GLOBE

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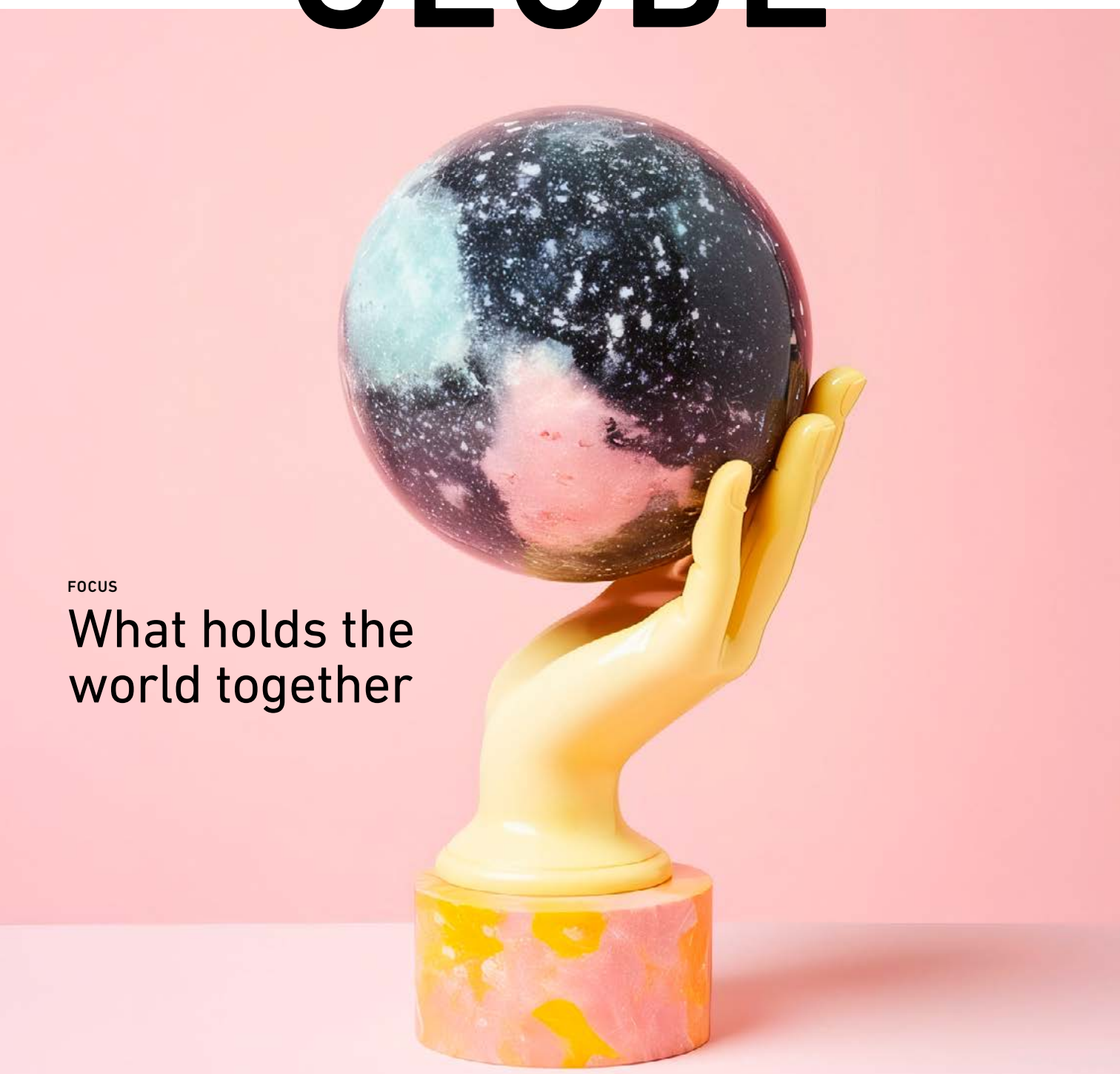

FOCUS

What holds the world together

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EDITORIAL

"The question of what holds the world together keeps resurfacing."

