in the human body—and Warinner’s work helps to shed light on how the microbiome has evolved. And although archaeology has traditionally focused on uncovering the remains of ancient civilisations, she is fascinated by prehistoric microbes—what she calls an “archaeology of the invisible”. Her particular fascination is DNA found in ancient dental plaque, and when giving presentations on her work, she jokes with her audience and suggests they refrain from brushing their teeth so that future archaeologists have plenty of material to work with.

Undeterred, innovative

That researching ancient dental plaque would become her profession was hardly preordained. Christina Warinner grew up in the Midwest of the US, in Kansas, where she was mainly encouraged to do sports. But Warinner was drawn more to reading science books of all kinds, and her many interests made it difficult to settle on a major at university. In the end, she studied microbiology and archaeology, and she discovered her true vocation in uniting the natural sciences and the field of archaeology.

After earning her PhD at Harvard, Warinner took on a post-doctoral position at the University of Zurich, where she was the world’s first researcher to examine the microbiome in the mouths of prehistoric humans; her main focus was analysing the remains of DNA found in dental plaque. Looking back, Warinner says that “a lot of my peers thought I was crazy and said I would never find DNA, that it would have decayed long ago”. But Warinner was not to be deterred—and found what she was looking for. Using traces of DNA and proteins from the microbiome, she was even able to reconstruct when and where humans began dairy farming.

Curious, dedicated

Nevertheless, many other questions remain unanswered, and Warinner says we “still don’t have a good understanding of what the microbiome does”. We do, however, know that the microbiome of modern humans in Europe and North America is significantly less diverse than that in non-industrialised societies. This is presumably due to changes in diet and hygiene in addition to the wide use of antibiotics. Christina Warinner wants to combine archaeological methods with state-of-the-art technology to discover what the human microbiome looked like in pre-industrial times.

For her work, she commutes between two universities and two continents: she is professor at the Max Planck Institute for the Science of Human History in Jena and at Harvard University in Cambridge, Massachusetts. At the Max Planck Institute, Warinner found a kindred spirit in Pierre Stallforth: “We’re both enthusiastic about our work, and we’re ready to explore new paths.”

Harvesting prehistoric DNA

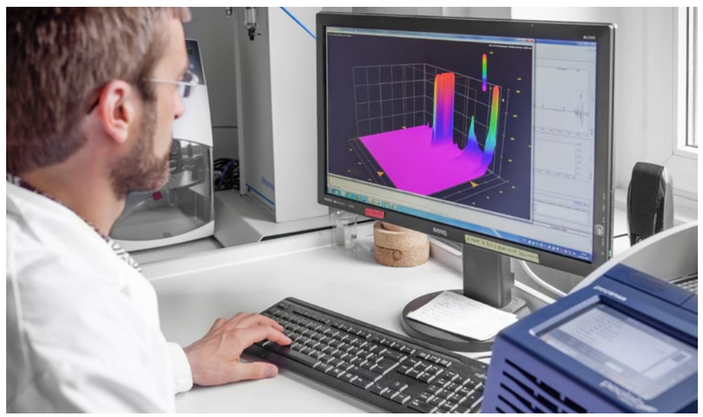
Researchers in the new discipline of palaeobiotechnology want to use the DNA found in prehistoric bacteria to develop antibiotics that are effective against resistant pathogens. The following photo essay shows how archaeologist Christina Warinner and chemist and biotechnologist Pierre Stallforth are working towards this goal.

1. The search

Christina Warinner (left) and her team are working with a stock of thousands of archaeological finds from sites located all over the world; some of the finds are up to 100 000 years old. Many have already undergone genetic testing, and now the next step is for the team to select the specimens in the database that are most likely to lead to natural products having antibiotic properties—and that are thus promising candidates for developing new antibiotic drugs.

2. The dental plaque

The teeth preserved in a 3 000-year-old mandible are prized objects for Christina Warinner and her team: nowhere else have researchers found more or better-preserved ancient DNA than in dental plaque, where food scraps and bacteria have been naturally conserved. The archaeologist scrapes away the plaque in a cleanroom, where the air is largely particle-free to avoid contamination. She also wears protective gear to prevent her own DNA from mixing with the prehistoric samples.



3. The puzzle

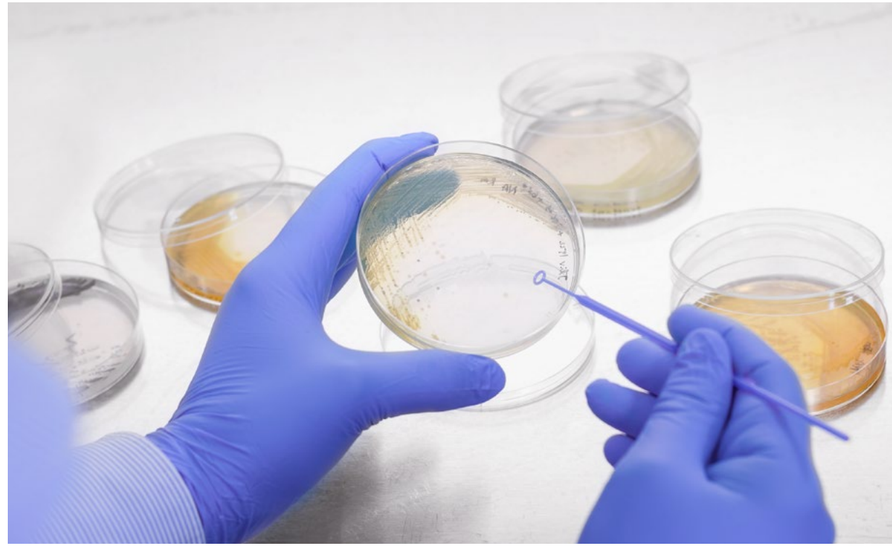
The latest genetic-sequencing technology makes it possible to determine the structure of prehistoric DNA in dental plaque and then identify the genetic sequences responsible for producing natural products. The researchers apply bioinformatics methods to piece together the scraps of DNA and close gaps in the sequence.

4. The reactivation

Once the DNA sequences responsible for producing antibiotic natural products have been identified, biotechnologist Pierre Stallforth (centre) and his team can introduce them to modern bacteria in cultures. Despite recent technological advances, the researchers must first develop some of the instruments needed for the project.

5. The harvest

The bacteria with additional DNA are grown in steel tanks. During the so-called fermentation process, the bacteria multiply and produce natural products—including ancient natural products, which was the aim of changing the genetic structure of the bacteria. Over the course of the multistep procedure, the researchers extract the natural products from the bacteria cultures. Afterwards, the pure natural product is separated out in special flasks (photograph at left).



6. The moment of truth

The researchers then examine the natural products in culture dishes and can quickly determine whether they are effective against the most common kinds of multiresistant bacteria. By 2029, Pierre Stallforth and his team aim to have developed new kinds of agents from the ancient DNA that are interesting to the pharmaceutical industry—as potential antibiotics or cancer drugs.

Ideal conditions: the lab bacteria containing ancient DNA are grown in steel tanks.

Facts and figures

Project

Researchers at the Leibniz Institute for Natural Product Research and Infection Biology – Hans Knöll Institute and the Max Planck Institute for the Science of Human History in Jena are examining prehistoric DNA for natural products that can be used to develop new antibiotic drugs.

Support

The Werner Siemens Foundation is supporting the establishment of the new research discipline of palaeobiotechnology in Jena, including a professorship, two postdoctoral positions, seven PhD students, two technical assistants and research infrastructure.

Funding from the Werner Siemens Foundation

10 million euros

Project duration

2020 to 2029

Project leader

Dr Pierre Stallforth, group leader of Chemistry of Microbial Communication at the Leibniz Institute for Natural Product Research and Infection Biology – Hans Knöll Institute in Jena

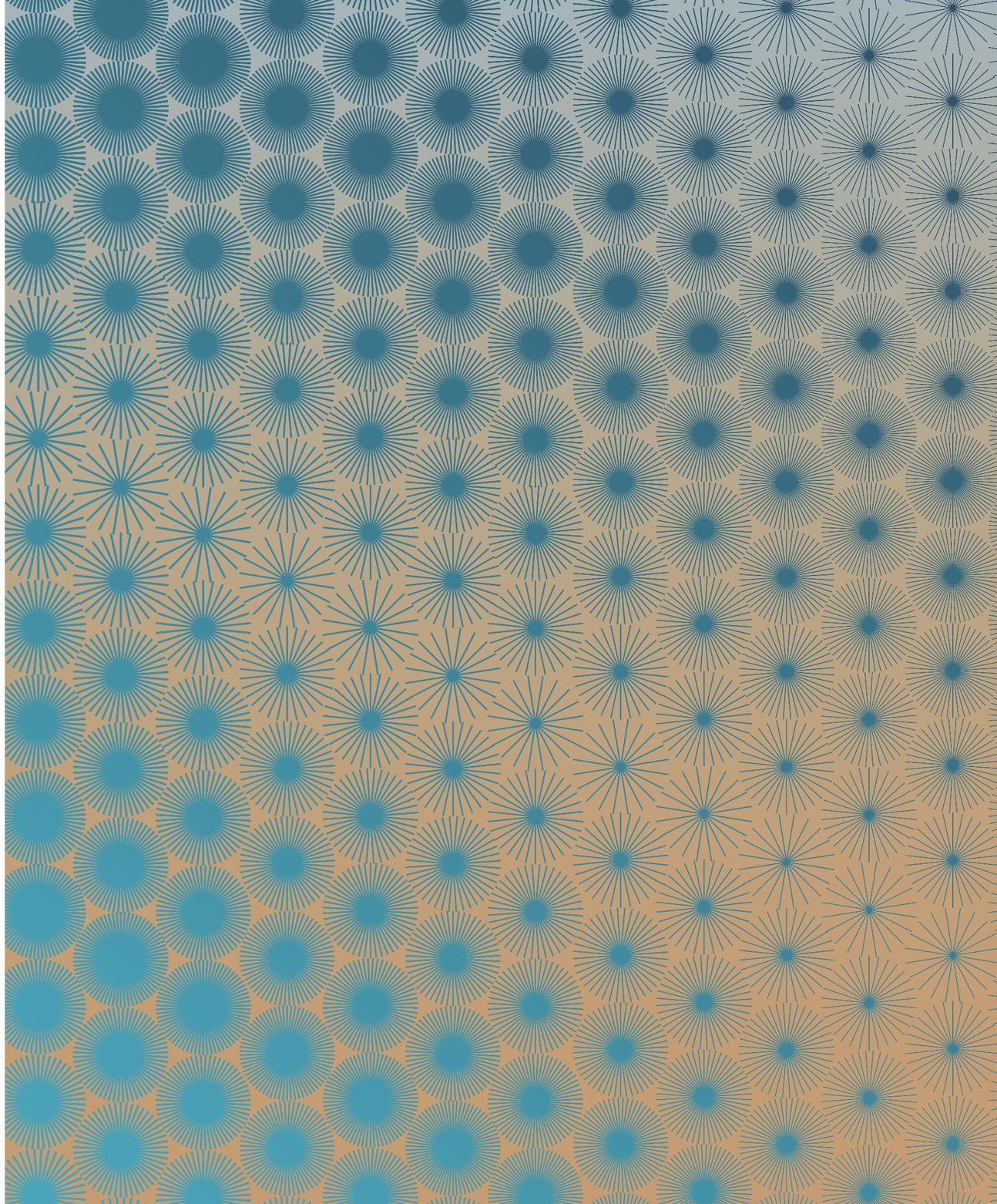
Academic partner

Prof. Dr Christina Warinner, group leader of Microbiome Sciences at the Max Planck Institute for the Science of Human History in Jena and assistant professor at Harvard University in Cambridge, Massachusetts

creative surprising necessary

Innovation

The Werner Siemens Foundation is financing the establishment of the new research discipline “palaeo-biotechnology” in Jena—because the interdisciplinary research team there is taking a promising and creative approach to solving the problem of life-threatening antibiotic resistance.



Safe, safer, internet

Cyber Trust research project at ETH Zurich

There are times in life when exchanging pleasantries is not enough. When we need to share important information that is perhaps confidential, sensitive or even embarrassing. For centuries we have been certain with whom we were sharing information—because we had built a relationship of trust with a real person. But along came the internet and with it a virtual world where we can no longer be sure that people are really who they claim to be.

Safer data exchange

Most of us use the internet regularly to exchange sensitive data—be it to make online payments or to send confidential emails. But the security measures and technologies we currently depend upon are vulnerable to attack: cybercrime has risen dramatically and users are losing faith in digital data exchange. With their new Cyber Trust project, IT professors from ETH Zurich and the University of Bonn are aiming to develop security systems that are one hundred percent trustworthy.

In the age of the internet, we still trust the postal service to deliver important messages.

Although digital technologies make our everyday lives more efficient, they also demand a great deal of faith from users: we place our trust in the card-reader at the supermarket, in the electronic forms of government authorities and in payment systems for online shopping and e-banking. In the physical world, we usually learn from experience whom we can trust and under what circumstances. But it is difficult to rely on these instincts when we use the internet. Indeed, between 2011 and 2016, reports of cybercrime in Switzerland increased from 5330 to 14033. Digitisation has also changed the face of crime itself: the methods of cybercriminals are growing ever more sophisticated and their scope greater—hackers can now target a large number of potential victims in one fell swoop.

Deception and fraud

Scammers are continually developing new methods to gain fraudulent access to money or valuable data. A common scheme is to trick users into entering their login data for accounts on authentic-looking websites or into responding to fake emails. In addition to such “phishing” attempts, there are also attacks via malware that, for instance, aim to intercept data moving between a bank and its clients. Indeed, all it takes is a visit to a dubious website for spyware to be installed on a user’s computer; the hackers then try to access the data they need to build an identity.

In certificates we trust

But in what exactly do we place our trust when we receive—and pay—an e-bill from our phone company? The name of the company on the bill? The fact that we have a contract with the company? This makes sense on the surface level, but whether or not we are aware of it, what we are counting on is our phone company using reliable encryption technology.

For data to be transferred securely online, they must first be digitally signed and then verified using a system of keys administered by what is known as the public key infrastructure. A public key is allocated to a specific person or internet address via a digital certificate issued by one of the 1400 certificate authorities located throughout the world; certificate authorities certify the key allocation via their own digital signature. In practice, web browsers such as Safari and Internet Explorer have pre-set lists of such certificates—and they rely on receiving trustworthy authentications from the certificate authorities.

No security guarantees

This system was developed in the early days of the internet and no longer meets today’s online security needs. One fundamental problem is that it takes only one compromised certificate authority to undermine the security of the entire internet—if a computer system is infiltrated and stored data are manipulated, online security is no longer guaranteed. Indeed, hacked certificates are no rarity: big-name firms such as Microsoft, Yahoo, Skype, Mozilla and Google have all been affected, and in 2013, the US National Security Agency used hacked certificates to pose as Google and spy on American citizens. Even if we see a padlock symbol in our browser window when doing

banking online, there is still no guarantee that we are actually on the website of our bank.

Benefiting from relationships of trust

The major questions in internet security today revolve around identity and authenticity. In order to address these problems in the transfer of sensitive data, IT professors David Basin, Peter Müller and Adrian Perrig from ETH Zurich and Matthew Smith from the University of Bonn have developed a novel approach: trusted relationships from the physical world should be transferred to the digital world. In other words, digital communications should be secured in advance through physical, trust-based relationships that clearly verify the identity of the person sending confidential information. In future exchanges, users can then be certain that they really are accessing the actual website of their bank or that the recommended software updates are, for instance, truly from Microsoft. Conversely, these secured digital trust-based relationships can also be used to secure physical communication—for example to verify that a letter was actually sent from the purported bank and not a scammer.

Potential scenarios

The IT professors at the Centre for Cyber Trust are currently working on various scenarios that involve transferring established trust-based relationships from the physical world to the digital realm.

Scenario 1: A tax advisor and her client want to be sure of each other's identity when they exchange confidential emails. At their first meeting, they simulate a "handshake" with their mobile phones to exchange a cryptographic key for their future digital correspondence. All they need for this is an app.

Scenario 2: A bank wishing to protect its clients from phishing attacks sends emails that are signed with a digital certificate. Wherever possible, the clients trust only certificates from Switzerland, meaning that trust is based on geographic information.

Scenario 3: A client wants to check whether the physical mail he receives from his bank is authentic. He visits his branch in person and photographs a code that provides him with a cryptographic key. When he later receives a letter from the bank, he uses the key to read the QR code on the letter and verify its source.

The coming years will tell which of these paths is best suited to establishing one hundred percent security in the exchange of digital data.

IT professor Adrian Perrig and two colleagues (see following pages) are in charge of the Cyber Trust research project at ETH Zurich.

A firm phoneshake

Developing a new IT security architecture for the exchange of sensitive digital data is a complex undertaking. At the Centre for Cyber Trust of ETH Zurich and the University of Bonn, IT professors believe the physical world offers the safest path—because when communicating face to face, identities can be guaranteed. In future, online communication should also be this secure.

IT professor Peter Müller, ETH Zurich

Why are cybercriminals so successful these days?

Peter Müller: Scammers often go to great lengths to ensure that the average internet user can't detect their schemes.
David Basin: When hackers fake a certificate, they can control the server and cause internet browsers to identify a fake website as authentic. Even experts can't detect such attacks.
Peter Müller: If just one single certificate authority is compromised and wilfully or negligently issues a false certificate, then the whole security system collapses.

How do you want to stop such attacks?

David Basin: We want to develop new methods for the authentication process. Our aim is to use attributes from the physical world to guarantee the authenticity of objects in the digital realm.
Peter Müller: We want to use physical attributes that can't be easily manipulated, such as the location of a bank branch. This will help to put trust in digital data on a more solid footing.

What will this trust be based on?

Peter Müller: When clients visit a bank branch to deposit money, they don't ask to see the employment contract or ID card of the clerk behind the counter—the building and behaviour of other people are reason enough for them to trust the employee. It's precisely these relationships of trust from the physical world that we want to transfer to the digital world. But relationships of trust can also be revoked, which is another complex problem that we're aiming to find a secure digital solution for.

In what ways can relationships of trust be transferred to the digital world?

Peter Müller: One way is to use attributes such as geographic proximity. For instance, we envision that two people who want to start exchanging important digital data meet not to shake hands, but to "shake phones". The synchronised movement of the two mobile phones would allow a common digital key to be exchanged between the two parties. Here, trust has been established by the fact that the two individuals are at the same location and know for sure with whom they "shook phones".
David Basin: This kind of key would suffice to establish secure communication. After shaking phones with someone, I still know in future—even when the other person isn't present—with whom I'm communicating. But we could apply the same principle to authenticate objects in the physical world, too. For instance, a bank could sign letters to clients by affixing a code, similar to a seal. The recipient can then use an app to decrypt the code and verify the identity of the sender.

Wouldn't this key be digitally stored and still at risk of theft?

Peter Müller: When, for instance, the IT system of a bank is hacked, information such as keys can be stolen, but the obstacles to hacking are much higher than forging a letter. It would also be possible to store the key offline—for instance on a smart card—which would make it very difficult to hack.

IT professor David Basin, ETH Zurich

Why is such a large project necessary for these new security measures?

David Basin: Our task is nothing less than redesigning today's public key infrastructure—because the entire system for issuing, distributing and verifying digital certificates is vulnerable to attack. A great deal needs to be done if internet-based communication is to be made truly secure.
Peter Müller: First of all, we want to technically implement our principles of trust in a newly developed infrastructure. We need solutions for administering keys—and for revoking them when necessary. Then we need to develop actual applications for secure email correspondence with banks, the distribution of voting documents and other transactions. But it's only after achieving these two major steps that things will really get going. In practice, technical systems don't always work, usually due to technical or human failure, and we want to exclude both types of error. Technical errors can be prevented to a great extent using mathematical methods that can help to guarantee that technologies and their applications in software really do have the desired attributes.

And how do you plan to exclude human error?

Peter Müller: That's what Matthew Smith, our partner at the University of Bonn, is working on. He's researching the security of the human interface using methods from behavioural science and by conducting experiments. In one experiment he gave programmers a task and observed their approach to solving it—and thus identified potential gateways for hackers. But it isn't just software developers who can inadvertently or deliberately compromise a system: system administrators and end users are also susceptible to error. When designing security architecture, every form of human error needs to be minimised by taking into account the behaviour of programmers, administrators and users right from the outset.

Are you aiming to replace today's entire system of certificate and authentication authorities?

David Basin: We want to offer better alternatives and develop prototypes for commercial applications in technology firms. Whether the world wants to use these to replace the current infrastructure remains to be seen. First we want to develop advanced prototypes that prove it's possible to make the digital world more secure. But in principle, the old and new systems should be able to coexist.

These cybersecurity problems have existed for a long time. Why are the solutions only coming now?

Peter Müller: There are five central IT topics in this project that have been developing since the 1970s and that have just now advanced far enough—thanks in part to our own research—that authentication issues can be solved. Five years ago, that would have been impossible.

There are plans to increase the cellular network standard from 4G to 5G to ensure that ever greater quantities of data can be transmitted at ever faster rates—but faster data transmission does not mean safer data transmission.

Facts and figures

Project

The computer scientists at the Centre for Cyber Trust of ETH Zurich and the University of Bonn are developing a fundamentally new security infrastructure for the internet. Their aim is to transfer relationships of trust from the physical world to the digital realm as a means of authenticating the identity of online communication partners.

Support

The Werner Siemens Foundation is supporting the development of the Centre for Cyber Trust and is financing some 15 positions for doctoral candidates, postdoctoral researchers and software developers.

Funding from the Werner Siemens Foundation

9.83 million Swiss francs

Project duration

2019 to 2027

Project leaders

Prof. Dr David Basin, Department of Computer Science, Information Security, ETH Zurich
Prof. Dr Peter Müller, Department of Computer Science, Programming Methodology, ETH Zurich
Prof. Dr Adrian Perrig, Department of Computer Science, System and Network Security, ETH Zurich

Academic partner

Prof. Dr Matthew Smith, Institute of Computer Science, Usable Security and Privacy, University of Bonn

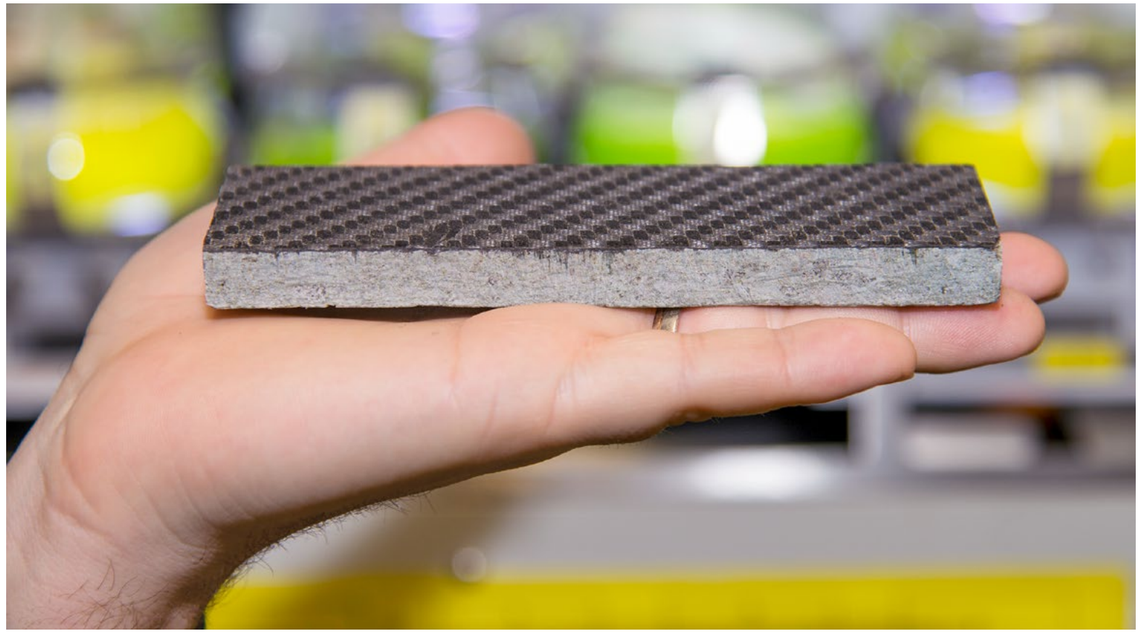
trustworthy
essential
secure

Innovation

The Werner Siemens Foundation is supporting the Centre for Cyber Trust—because internet users must be able to rely on secure data transmission, today more than ever.