For nearly half a millennium, science has shaped the way we see ourselves and the world around us. New discoveries have continually added to this picture, sometimes leading us to adopt radically new perspectives. Yet one constant remains: human curiosity – and the perennial question of what holds the world together. This question is also the motto of this year's Scientifica, the science festival run jointly by ETH Zurich and the University of Zurich.

To give you a taste of what to expect at September's Scientifica, this issue of *Globe* features a series of fascinating articles that draw on cutting-edge research to answer age-old questions. For example, we ponder why physics is still in search of a theory of everything that would unify quantum mechanics with Einstein's general theory of relativity. Closer to home, researchers discuss the forces that are causing society to drift apart and consider what we can do to heal the rift. And we even offer some food for thought to inspire your next conversation about ChatGPT.

I very much hope you can join us at Scientifica. The science festival runs from 28 August to 2 September and will include a wide variety of activities, ranging from lab tours and presentations to drone racing. You can also find information about other upcoming events in this issue of Globe.

I hope you have a relaxing summer – and I look forward to seeing you at Scientifica!

Joël Mesot,
President of ETH Zurich

Images: Sir Mary / Midjourney; prompt: sculpture of a marble hand holding a dark-milkway-galaxy-sphere on a marble pedestal. hyperrealistic sculptures, pastel colours (cover); Alexandra Compain-Tissier (editorial)

NEW + NOTED

FOCUS

Images: Annick Ramp; Gian Marco Castelberg

COMMUNITY

REPORT

PROFILE

COVER The cover picture and the photo series on "What holds the world together", which starts on page 14, were generated by the digital agency Sir Mary using the AI software Midjourney. None of the images have been altered or retouched.

NEW + NOTED

Image: ETH Foundation / Nicola Pitaro

Siddhartha Mishra, winner of the Rössler Prize, together with award sponsor Max Rössler and ETH Zurich President Joël Mesot (left to right).

Siddhartha Mishra wins the Rössler Prize

Mathematician Siddhartha Mishra has been awarded this year's Rössler Prize for his research into highly complex flow and wave phenomena. The award comes in recognition of his contribution to advances in computer modelling, which have enabled faster and more accurate prediction of weather events, climate patterns and tsunamis.

Two of Mishra's most spectacular breakthroughs came with his work on the Euler equations, named after the Swiss mathematician Leonhard Euler. Firstly, in suggesting a new algorithm for an approximation method, he settled a question that had remained unresolved for 30 years. Secondly, he developed a new approach to certain Euler equations that enables a more precise characterisation of the dynamics of unstable, chaotic and turbulent flow phenomena.

The award of the Rössler Prize also recognises Mishra's success in bridging the gap between fundamental mathematics and its application in research and industry. His achievements include the design of robust and efficient algorithms that enable faster and more accurate supercomputer modelling of nonlinear partial differential equations. These simulations offer new ways of solving real-world problems in research areas such as astrophysics, solar physics, geophysics, climate dynamics and biology.

The Rössler Prize is worth 200,000 Swiss francs, making it the most richly endowed research award at ETH Zurich. It is conferred annually at the ETH Zurich Foundation's thanksgiving event. Prize donor Max Rössler studied mathematics at ETH Zurich and completed a doctorate on orbit calculations for space travel. ○

Spy in the abdomen

One of the chief dangers following surgery to the stomach or intestines is when the contents of the digestive tract leak through the stitches and seep into the abdominal cavity, potentially leading to fatal complications. To counter this threat, a team led by Inge Herrmann, Professor of Nanoparticulate Systems at ETH Zurich and a researcher at Empa in St. Gallen, has joined forces with Andrea Schlegel, a surgeon at the University Hospital Zurich. In an initial development, the group produced a plaster made of polymers that form an absorbent hydrogel. These polymers cross-link with the intestinal tissue to form a patch that seals the wound and thereby prevents gastric acid and germ-laden food residues from leaking out of the digestive tract and triggering peritonitis or even a life-threatening case of blood poisoning.