Green carbon

Update: Synthetic Biotechnology



Carbon is solid yet light, making it an in-demand building material. But manufacturing carbon contributes to global warming. Now, the team from Synthetic Biotechnology is offering a solution with “green” carbon: production of the innovative material actually removes more CO_2 from the atmosphere than it releases.

2019 proved another successful year for Werner Siemens Foundation Endowed Chair Thomas Brück and his team at the Technical University of Munich: their innovative organic pest spray won the backing of major partners from research and industry, and they landed another coup with their Green Carbon project, a CO_2-neutral process for producing carbon fibres.

The new organic pest spray developed in 2018 by Werner Siemens Foundation Endowed Chair Thomas Brück and his team at Synthetic Biotechnology could not have been unveiled at a better time. Shortly beforehand, the EU had issued a ban on standard neonicotinoid pesticides, as these products destroy not only pests but also beneficial insects such as bees and butterflies. Rather than killing insects, the innovative organic pest spray uses cembratrienol, an odorous natural substance, to repel the pests for a certain period of time.

Perfecting the pest spray

In 2019, Thomas Brück was able to partner with the Institute of Sugar Beet Research in Göttingen and German agricultural company Südzucker to carry out the first tests with the organic pest spray; the results confirmed that cembratrienol repels aphids, whiteflies and fruit flies. Based on this success, Thomas Brück and the two partners acquired a large follow-up project entitled “OleoBuild”, which aims to transfer the production of cembratrienol to the oil-producing yeast *Rhodotorula sp*. This would increase the yield of cembratrienol and make it available as a completely formulated product for direct use in agriculture. The necessary financing is expected to be secured by the end of 2019.

Yeast: the ideal host

The researchers have already analysed the biochemical processes behind the production of cembratrienol in tobacco plants and were also able to identify and genetically modify the genes responsible. As a result, they no longer need to import tobacco plants to produce cembratrienol: the entire process takes place in the labs of the Synthetic Biotechnology group at the Technical University of Munich (TUM). The researchers now plan to chemically modify the active agent, further concentrating it until the odour is twice as potent as in its natural state.

Waiting for EU approval

The next step for the team is to obtain EU certification for the organic insect spray. The regulatory authorities carry out tests on toxicity, degradability, stability, storage life and other aspects of new agricultural chemicals—a process that takes about three to five years. “We have very little experience in approval procedures,” says Brück, “but Südzucker is one of Europe’s largest sugar producers, so we’re fortunate to have their know-how and support.”

When developing new products, having major partners from industry on board is important—also for financial reasons, as approval procedures cost hundreds of thousands of euros. But the investment is worthwhile: if the application is successful, the new crop-protection product can be sold throughout the entire European market.

Fuel from algae

Another major success for Thomas Brück and his team in 2019 was the progress made in their oleaginous algae project. The team created a procedure that enables a steady production of fuel from algae, a development that has been greeted with enthusiasm by cooperation partner Airbus, which is interested in non-petroleum fuels for aeroplanes.

The Synthetic Biotechnology researchers have also turned their attention to a by-product of algae-oil production: glycerol. When algae produce fatty acids, a considerable amount of glycerol is also produced—and the potential of this natural by-product has not escaped the researchers. They have now developed a chemical process that enables carbon fibres to be produced from the CO_2 released when the algae perform photosynthesis.

The basic substance the researchers use is algae oil, which, with the help of enzymes, is broken down into free fatty acids and glycerol. The glycerol is then chemically converted into polyacrylonitrile, the standard basic product for all commercial carbon fibres. The new process is 100 percent emissions-free and absorbs more CO_2 from the atmosphere than it emits. How is that possible? The basic organisms are fast-growing microalgae that store CO_2 as biomass and bind it in, for instance, the form of sugar and algae oil.

CO_2-neutral carbon fibres

Thomas Brück is delighted with the developments: “Our process has the potential to revolutionise the

production of carbon fibre. Until now, carbon fibres have left a considerable carbon footprint because their production is energy-intensive and uses unecological petroleum precursors. Now, climate change is making it urgent that we soon shift to a CO_2-neutral und economical process."

On the basis of various technological and economic criteria, Thomas Brück and his team evaluated the process for producing algae-based carbon fibres and came to the clear conclusion that the process is industrially viable. Soon after the results were published, they were cited in the World Climate Report in the section "Substitution and circularity" as a systemically relevant net sink of CO_2 to mitigate global climate change. For this innovation, Thomas Brück was awarded the 2018 "e-ward" of the European Business Council for Sustainable Energy, an NGO that is dedicated to the implementation of climate-friendly production processes.

Major project: Green Carbon

In July 2019, Thomas Brück launched a major project for his innovative method of carbon production. Named "Green Carbon", the project receives 8.9 million euros in funding and involves five academic departments at TUM: materials science, chemical tech-nology, mechanical engineering, biochemical engineering and synthetic biotechnology. The industry partners involved in the project are Daimler-Benz, Airbus and SGL Carbon, the largest European producer of carbon fibres. "We pretty much invented the project and coordinate it," Thomas Brück says with pride.

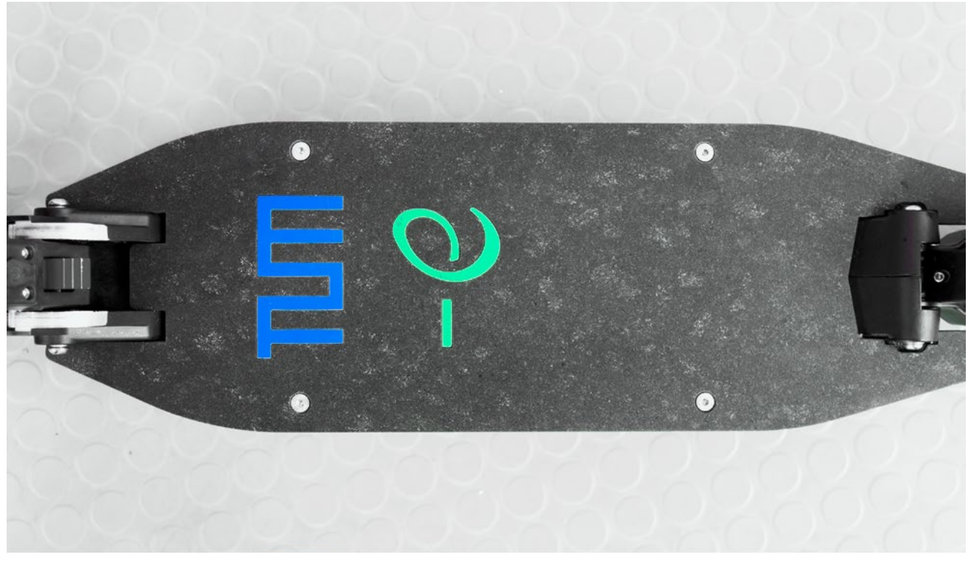
Sturdy, light, flexible

Another significant player in the Green Carbon project is a mid-size company: TechnoCarbonTechnologies. The company was founded by engineer Kolja Kuse, who was the first to combine carbon fibres with natural stone to create CO_2-negative construction elements. And the construction industry urgently needs such solutions, as it consumes gigatons of materials such as cement and steel, whose production is CO_2-intensive. "With our carbon fibres made from glycerol produced by algae, we can make a relevant contribution to countering climate change by replacing cement with a carbon-stone composite," says Brück. The most suitable stone for the composite material is granite: it is available worldwide and, when combined with carbon fibres, is as light as aluminium and even flexible. That means that instead of constructing buildings with steel frames and concrete walls, they could be constructed using strong, light and flexible carbon-granite. Green carbon would also be a viable material for the production of e-bikes, electric cars and aeroplanes.

Repositories in brown-coal mines

Thomas Brück has already given thought to the disposal of the new material: after diamonds, carbon fibre is the most stable form of carbon and it neither releases toxic substances nor outgases CO_2. For this reason, used carbon-granite could be disposed of in renaturalised brown-coal opencast mines, and with it the carbon contained therein. "We are aiming to achieve reverse geo-engineering," says Brück. "Our process makes it possible to put CO_2 emissions to economic use and then dispose of them effectively—a revolutionary concept!"

In future, this electric scooter made of green carbon won't be the only product made of algae-based carbon fibres: the EU has pledged millions of euros to further develop the innovative technology, and major industrial partners have expressed their interest.



The creative minds at Synthetic Biotechnology know no limits: in 2019, they even "invented" delicious algae cookies that are rich in protein.

Delicious algae cookies

Thomas Brück and his researchers are also cooking up smaller but no less creative ideas with their newest product made from *Dunaliella sp*. These algae produce more folate than any other algae, and it was this property that inspired the team to branch out a little—and bake algae cookies! The novel swirl cookies not only contain more folate than the average cookie, but also 30 percent more protein. That is why they taste so good, even with only half as much sugar as similar types of baked goods. The team served the algae cookies to the Bavarian association of millers, who were very impressed with the new idea. And no wonder: the algae cookie is vegan and thus fully on-trend.

A worthwhile investment

Certification processes cost considerable time and money, and not all proposals made by the Synthetic Biotechnology team are approved first go—their proposal to the EU to produce the cancer drug Taxol was narrowly rejected. Nonetheless, Thomas Brück is convinced that the Werner Siemens Foundation is right to support the new discipline: "The funds invested in the new professorial chair for synthetic biotechnology and its staff have increased over tenfold in the past two years. Today we are leading the way in the development of sustainable technologies that convert CO_2 and residual biomass into valuable processes—for the food and cosmetic industries as well as for chemical and pharmaceutical companies. The citation in the World Climate Report confirms the global significance of our research. We thank the Werner Siemens Foundation for giving us the freedom to convert our innovative ideas into real processes and products that generate value for society—fully in the spirit of our new motto 'Bringing Synthetic Biotechnology to Life'."

Funding from the Werner Siemens Foundation

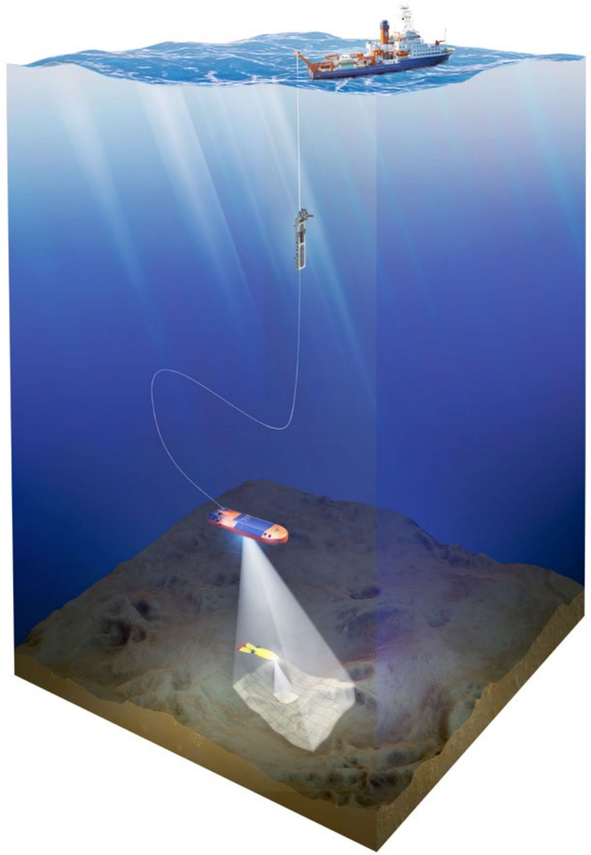
11.5 million euros

Project leader

Prof. Dr Thomas Brück, Werner Siemens Foundation Endowed Chair for Synthetic Biotechnology at TUM

Project duration

2016 to 2021



In 2019, Werner Siemens Foundation Endowed Chair Ralf Bachmayer and his research group developed a strategy to chart the deep sea without disrupting its fragile ecosystems: a “mother submarine” (orange) guides a small, agile submarine (yellow) through the depths where, floating as gently as a deep-sea medusa, it takes high-resolution photographs of the seabed.

Treading softly in the deep sea

Update: Innovation Center for Deep-Sea Environmental Monitoring—safeguarding the deep sea

How can we protect the vulnerable ecosystems of the deep sea once it has become the site of disruptive mining operations? A daunting task. But the Innovation Center for Deep-Sea Environmental Monitoring at MARUM in Bremen is up to the challenge—thanks to a 10-year grant from the Werner Siemens Foundation.

The unique ecosystems of the abyssal ocean are in danger. The seabed harbours large deposits of valuable resources such as gold, silver, copper and rare earth elements, and numerous countries and businesses are eager to lay their hands on these treasures. The first company to announce plans to mine the deep sea was Nautilus Minerals Inc. But the operations, scheduled to begin in 2019 in the Bismarck Sea off the coast of Papua New Guinea, have been delayed—a stroke of good fortune for the deep sea.

Getting to know the territory

The delay is also good news for the Innovation Center for Deep-Sea Environmental Monitoring, as it gives the team additional time to develop the technology needed to monitor the environment of the deep sea. Currently, no environmental protection organisation is in the position to monitor large swaths of the deep sea, let alone protect it. After all, 90 per cent of the abyssal sea is a true terra incognita, and the researchers must first understand what exactly there is to be protected. What they do know: at a depth of 200 to 1100 metres, life forms regenerate only at an extremely slow pace, if at all, meaning that deep-sea mining would have grave consequences for the ocean’s ecosystems.

Map with care

For Werner Siemens Endowed Chair Ralf Bachmayer and his team, the first step towards developing a protection strategy for the deep sea is finding a way to create precise maps of the subaquatic terrain. Like most research in the abyssal sea, this is easier said than done, because virtually all aspects of charting the seabed pose major challenges: how to transmit data, how to power the various instruments in the depths and, last but not least, how to guide a camera over a seabed that is highly sensitive to water turbulence. The loose seabed layer below the water column is only partially made of stone; instead, much like moorland, it consists mainly of unstable, floating particles that even the slightest of motions can disturb—and which could lead to serious disruptions in the deep-sea ecosystem.

Better in tandem

To accommodate the hyper-sensitivity of the ocean floor, Ralf Bachmayer and his team have developed a strategy with two underwater vehicles that operate in tandem. From a safe distance, a “mother submarine” (for instance the H-ROV, a hybrid underwater vehicle that operates autonomously or via remote control) shines a light on a large swath of the seabed and takes low-resolution photos of the general area. At the same time, the mother submarine steers a small, agile vehicle moving close to the seabed. This device makes high-resolution images and sends them to the mother submarine.

The vehicle hovering above the ocean floor is a minimally invasive autonomous underwater vehicle, or AUV. Minimally invasive means that the vehicle is able to inch gently over the seabed, thus preventing it from disturbing the soft upper seabed layer and clouding the waters. Autonomous means that, although the researchers can define where and how close to the seabed the AUV should chart a map, the vehicle nevertheless retains the ability to react independently should it suddenly encounter rocky crags or seamounts in the dark. Because the vehicle is partially intelligent, it can spontaneously decide how it should avoid obstacles, even though the mother submarine is monitoring all its movements.

Data transmission

The current plan is for the AUV to use an innovative optic modem to transmit the high-resolution images of the seabed via the mother submarine up to the research team. The modem was successfully tested in the Mediterranean, off the coast of Nice, in September of 2019. This is good news, as an optic modem is more efficient and can transmit a greater mass of data than the acoustic technologies generally used for underwater data transmission. Two additional tests covering larger swaths of territory and in deeper waters are planned for 2020. With these achievements, Ralf Bachmayer and his team have taken considerable strides in their endeavour to safeguard the deep sea.

Funding from the Werner Siemens Foundation

4.975 million euros

Project leader

Prof. Dr Michael Schulz, director of MARUM – Center for Marine Environmental Sciences at the University of Bremen

Project duration

2018 to 2028

Sailing on

The *Eugen Seibold* is the world's greenest research vessel and was constructed with funding from the Werner Siemens Foundation. Since May of 2019, the innovative yacht has been sailing the high seas—and on the vessel's maiden voyage, the researchers onboard tested the waters of the Atlantic north of the Canary Islands. The next step will be to collect samples throughout the North Atlantic Ocean: from tropical regions to the polar cap, from the equator to the Svalbard archipelago. By gradually gathering data on the various marine provinces, the climate geochemists at the Max Planck Institute for Chemistry in Mainz will be able to chart a detailed description of the world's oceans, characterising their current properties and even reconstructing how they change over time. Scenes from the maiden research voyage of the *Eugen Seibold*.

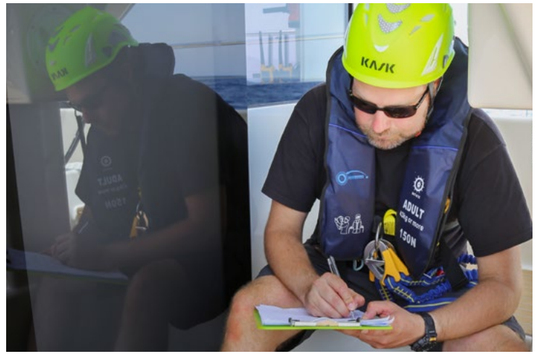
The *Eugen Seibold* setting out on its maiden research voyage in May of 2019. A crew of four navigates the yacht north of Lanzarote, where they will collect a comprehensive range of samples of the Atlantic's waters. Onboard are project leader Ralf Schiebel and scientists Hedy Aardema, Maria Calleja and Hans Slagter. The most ecological research vessel in the world is the brainchild of Gerald Haug, director of the Department of Climate Geochemistry at the Max Planck Institute for Chemistry in Mainz and professor at ETH Zurich.

The team uses a rosette sampler to collect water samples from various ocean depths. Because the *Eugen Seibold* is a sailing yacht with a fibreglass hull, it does not contaminate the very waters it samples—unlike standard research vessels, which are motorised and have metal hulls.

To gather plankton samples, the oceanographers lower a special net into the water. The finely woven nets are made of titanium and have multiple opening and closing devices to collect even the smallest creatures living in the seawater (micro-zooplankton); the crew then analyses the specimens.

The *Eugen Seibold* crew retrieves the collecting net from the water. The five compartments for collecting specimens are opened and closed remotely via computer.

The water samples can be analysed directly onboard the *Eugen Seibold*: oceanographer Hedy Aardema in the lab. The Max Planck Society finances the research work and the instruments.



Marine chemist Hans Slagter keeps an exact record of the samples. Over the course of the next several years, the researchers will combine the individual puzzle pieces to create a clear picture of the geo-chemical properties of the ocean waters.

Funding from the Werner Siemens Foundation

3.5 million euros for the construction of the *Eugen Siebold*

Project leader

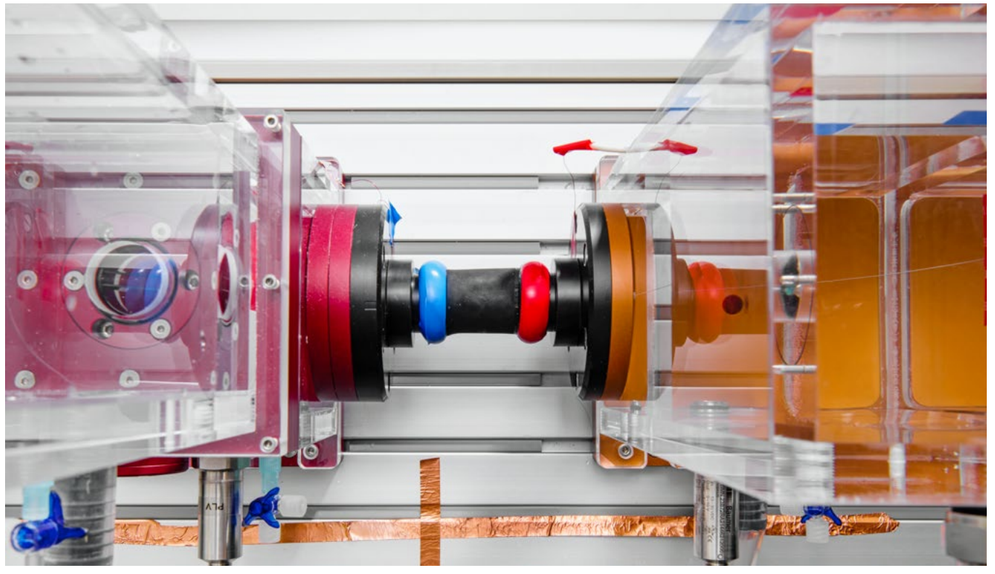
Prof. Dr Gerald Haug, director of the Department of Climate Geochemistry at the Max Planck Institute for Chemistry in Mainz, Germany, and professor at ETH Zurich, Switzerland

Project duration

2015 to 2018

A boost for weak hearts

Update: Center for Artificial Muscles



In 2019, researchers at the Center for Artificial Muscles developed a testing unit that simulates how blood circulates through the chambers of the heart (left and right) when an artificial muscle (black membrane, centre) boosts pumping capacity.

At the Center for Artificial Muscles in Neuchâtel, researchers are developing a ring that can be fitted around the aorta to help the hearts of patients with cardiac insufficiency pump blood through the body. The team in the innovative project have made major advances over the past year in key areas of the project: the required pumping capacity of the artificial muscle, the material and the energy supply.

Yves Perriard and his team of 10 researchers at the Center for Artificial Muscles in Neuchâtel have set their sights high: they are developing a ring-shaped muscular membrane that can be wrapped around the aorta to support the heart function of patients suffering from cardiac insufficiency. Because the heart is such a powerful muscle, the greatest challenge lies in guaranteeing the necessary pumping capacity. But now, two years on in the project, the researchers have discovered that the heart's strength works in their favour. Initially, the team presumed that an additional titanium spring would have to be fitted around the membrane to generate enough pressure on the aorta, and they even had their design for the spring patented in 2019. But then, new calculations showed that even the weak hearts of patients with cardiac insufficiency could generate enough force on the ring, making the additional spring unnecessary. That is excellent news for patients—and for heart surgeon Thierry Carrel, who will be testing the aorta ring in clinical trials.

The right stuff

The team also made progress in their search for the right material for the membrane. It soon became apparent that electroactive polymers—which change their shape when stimulated by electricity—are highly suited. The researchers then shifted their focus to determining the optimal chemical composition and degree of thickness for the polymer and developed a four-layer membrane that is currently being tested in a purpose-built testing unit to assess the elasticity of the polymer and determine how much force it can withstand. As part of the search for the right material, Yves Perriard also initiated a collaboration with the French University of Cergy-Pontoise in 2019 to benefit from the expertise there.

One ring does the trick

One of the key components of the project is ensuring the energy supply to the muscle-like membrane, and in 2019, Perriard's team designed a blueprint of the electronic components required. In another part of the project, the researchers developed an innovative testing unit that simulates the flow of blood in the body (image above). The tests and simulations provided another important answer: to generate the necessary pumping capacity, fitting multiple rings around the aorta will not be necessary—a single ring, and thus a single membrane, would suffice. Because using just one ring simplifies the surgical procedure, the advance is also excellent news for patients.

An artificial muscle to support heart function—it would be a world's first. But the researchers in Neuchâtel also see other potential applications for their invention: they hope that the membrane can also be used as an artificial sphincter for people suffering from urinary incontinence or to restore chewing function and facial expressions to accident and burn patients.