Now the researchers have gone one step further and equipped the patch with non-electronic sensors that detect when gastric juices are about to leak into the abdominal cavity. Incorporated in the patch itself, these are proteins or salts that react either to changes in pH caused by escaping gastric acid or to certain enzymes present in the intestine. If the sensor elements come into contact with gastric juices, their structure changes – a modification that can then be detected from outside the body by means of biomedical imaging.

As such, this intestinal patch might not only reduce the risk of complications following abdominal surgery but also shorten hospital stays and thereby cut healthcare costs. With the project already sparking major interest in the medical profession, the next step is to advance its application in everyday clinical practice. ○

Robot team for lunar mission

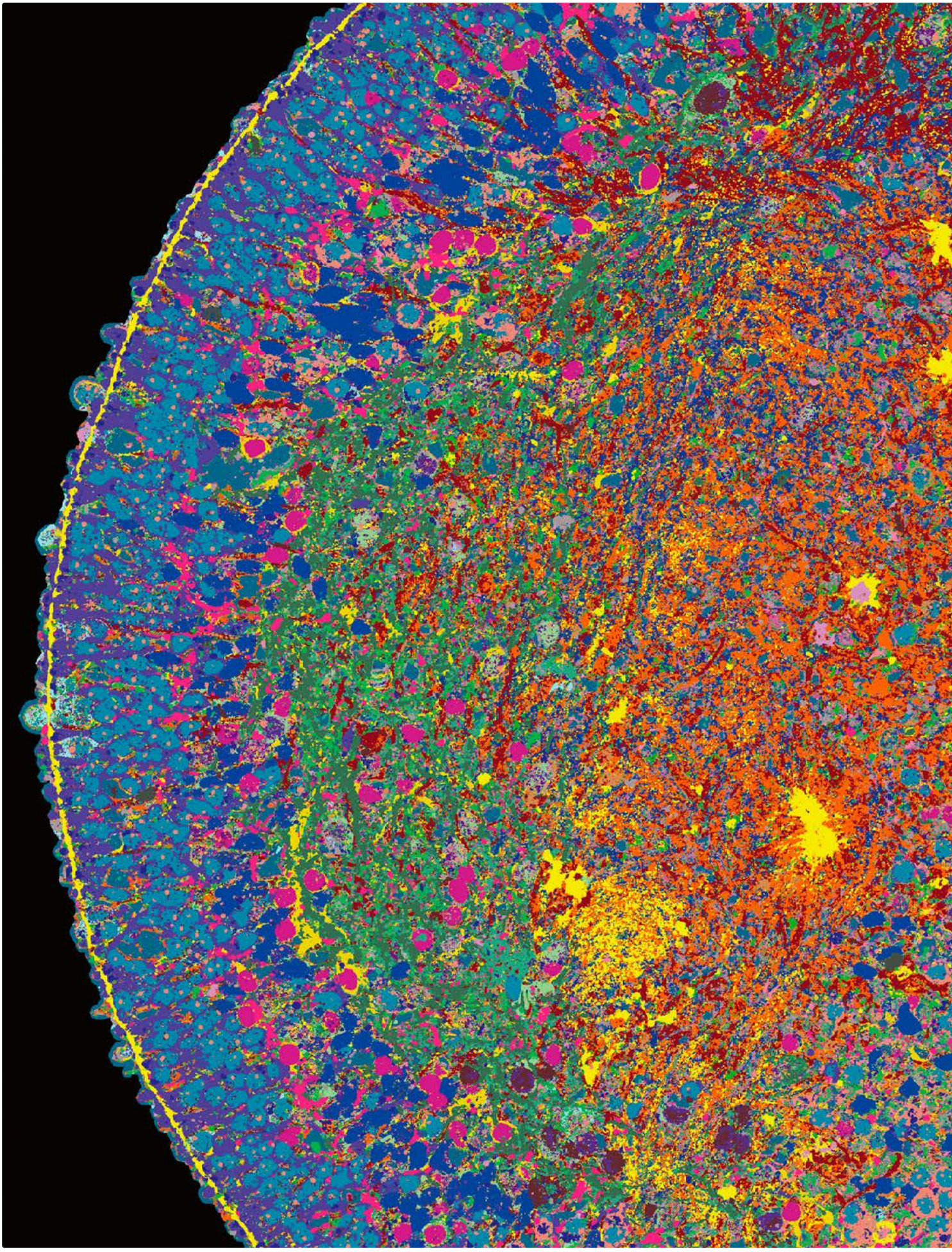
Tempted by a treasure trove of raw materials, a number of space agencies are already planning missions to the Moon in search of minerals. A Swiss research team led by ETH Zurich is now exploring the idea of sending an entire team of robots, comprising both surface vehicles and drones. This has a number of advantages: firstly, a team of specialised robots can perform individual tasks simultaneously; secondly, inbuilt redundancy means that the failure of an individual robot can be compensated for by another member of the team.