Funding from the Werner Siemens Foundation

12 million Swiss francs

Project leader

Prof. Dr Yves Perriard, director of the Center for Artificial Muscles and the Integrated Actuators Laboratory (LAI), Swiss Federal Institute of Technology Lausanne

Project duration

2018 to 2029

Bone-afide success

Update: MIRACLE—minimally invasive bone surgery using laser technology

Minimally invasive, highly precise, quick recovery times—this is how some 50 researchers in the MIRACLE project envision bone surgery of the future. And the team at the University of Basel are getting closer to achieving their goal: their robot-guided laser tool is five times more precise than a conventional bone cutter and their SpectoVR 3D software is a runaway success. With their project firmly on track, the researchers have now trained their sights on miniaturisation and integration of the various components.

The 3D control sensor now measures just 1.5 millimetres (the three tiny black squares at the top of the image).

Using a bone cutter to saw through bone is a rather unpleasant thought for most of us. But now, the time-old medical instrument may soon belong to the past: since 2014, researchers at the Department of Biomedical Engineering at the University of Basel have been developing a robotic arm with a laser scalpel for use in high-precision bone surgery. Located at the Switzerland Innovation Park Basel Area, the MIRACLE project is led by Philippe Cattin, professor of medical image analysis, and Hans-Florian Zeilhofer, head of the Clinic of Oral and Maxillofacial Surgery at the University Hospital Basel. The main objective of MIRACLE (Minimally Invasive Robot-Assisted Computer-guided Laser OsteotomE) is to enable minimally invasive surgical operations using a laser osteotome—a surgical device used to cut through bone.

The art of engineering in medical care

The MIRACLE team unites specialists from medical robotics, laser technology, planning, navigation and intelligent implants. In their work to develop innovative software solutions and various prototypes, the researchers are in close contact with medical staff from the University Hospital Basel and the University Children's Hospital Basel. "Some 50 researchers from our team are making the art of engineering available to doctors, to support them in their work," says Philippe Cattin.

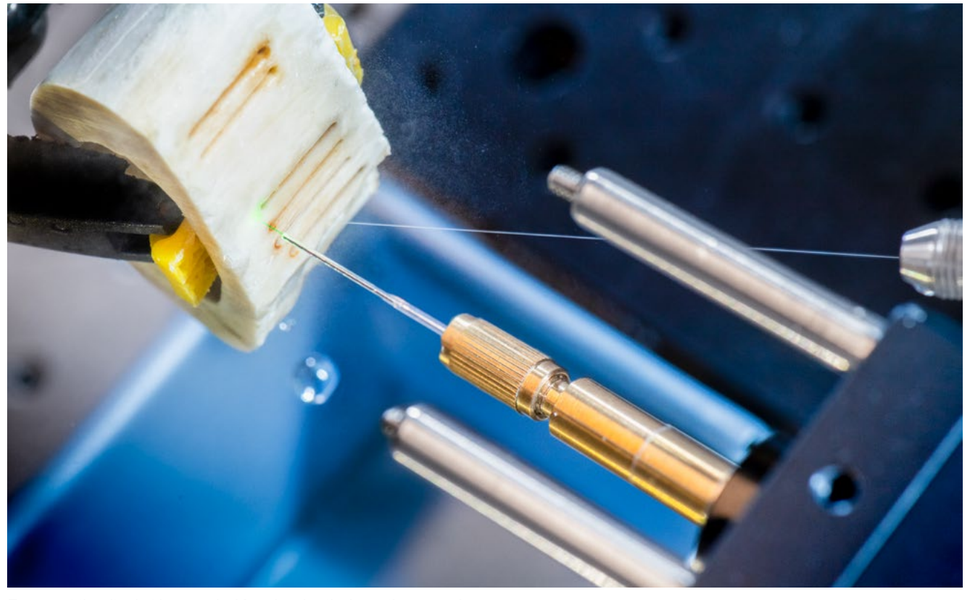
The researchers have already created the laser robot GG1, which secures coordinated communication between laser technology, robotics and planning software. Most importantly, GG1 can make incisions as narrow as half a millimetre, meaning its laser incisions are up to five times finer than those of a conventional bone cutter. Thanks to the clean, precise cuts, bones can heal faster after an intervention.

The smallest order

The year 2019 was dedicated to miniaturisation and integration. "Our goal is to make the laser endoscope components as small as possible, so they can fit into the tip of the robot-guided endoscope," says Phillipe Cattin. When operating with the endoscope, surgeons can move the laser "scalpel" with high precision through the human body. In addition, the robotics team of MIRACLE professor Georg Rauter created a miniature version of a parallel robotic endoscope tip to enable repetitive, exact incisions in minimally invasive interventions; the researchers are currently optimising the technology.

Intelligent lasers

The Biomedical Laser and Optics Group of Professor Azhar Zam are currently working on an intelligent laser able to detect tissue in the body; in a future development, the laser will be able to identify tumours. The research group of Hans-Florian Zeilhofer is now focused on further developing minimally invasive implant and device technologies. Over 120 patients have already received implants during neurosurgical interventions. In collaborative projects with large clinics in Switzerland and Germany, the first minimally invasive implants are now in the planning stages.



To prevent the ultra-hot laser scalpel from burning the bone, the researchers created a miniature water jet to cool the operation site (far right).

Doctors at the University Hospital Basel are already using SpectoVR 3D software to advise patients before complex interventions; the virtual tour of the body helps to demonstrate why an operation is necessary.

Smart implants

In April of 2019, privatdocent Dr Stefan Stübinger, co-head of the MIRACLE group "Smart Implants", launched "BioInitials", yet another spin-off company of the MIRACLE project. BioInitials develops miniaturised biochemical sensors that make it possible to monitor periodontitis and analyse biomarkers in saliva. The sensors created by the team at BioInitials will also benefit the MIRACLE project—for example, in dentofacial surgery.

Practical 3D software

To optimise surgical planning, surgeons can rely on SpectoVR, the virtual-reality software developed within the MIRACLE project. Using high-tech goggles, doctors and patients alike can view data from CT scans in 3D. Philippe Cattin reports that the University Hospital Basel already has eight SpectoVR stations that are connected to the hospital's IT system. The visualisation software is now also being used for patient consultations; moreover, a study by Moorfields Eye Hospital in London has confirmed the medical benefits of using SpectoVR.

SpectoVR: a crowd pleaser

In 2019, doctors from neurosurgical medical clinics in Switzerland and the University Children's Hospital Basel had the opportunity to get to know SpectoVR at a continuing education seminar, while experts from all over the world were introduced to the innovative software at conferences, symposia, exhibitions and events such as Swiss Digital Day. And on 26 September 2019, the showroom at Switzerland Innovation Park Basel Area was opened. At the Innovation Park, numerous MIRACLE prototypes, some of which are interactive, illustrate how the research project has progressed. Visitors can even try out a SpectoVR station and take a virtual tour through the body—in addition to being innovative and beneficial in medical care, SpectoVR is also a real crowd pleaser.

Funding from the Werner Siemens Foundation

15.2 million Swiss francs

Project leaders

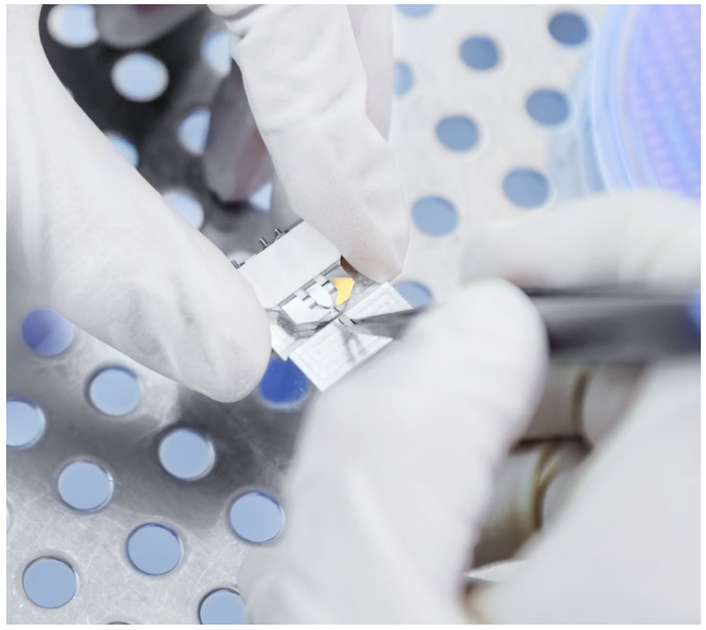
Prof. Dr Philippe Cattin, professor of Medical Image Analysis and head of the Department of Biomedical Engineering, University of Basel and University Hospital Basel
Hans-Florian Zeilhofer, head of the Clinic of Oral and Maxillofacial Surgery, University Hospital Basel

Project duration

2014 to 2021

Little big breakthrough

Update: Center for Single Atom Electronics and Photonics—the microchip of the future



On track for a new world record: researchers at the Center for Single Atom Electronics and Photonics are developing an innovative, atom-sized microchip.

Researchers at the Center for Single Atom Electronics and Photonics are experimenting on an entirely new kind of microchip—one that functions at the atomic level. Financed by the Werner Siemens Foundation, the innovative project has already produced excellent results, with laboratory experiments now revealing the enormous potential of the microchip's core component: the single-atom transistor. Researchers in the project led by Jürg Leuthold, head of the Institute of Electromagnetic Fields at ETH Zurich, have developed a new transistor version in a gel electrolyte that requires only six millivolts to function at room temperature: a world record.

Entering uncharted territory means encountering unheard of problems—an experience that holds true for Jürg Leuthold, Thomas Schimmel, Mathieu Luisier and their teams, as they endeavour to develop an innovative, atom-sized microchip. The three professors and their research groups have already worked together to create a prototype of the incredibly tiny single-atom switch. Unlike standard microchips that function via electrons, the new switch operates using a single atom that is shunted back and forth. The principle behind the microchip is as follows: two miniscule metallic contacts are placed close together—so close that the space between them is large enough for only a single atom. When an atom is shunted between the metallic contacts, it closes the gap and enables an electric current to flow from one side to the other. When the atom is removed, the gap re-opens, meaning the electric circuit is broken and no current can pass through. The basic concept of using a single atom for "switching" an electric current or an optical signal can find a number of practical applications: depending on the configuration, the microchip could function as an on-off switch, a transistor, a modulator or even a storage cell.

Atomic building blocks

Physicist and nanotechnologist Professor Thomas Schimmel and his team from the Karlsruhe Institute of Technology (KIT) improved upon the existing single-atom transistor and created a new version in a gel electrolyte that functions at room temperature at an even lower voltage: under laboratory conditions, its control voltage is only 6 millivolts—in contrast to the 700 millivolts needed by even the most modern generation of traditional transistors. "What was unthinkable a short time ago is now reality," says Thomas Schimmel, who has recently applied for a patent. Now, a future microchip that is not just 100 times but up to 10 000 times more energy-efficient is theoretically possible. Nevertheless, a great deal of work remains before the theory is transformed into practice and used to manufacture ordinary electronic devices. "But our experiments already indicate what is physically possible," says Schimmel.

The single-atom transistor is just one of a dozen or so building blocks that will be used to construct the innovative microchip. The modulator—a part that converts an electric signal into an optical (light) signal—and its counterpart, the photodetector, have also been created. In addition, an electric switch and a volatile memory component are under development. Volatile memory components can retain content over the duration of an electric current. Now, Jürg Leuthold and his team must also find a way to make non-volatile memory components to ensure that data stored on the microchip are not lost when the chip is no longer connected to an energy supply—for instance when a computer is turned off.

Meticulous craftsmanship

The goal is to have all key components of the atomic microchip ready by 2021. "It's an ambitious schedule, but the three research groups are committed to succeeding," Leuthold says. Nevertheless, quite a few factors in the research field depend on smaller and larger breakthroughs—and breakthroughs are notoriously difficult to predict. One aspect that has proven a major challenge is the manufacture of tiny, atomic-scale wires. Moreover, the production steps in making the atom-sized transistors are complex and demanding, meaning that Leuthold, Schimmel and their teams are experimenting with a wide range of materials and geometries.

Computer simulations

Computer simulations can help explain the principle of the single-atom switch even before all building components have been perfected, and the researchers in the group of Professor Mathieu Luisier at ETH Zurich are currently working on such simulations. Jürg Leuthold says that important milestones have been achieved in this area: last year, for instance, the researchers succeeded in simulating potential materials—silver, platinum and glass—and then conducted experiments to observe how they react to heat, light and electronic impulses. "We pretty much know exactly what process will lead to an atomic switch," says Jürg Leuthold.

Funding from the Werner Siemens Foundation

12 million Swiss francs

Project leader

Prof. Dr Jürg Leuthold, head of the Institute of Electromagnetic Fields, ETH Zurich

Project duration

2017 to 2025

All in: girl power for technology

Update: Swiss TecLadies mentoring programmes

The science-minded girls in the first Swiss TecLadies mentoring programme love being part of the action. For example Rahel (centre), who is fascinated by rocket technology.

The fact that girls are interested in robotics and programming often goes unnoticed—and they also receive little support. To change this, the Swiss TecLadies Mentoring Programme encourages girls aged 13 to 16 to cultivate their curiosity for science and technology.

"The girls get all fired up when they can make something move," says Astrid Hügli, head of the Swiss TecLadies Mentoring Programme. MAN, a commercial vehicle manufacturer, had organised a workshop for the girls to try their hand at software coding, and programming mini self-driving cars proved a big hit with the girls. "They were all completely absorbed by it," Hügli says with a smile, adding that the girls were especially intrigued by robotics.

As an engineer and secondary-school teacher of science and technology, Astrid Hügli knows what she is talking about. Her experience and know-how were instrumental in shaping the mentoring programme, which is run by the Swiss Academy for Technical Sciences (SATW) and supported by the Werner Siemens Foundation.

Making discoveries together

The mentoring programme unites 44 women from technical or scientific professions (mentors) with 44 girls aged 13 to 16 (mentees). Finding the right mentor for each mentee proved challenging, as the women and girls came from all over German-speaking Switzerland and long trips were to be avoided. At the same time, the subject-specific interests needed to be considered: the most popular subjects among the girls were robotics and medical technology.

Because developing trust is an important aim of the mentoring programme, the mentors and mentees are free to decide for themselves whether to meet at the mentor's place of work or privately. In particular, it is important for the girls to see that women in technical professions are not exotic creatures, but rather people with perfectly normal lives. And so "a Ferris wheel ride or walking the dog were also good activities", Astrid Hügli explains. Some mentors were even invited by the mentees and their parents to their homes.

As part of the mentoring programme, 16 workshops were held in a variety of firms. Although they were voluntary, Astrid Hügli was pleased to see that attendance was high. There were also various learning excursions on offer, such as a visit to the Paul Scherrer Institute, Switzerland's largest research institution for engineering and natural sciences, and a day at RUAG Space, a division of Swiss technology firm RUAG. Finally, two career days, run with support from the Canton of Zurich office for gender equality, were held to help the girls develop self-confidence and learn strategies for asserting themselves in male-dominated professions.

Building a network

The first programme concluded in June 2019, and the second will begin in late 2020. In addition, a network has already been established for the women and girls to maintain their contact through organised gatherings. At regular intervals, the girls from the programme are asked about their career aspirations; currently 60 percent of the participants have serious intentions of pursuing a technical career. When the time comes for the girls to choose a profession, the mentors will be available again to offer their advice. The activities and interests shared by the mentors and mentees have paved the way for lasting contact, and all the women and girls took part in the programme's final event: a trip to Europa-Park, Germany's largest theme park.

Shooting for the stars

13-year-old Rahel Rüefli from the town of Grenchen is one of the girls who took part in the Swiss TecLadies mentoring programme. She liked it so much, she wishes she could take part a second time. When asked about her future goals, Rahel does not hesitate: "I want to travel to the International Space Station." The secondary-school student has long been interested in astrophysics and rocket technology, and so she found the programme's tour of the RUAG Space company "totally cool". Together with the mentors and her peers in the Swiss TecLadies mentoring programme, she visited several research institutes, universities and firms, and also attended workshops. Now she has been to the Paul Scherrer Institute twice—and was no less fascinated the second time around by the experiments with the particle accelerator.

It was Rahel's mother—well aware of her daughter's enthusiasm for science—who drew her attention to the mentoring programme. Because she has made the experience that not too many girls share her interest in technical subjects, one of the things Rahel liked best about the Swiss TecLadies programme was working together with like-minded girls.

Funding from the Werner Siemens Foundation

900 000 Swiss francs

Project leader

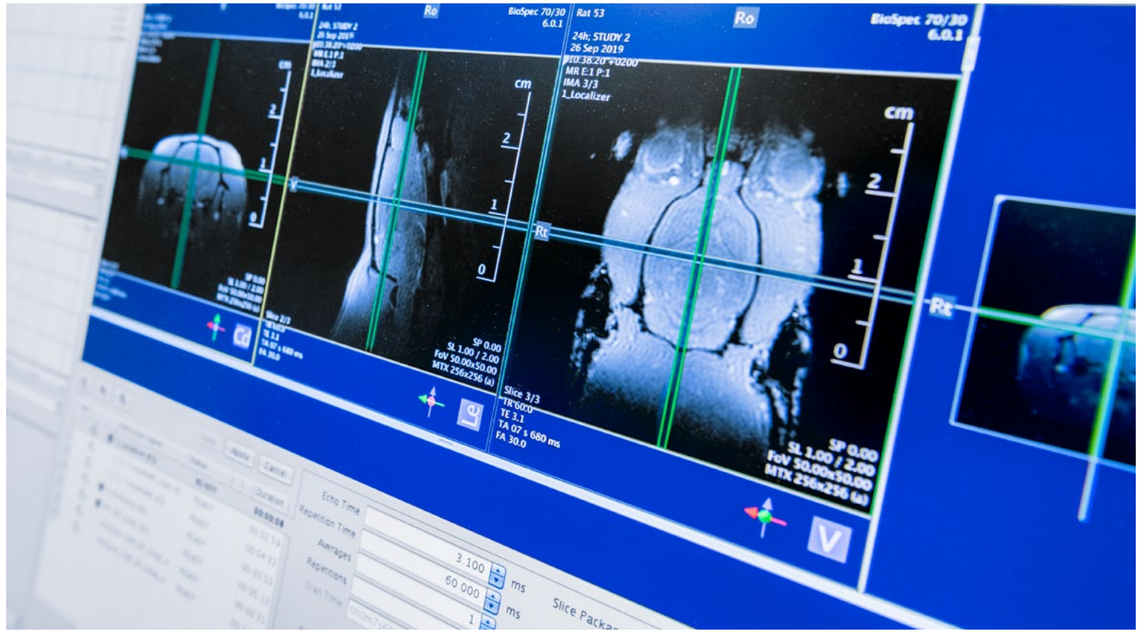
Swiss Academy of Technical Sciences (SATW)

Project duration

2017 to 2021

A closer look into the molecule

Update: medical imaging techniques at the Werner Siemens Imaging Center in Tübingen



In 2019, a high honour was conferred on the research units for personalised tumour therapies at the Werner Siemens Imaging Center in Tübingen: they became part of Germany's national Excellence Strategy.

The Werner Siemens Imaging Center (WSIC) is a pioneer in research on medical imaging and collaborates with the University of Tübingen and the University Hospital Tübingen to translate academic findings into clinical care. In 2019, WSIC research on tumour therapies became part of Germany's national Excellence Strategy. The next goal? Developing sustainable cancer therapies.

Since its foundation in 2014, the Werner Siemens Imaging Center (WSIC) in Tübingen has grown into one of the world's leading research facilities for preclinical imaging and medical imaging techniques; basic research on cell and animal models is the focus at WSIC. Professor Bernd Pichler—holder of the Werner Siemens Foundation Endowed Chair—leads the WSIC team of some 60 researchers who contribute their specialist knowledge from the fields of biology, physics, medicine, chemistry and engineering science. The interdisciplinary approach at WSIC is leading to a better understanding of how illnesses arise, progress and spread through the body. "Our overarching goal is to obtain research findings that will lead to more effective treatments of diseases like cancer, Alzheimer's or Parkinson's," says Bernd Pichler.

Combined PET/MRI systems

Taking one of the WSIC projects as an example, Bernd Pichler describes the complex research activities he and his team conduct: "At WSIC, we developed a medical imaging system to examine mice. The system combines positron emission tomography with magnetic resonance imaging, and the combined PET/MRI system makes it possible to gain insight into how a disease arises and progresses in the mice's bodies." These combined medical imaging systems are of major importance both in research and in cancer diagnostics.

Rapid translation into clinical practice

The team at WSIC is also developing biomarkers: radioactive or fluorescent chemical compounds that medical imaging techniques make visible in the body. For instance, the researchers succeeded in using radioactively labelled antibodies to detect the fungus *Aspergillus fumigatus*, which is extremely dangerous to humans. To ensure that patients can benefit from the stream of new findings as quickly as possible, the WSIC team works closely with doctors and researchers at the University Hospital Tübingen—and in 2019, the procedure for fungus labelling and diagnostics was successfully used on the first patients at the hospital. A new biomarker is also being developed for early recognition of Parkinson's symptoms, and Bernd Pichler reports that excellent progress has been made in medical imaging of tumours.

National success

Germany's national Excellence Strategy promotes state-of-the-art research at German universities and internationally competitive research facilities. The University of Tübingen has been part of the programme since the start of 2019 and has received funding for its three outstanding research clusters: molecular oncology, immuno-oncology and multiparametric imaging techniques; the federal grants for these "Clusters of Excellence" are distributed over a seven-year period. Bernd Pichler stresses that "this recognition was only possible thanks to the sustained support of the Werner Siemens Foundation".

The three Clusters of Excellence work together at the Image-Guided and Functionally Instructed Tumor Therapies (iFIT) Cluster of Excellence. The associated teams are aiming to achieve a comprehensive understanding of biological processes in cancerous tumours. State-of-the-art medical imaging techniques are used to visualise stress states in tumours, and the researchers hope the images will lead to novel molecular cancer therapies that can be tailored to the individual patient.

Expanding tumour research

Tumour research will continue to grow at WSIC in the coming years. As one of the first steps, Dr Bettina Weigelin from the University of Texas MD Anderson Cancer Center will join the team in Tübingen. Bettina Weigelin is responsible for setting up the section for intravital microscopy at WSIC, with the aim of making tumour research on diverse dimensional scales possible; using this technology, molecular and cellular processes can be analysed in detail. "The analyses can provide indications on the cause of therapy resistance," says Weigelin, "or they show how tumours grow and metastasise."

Funding from the Werner Siemens Foundation

12.3 million euros (2007–2016)
15.6 million euros (2016–2023)

Project leader

Prof. Dr Bernd Pichler,
Werner Siemens Foundation Endowed Chair and director of the Werner Siemens Imaging Center

Project duration

2007 to 2023

Entrepreneur in the incubator

Update: MedTechEntrepreneur Fellowships funding programme

Yannick Devaud at the UZH Life Science Incubator Lab in Schlieren, near Zurich, where the biotechnologist is free to use the research equipment to prepare and perfect his invention for market.

Translating findings from medical research into applications to help people—that is the overriding aim of the MedTechEntrepreneur Fellowships at the University of Zurich, which are funded by the Werner Siemens Foundation. Since the establishment of the programme in 2018, seven Fellows with high-potential ideas have embarked on the path to entrepreneurship.

The road from lab to market is long and steep, and researcher Yannick Devaud is not even officially off the starting blocks. “Before I establish a company and start seeking investors, I have to prove that my method actually works,” he says.