The potential team includes three ANYmal robots, a four-legged robot originally developed at ETH by Marco Hutter and his group. Equipped with various measuring and analytic instruments, this trio was recently tested on a range of terrain in Switzerland and at the European Space Resources Innovation Centre (ESRIC) in Luxembourg. It was at ESRIC that the Swiss team won a lunar rover competition, together with colleagues from Germany. The robots had to detect and identify minerals on a test site modelled on the surface of the Moon. ○

Image: ETH Zurich / Takahiro Miki

The power of teamwork: a trio of robots on legs undergoes testing in a Swiss gravel quarry.

Video of the robot team:
→ youtu.be/KbulE0_owO0



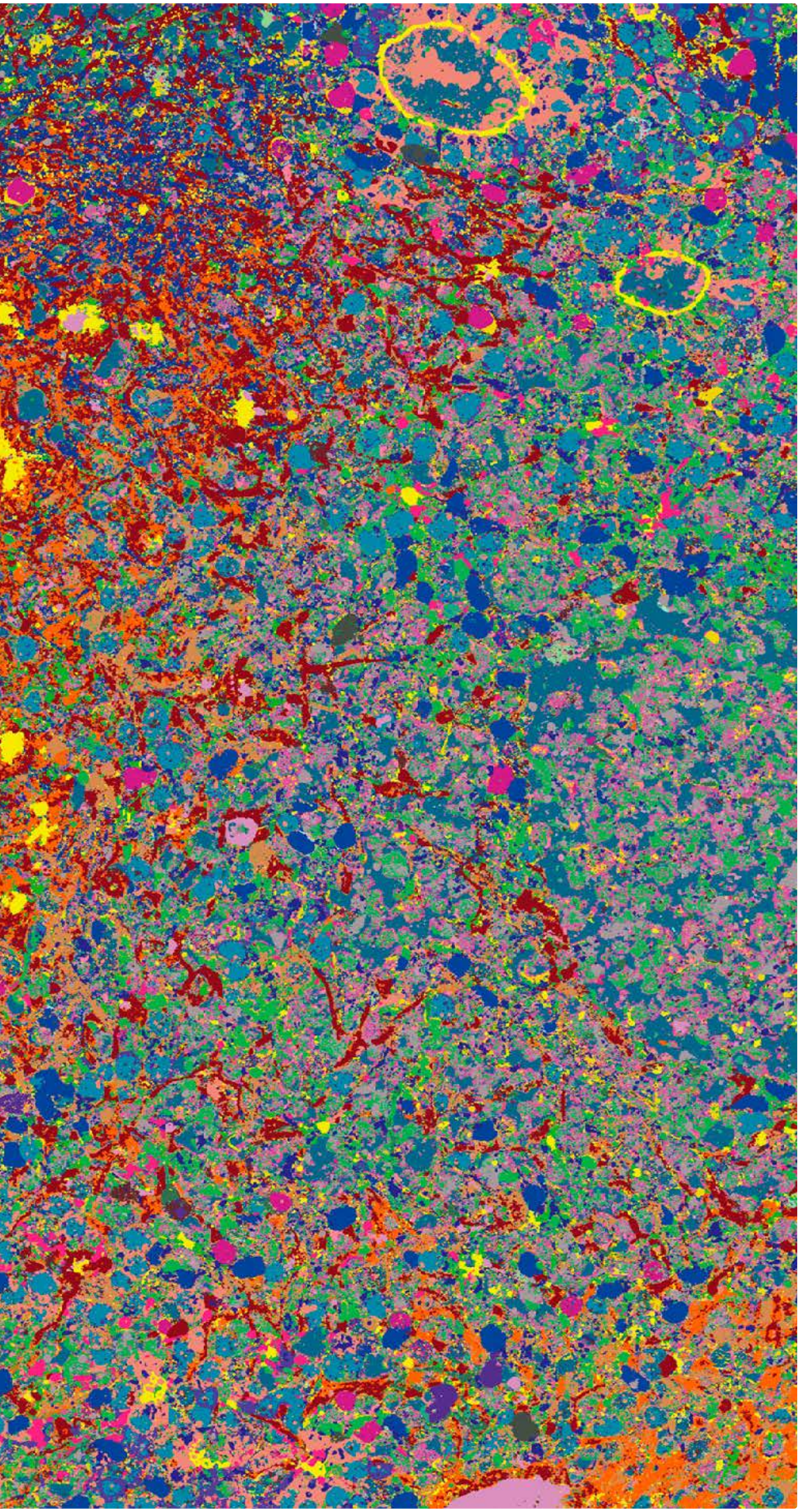


Image: Wahle et al., Nature Biotechnology, 2023

Eye-catching images

This might look like abstract art, but it's actually a detailed picture of the human retina. Using a new imaging method, researchers have been able to visualise over 50 proteins in one single image of retinal tissue. To achieve this, a thin section of tissue was stained with fluorescent dyes and imaged using fluorescence microscopy. This process was repeated multiple times on the same tissue section with different dyes. A computer then amalgamated the results into a single microscopy image. This is the first time researchers have used this process to image 3D tissue structures cultivated in the lab. Visualisation of these structures, which are known as organoids, offers an insight into how individual cell types function. In this project, the researchers worked with organoids of different ages in order to investigate how the various cell types in the retina form during embryonic development. In