Yannick Devaud has developed a medical procedure that uses a type of sticking plaster to protect the amniotic sac of pregnant women after fetoscopic interventions. If the amniotic sac is damaged—which is a common occurrence during such operations—preterm delivery often results, and survival rates are low. That is something Devaud wants to change. “I want to save those babies,” he says.

The 31-year-old biotechnologist will, however, need considerable patience to reach his goal. It can take up to 10 years for a start-up firm in medical technology to produce a marketable product—mainly due to the long and complex regulatory procedures. It is a marathon that demands not only great perseverance, but also a good deal of money and support. And that is the exact purpose of the MedTechEntrepreneur Fellowship at the University of Zurich (UZH), which the Werner Siemens Foundation is funding in its first 10 years (2018 to 2027).

First tests on sheep

One of the first two Fellows in the programme, Yannick Devaud received a grant of 150 000 Swiss francs in 2018 and also benefits from the infrastructure, coaching and networks that are open to all Fellows. With this support, he has been able to further develop his medical procedure while also establishing contacts in the industry, working on his business plan and, mainly, preparing the first experiments. In July 2019, he reached an important milestone: he tested his procedure on sheep for the first time. “The initial results are promising,” says Devaud. But because the sticking plaster must protect the amniotic sac of the patient for the duration of pregnancy, the long-term results are critical for the project’s success.

Competitive

In early 2019, Devaud received additional support from the private funding organisation Venture Kick. This sum adds 50 000 Swiss francs to his start-up capital, and another 100 000 Swiss francs could potentially follow. For Professor Michael Schaepman, Vice President Research at the University of Zurich and head of the MedTechEntrepreneur Fellowships, the additional award is a good sign. “When our Fellows are supported by other funding programmes, it shows that we are selecting first-rate projects that are competitive at an international level,” he says.

Wanted: high-potential ventures

The MedTechEntrepreneur Fellowships are awarded twice a year by a jury of experts from academia and industry. Since the programme was launched in 2018, 15 applications have been received, and funding has been awarded to 7 projects. The number of applications is gradually increasing, but Michael Schaepman emphasises that the quality and not the quantity of the projects is what counts. “What matters is how many of the proposed projects contain viable ideas. And in this respect, we can be very happy,” he says. The funded projects cover a broad range of topics and disciplines—from a computer vision technology that supports artificial respiration to a quick test for antibiotic resistance and a new technology for refrigerating lab samples.

Offices and labs

One year after the launch of the MedTechEntrepreneur Fellowships programme, the Life Science Incubator Lab at the Schlieren Campus of the University of Zurich is also up and running. The facility comprises offices as well as dedicated labs for biotech and medtech experiments. Michael Schaepman confirms that three Fellows have already taken up quarters in the building; the young entrepreneurs are also free to use the facilities belonging to the Institute for Regenerative Medicine (IREM), although this is not a requirement. Indeed, the Fellows themselves are responsible for deciding how to develop their projects. Schaepman compares the support given by UZH with Switzerland’s network of hiking paths. “We set up the yellow signposts, but the Fellows have to choose and then walk their own route,” he says.

Next milestone: company formation

Yannick Devaud, who wants to protect unborn babies with his medical procedure, is now approaching a fork in his entrepreneurial road: if the long-term results of his experiments are successful, founding a company is the next step. “It will be a challenge to find the right people for the team,” he says. If everything works out, his firm, probably named KOVE, should be able to start up in early 2020. Nonetheless, Devaud has already learned to be prepared for the unexpected. “In order to collect enough data, I’m dependent on the sheep actually mating,” he says with a laugh, “so some things are totally beyond my control.”

Funding from the Werner Siemens Foundation

10.67 million Swiss francs over a period of 10 years

Project leader

Prof. Dr Michael Schaepman, Vice President Research, University of Zurich

Project duration

2018 to 2027

The outstanding young academics who were awarded an Excellence Fellowship from the Werner Siemens Foundation enjoy the opportunity to exchange ideas and broaden their horizons—here on an excursion to an innovative infrastructure project in Zurich.

Brilliant minds

Update: Werner Siemens Fellowships to foster talent in STEM subjects

In mathematics, IT, the natural sciences and technology, there is an ongoing shortage of highly qualified professionals capable of filling key positions in society and developing innovative solutions to the challenges of our time. That is why the Werner Siemens Foundation supports the Swiss Study Foundation and its programme to foster talent in STEM subjects.

The Swiss Study Foundation uses the funding provided by the Werner Siemens Foundation in a variety of ways. In particular, it awards 10 annual grants for excellence—the Werner Siemens Fellowships—to outstanding students in mathematics, IT, the natural sciences, technology, medicine and pharmaceutics. The recipients of the Werner Siemens Fellowships not only excel in their discipline—they are also committed citizens with an interest in key societal issues in their areas of expertise.

Werner Siemens Fellowship

Each Werner Siemens Fellow receives a one-year grant of 19 800 Swiss francs and the opportunity to take part in the broad educational programme of the Swiss Study Foundation. The Swiss Study Foundation also fosters exchange between the Werner Siemens Fellows and students from other disciplines and organises networking opportunities with experts in STEM subjects. In 2019, 11 past and present Werner Siemens Fellows visited the Hunziker-Areal in the Leutschenbach neighbourhood of Zurich, the site of an innovative infrastructure project.

Mobility, infrastructure and innovation

At the Hunziker-Areal, the Werner Siemens Fellows learned how a derelict industrial and business park on Zurich's northern periphery was transformed into an attractive neighbourhood that integrates living, working and leisure spaces. The complex—distributed over four hectares—was designed with flexibility in mind and can be adapted to the changing needs of the residents.

The Hunziker-Areal was chosen for the outing because it is well-suited to the concepts of the Swiss Study Foundation programme for mobility, infrastructure and innovation, which is also supported by the Werner Siemens Foundation. Over the course of the year, the Swiss Study Foundation organises educational and networking events on these three key topics for talented students from throughout Switzerland.

Summer academies in southern Switzerland

The three annual summer academies in Magliaso, Ticino, also receive funding from the Werner Siemens Foundation. The summer schools are a highlight for the selected students: at the beautiful campus on the idyllic shores of Lake Lugano, they work in interdisciplinary groups for an entire week on topics that interest them, but for which they have no time during the university semester.

The 2019 Fellows

In July 2019, for the fourth time, 10 Werner Siemens Fellowships were awarded to outstanding students in the STEM subjects. One of these students is Eliane Röösli from Cham in Canton Zug, who is studying at the Swiss Federal Institute of Technology Lausanne for a master's degree in life science engineering with a minor in management, technology and entrepreneurship. Eliane Röösli is delighted with the award: "The Werner Siemens Fellowship gives me the freedom to focus entirely on my studies and realise new, fascinating projects. In addition, the chance to share ideas and experiences with the other Fellows is very rewarding and inspiring. I am thrilled to have the support of the Werner Siemens Foundation."

The Fellows bring a variety of backgrounds and experience to the network—as the two new Werner Siemens Fellows introduced in the following make apparent.

Nina Glaser from the Canton of Bern has always had a strong interest in three STEM subjects—mathematics, physics and chemistry—which is why she decided to study interdisciplinary natural sciences at ETH Zurich. In addition to planning her upcoming studies for a master's degree, she is also committed to action on gender equality and works as a mentor for refugees studying at ETH Zurich.

Pascal Lieberherr from Flawil in Canton St Gallen completed his vocational training as a plant and apparatus constructor. His education included work assignments in China, and after graduation, he went to the United States, where he trained apprentices in Minneapolis. He then earned his Swiss university entrance qualification (Matura). He is now studying mechanical engineering at ETH Zurich. His current projects include research on a robot that can perform agricultural tasks, including environmentally friendly weed-control methods.

The diverse and interesting portraits of the other Werner Siemens Fellows are available on the website of the Swiss Study Foundation.

Funding from the Werner Siemens Foundation

10 Werner Siemens Fellowships of 19 800 Swiss francs per year and Fellow 360 000 Swiss francs annually for the summer academies

Project leaders

Dr Klara Sekanina, director of the Swiss Study Foundation, Zurich
Dr Sarah Beyeler, research associate, Swiss Study Foundation, Zurich

Project duration

2015 to 2025

Who we are

Benefactors with an eye to the future

The daughters of Werner von Siemens: Anna Zanders (left) and Hertha Harries (right). The two sisters made generous donations to the Werner Siemens Foundation, which was established by their cousins Charlotte and Marie in 1923.

The founding capital of the Werner Siemens Foundation was donated by members of the Siemens family. After Charlotte and Marie—the daughters of Carl von Siemens—set up the Foundation in 1923, their cousins Anna and Hertha von Siemens as well as their brother's wife, Eleonore (Nora) Füssli, contributed significant funds. That much is clear, but otherwise very little is known about the original benefactors of the Foundation. Now, however, new publications are shedding light on the lives of the Siemens women.

Two authors—Béatrice Busjan and Yvonne Gross—are researching the lives and works of the Foundation benefactors on behalf of the Werner Siemens Foundation. Béatrice Busjan is a historian and art historian. Author and media specialist (libraries/archives) Yvonne Gross co-authored a book about Eleonore (Nora) Füssli, published in 2018, with Ludwig Scheidegger, the former director of Siemens Switzerland.

Because Nora Füssli (1874–1941) was the last Siemens woman to donate to the Foundation, her life will be portrayed in the 2020 report; this edition introduces the first benefactors of the Foundation, Anna (1858–1939) and Hertha (1870–1939), both daughters of Werner von Siemens. Yvonne Gross and Béatrice Busjan are currently writing the life stories of the two women. In the following conversation, we discuss their work.

Béatrice Busjan and Yvonne Gross, can you tell us why Anna and Hertha decided to donate a considerable amount of money to the Werner Siemens Foundation?

Yvonne Gross: Anna and Hertha were very close to their cousins Charlotte and Marie von Siemens, who set up the Foundation in 1923. After their traumatic experiences in post-revolutionary Russia and being forced to flee their homes, Charlotte and Marie were absolutely determined to provide for future generations of the Siemens family. Anna and Hertha shared this wish.
Béatrice Busjan: Like Charlotte and Marie, Anna and Hertha had a strong sense of family loyalty, but because they had no children, they focused their care-giving energies on their nieces and nephews. The two women also lived through the period of German hyperinflation in the 1920s, and after being widowed at a young age, they were naturally concerned about their own financial security and looked for ways to put their inheritance to good use. That is, in brief, the background of their donations to the Werner Siemens Foundation.

What did you know about Anna and Hertha before you began researching the two women?

Yvonne Gross: I knew that Anna was the oldest daughter of Werner von Siemens and that Hertha was the youngest. Anna married the paper manufacturer Richard Zanders in Bergisch Gladbach, and Hertha married the chemist Carl Dietrich Harries in Berlin. Neither woman had children. From my earlier research, I also knew about Hertha's great interest in art.
Béatrice Busjan: Anna's name has mainly been linked with the "garden city" estate in Bergisch Gladbach that she and her husband built for employees at the Zanders paper factory and that she continued to develop after Richard's death. Hertha, on the other hand, was known for her commitment to social issues within the Siemens company. But it was difficult to say much about their personalities and characters because, until now, no one had conducted serious research into their lives.

What discoveries about Anna and Hertha surprised you the most?

Béatrice Busjan: Hertha's close ties to the artistic and scholarly avant-garde of the early 20th century and her discerning tastes. Future Nobel Prize winners were frequent guests at her home, and she recognised the high quality of works by artists like Vincent van Gogh and Bruno Taut years before this became the general consensus.
Yvonne Gross: Anna's contemporaries describe her as very determined and well able to get her way. Now we've just discovered that, early on, she was coached by an experienced politician who gave her decisive tips. And just looking at her schedule from the year she died shows how much she still planned to do!
Béatrice Busjan: It's also very admirable how Anna and Hertha dealt with personal misfortune and the social upheaval of the day, and how they were always ready to begin anew.

Was it difficult to find information about the women?

Béatrice Busjan: When reading available scholarly literature or contemporary sources like newspapers, it becomes readily apparent that the two women often "disappeared" behind their husbands, meaning that activities attributed to their husbands may have been initiated by Anna or Hertha. This is, of course, typical of the historical era we're dealing with: the second half of the 19th and beginning of the 20th century. That's why it's important to read the contemporary sources against the grain and always question who was actually driving a decision. It was also clear from the start that studying source materials would be essential for a well-documented narrative of the women's lives. So we collected birth and death certificates, baptism records, purchase and share-holding contracts as well as private and business-related documents and correspondence.

Yvonne Gross: These documents are still in possession of the family or stored in public archives. The available sources haven't always been analysed by previous scholars, and in some cases they hadn't even been indexed yet, which was the case with the correspondence between Anna and her godson Werner Ferdinand von Siemens and her letters to her aunt Anne Gordon. Many a time we were the first people in 80 to 100 years to even look at these sources. In such cases, the first job is sorting and deciphering a lot of handwriting.

Where did you find the most information on Anna and Hertha?

Yvonne Gross: Most material stems from the Siemens Historical Institute, where we found many more documents on the two women than we had anticipated when starting our work. When clarifying individual questions, we contacted numerous other archives: the university archives in Berlin and Jena, the city archives of Bergisch Gladbach and Cologne, and the archives of the German states of Lower Saxony and North Rhine-Westphalia. When researching Hertha, we had to conduct searches in Italy, and we discovered quite a bit about Anna in America. In addition, the descendants of the von Siemens, Zanders, Harries and Eckener families also provided key information.

Béatrice Busjan: The letters their father, Werner von Siemens, exchanged with his brothers, especially his correspondence with Carl von Siemens, are an excellent source for the first part of the women's lives. The letters between Werner and Carl are also extremely touching, because the brothers weren't just business partners in an international company, they were also very caring parents who were in constant contact regarding the welfare of their children. This correspondence naturally ended with the death of Werner von Siemens in 1892, but afterwards, the letters Anna and Hertha wrote to their relatives also provide a great deal of information. Yet we found the best source to be the letters the sisters wrote to each other. In this setting, the two are "alone", and they tell each other things that otherwise remained unsaid. For example, Hertha smuggled champagne into a clinic where she was receiving treatment, and Anna was considering uprooting her entire life to support her godson Werner Ferdinand.

Publications

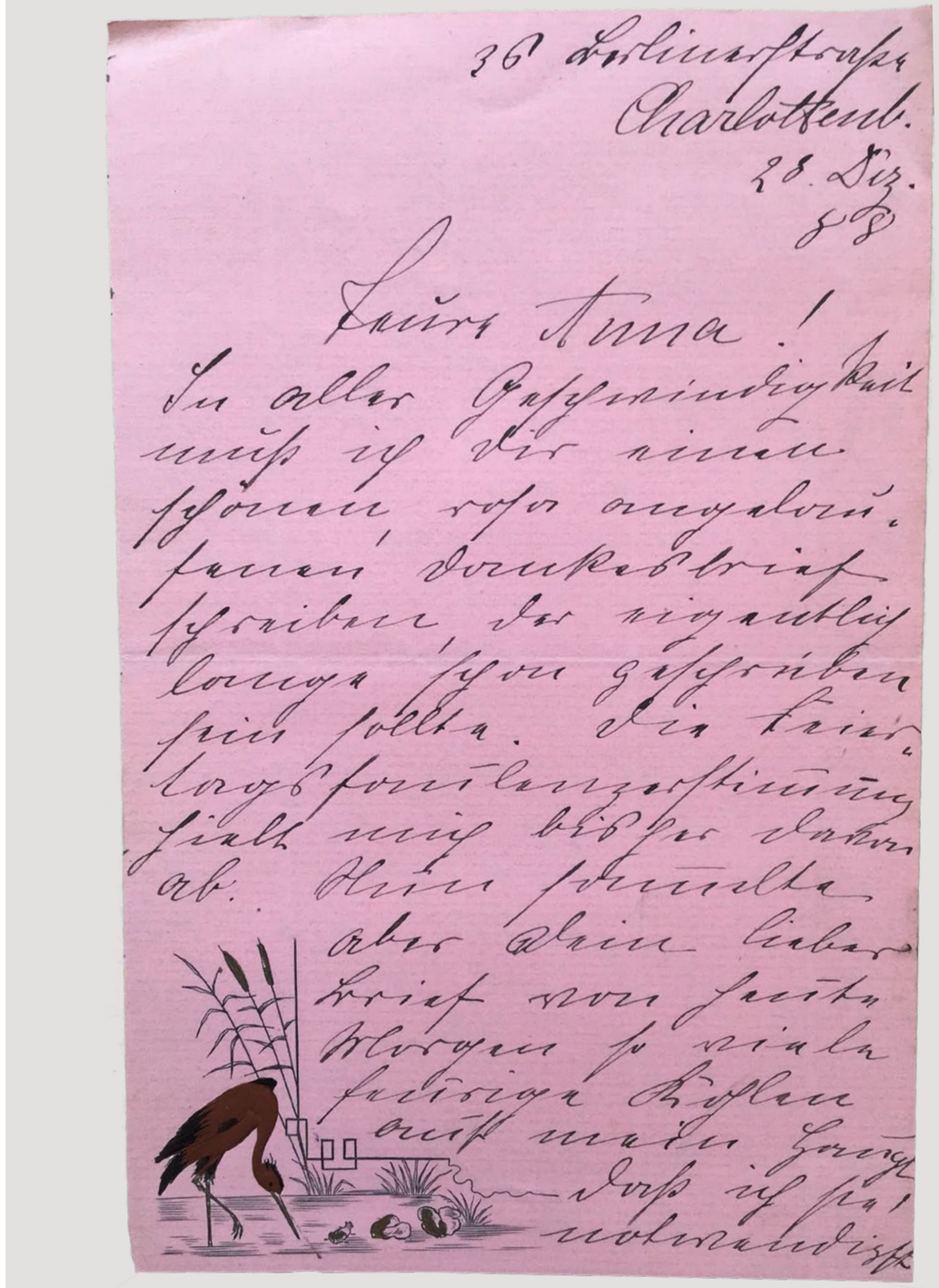
The life stories of Anna von Siemens and Hertha von Siemens, edited by the Werner Siemens Foundation, will be published at the end of 2020 by Thomas Helms Verlag, Schwerin.

Authors

Béatrice Busjan, MA, historian and art historian, director of the agency Geschichte + Kunst in Hamburg
Yvonne Gross, research specialist, media and information services in Berlin

Book on Eleonore (Nora) Füssli

Yvonne Gross and Ludwig Scheidegger: *Nora Füssli*, edited by the Werner Siemens Foundation, Thomas Helms Verlag, Schwerin, 2018



"*My dear Anna! It's in a great hurry that I pen you this pretty pink thank-you note, which I should have done long ago. A wave of holiday laziness has kept me from writing [...]* " The start of a letter Hertha wrote to Anna on 28 December 1888. The two sisters were frequent correspondents, much like their father, Werner, and his brother Carl von Siemens.

Governing bodies

Foundation Board

The Foundation Board oversees the governing bodies of the Werner Siemens Foundation. The Board bears responsibility for the overall management of all Foundation activities and acts as the supervisory body of the Foundation.

Gerd von Brandenstein
Chairman of the Board
Berlin, Germany

Oliver von Seidel
Member of the Board
Düsseldorf, Germany

Dr Christina Ezrahi
Member of the Board
Tel Aviv, Israel

Board of Trustees

The Board of Trustees manages the daily business of the Werner Siemens Foundation in consultation with the Foundation Board and the Advisory Council. The Board of Trustees also acts as the managing body of the Foundation.

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President of the Board of Trustees
Lucerne, Switzerland

Prof. Dr Peter Athanas
Member of the Board of Trustees
Baden, Switzerland

Beat Voegeli
Member of the Board of Trustees
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The Advisory Council of the Werner Siemens Foundation is an independent body that supports the Board of Trustees in finding suitable projects. Council members review and evaluate projects that fall within the mission of the Werner Siemens Foundation.

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ETH Zurich, Switzerland

Prof. Dr Peter Seitz, Member
ETH Zurich, Switzerland

Prof. Dr.-Ing. Matthias Kleiner, Member
President of the Leibniz Association
Berlin, Germany

Prof. Dr Bernd Pichler, Member
University of Tübingen, Germany

Selection process

Funding criteria

Every year, the Werner Siemens Foundation funds up to three groundbreaking projects in the fields of technology and the natural sciences. The projects are generally conducted at higher education institutions in Germany and in Switzerland, and may be in research or teaching. Requirements include upholding the highest standards and contributing to solving key problems of our time.

As a rule, each approved project is awarded generous funding of 5 to 15 million euros. Projects are selected in a series of steps by the Advisory Council, the Board of Trustees and the Foundation Board of the Werner Siemens Foundation.

In addition to projects, the Werner Siemens Foundation funds education programmes and young talent in the STEM subjects.

The Foundation does not support activities in the arts, culture, sports, leisure, politics, disaster relief, permanent projects, commercially oriented projects, project co-sponsoring with other foundations, individual scholarships, costs of studying or doctoral theses.

Project proposals

You are invited to submit a proposal if your project fulfils the funding criteria of the Werner Siemens Foundation. The selection process is as follows:

1 The project must fulfil the funding criteria
2 Application submitted online
3 Preliminary assessment by the Advisory Council
4 Additional information requested, if necessary
5 Proposal evaluation by the Board of Trustees and the Advisory Council
6 Decision
7 Contract

The selection process takes six months.

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Presenting Erika Koller

After 33 years at the Siemens Group, Erika Koller joined the Werner Siemens Foundation as head of administration in February of 2019. During her time at Siemens, she held a total of six positions, working her way up to the general directorate as assistant to former CEO Siegfried Gerlach.

Erika Koller is head of administration at the Werner Siemens Foundation.

You worked from 1985 to 2019 for the Siemens Group. How did you come to join the firm?

Erika Koller: The “Albiswerk”—the predecessor to Siemens-Albis that eventually became Siemens Switzerland—was already part of my childhood. I grew up in Zurich-Albisrieden, and my route to the swimming pool led past the company premises. But I never imagined that I would spend practically my whole career working for Siemens. After completing my commercial training, I first worked in banking. My partner at that time was working for Siemens and was very happy there—and he advised me to apply for a position. At first it was quite a challenge to get to grips with the technical language, which was quite new to me then. But this new world appealed to me, and I was proud when I saw the Siemens logo in public—on the tram, in the train or on a CT scanner.

It's a rare thing these days to work 33 years for the same employer. What kind of a career path did you have at Siemens?

I just worked my way up through the ranks, so to speak. I started out as a secretary and was offered various promotions within the firm. Over the years, I progressed through six different positions and steadily took on more responsibility. My final position was in the general directorate as assistant to Siegfried Gerlach, who was then CEO. There was just simply never any reason for me to change employers. I always worked with pleasant bosses in good teams, and I enjoyed my work very much. It was fascinating to get to know the different divisions of the firm over all those years. I also found it very satisfying to be able to give back to the company—as a member of both the foundation board and the investment commission of the prosperity fund that Siemens Switzerland established for its employees.

You have been running the administrative office of the Werner Siemens Foundation since February 2019. What led you to make this change?

(Laughs.) Hubert Keiber, the President of the Foundation’s Board of Trustees, is a former boss of mine. He’s been responsible for three of the job changes I made in my career. The third time was in spring 2018. He knew that Siegfried Gerlach was going to retire and called to ask if I would like to run the administrative office of the Werner Siemens Foundation. The idea of taking on a new challenge at the age of 57 really appealed to me. And the change takes me back to the roots, in a sense: away from a global firm and back to a small organisation where I take care of all the administrative work myself—all the way down to trips to the post office. Now I can become better acquainted with the Siemens family and the history of the company. I’ve been impressed to discover how the firm’s early founders introduced social improvements such as fixed working hours and health centres. I also enjoy the opportunity the Werner Siemens Foundation gives me to discover a new world—the world of research and science. To be able to support so many valuable projects from such different disciplines is a wonderful job. To name just one example: the project with the *Eugen Seibold* research vessel especially fascinates me.

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