collaboration with researchers from the Universities of Zurich and Basel, Barbara Treutlein, Professor of Quantitative Developmental Biology at the Department of Biosystems Science and Engineering at ETH Zurich in Basel, now plans to collate this information in a special atlas and make it publicly accessible. It is hoped that this atlas will improve our understanding of degenerative eye diseases and ultimately help halt their progression. ○

→ bsse.ethz.ch/qdb

Switzerland needs a renewables-based energy system

Gabriela Hug, an expert in power transmission networks, argues that Switzerland's efforts to secure an affordable energy supply from renewable sources are both sensible and doable.

GABRIELA HUG is a professor at the Power Systems Laboratory and chair of the managing board of the Energy Science Center at ETH Zurich.

Switzerland has everything it needs to make the transition to a sustainable, secure and affordable energy supply: advanced infrastructure, capital resources, world-leading universities and traditional craftsmanship. What's needed now is the social and political will to make it happen.

The Paris Agreement requires the Swiss government to reduce its greenhouse-gas emissions to net zero by 2050. At ETH Zurich, 15 energy experts decided to join forces to analyse the security of Switzerland's energy supply in a carbon-neutral future, based on current scientific research. Our report came to a clear conclusion: transforming Switzerland's energy system to reach net zero is technically feasible and can be achieved at a reasonable cost, possibly even with cost savings. This is conditional, however, on Switzerland rapidly expanding renewable electricity generation and maintaining the ability to efficiently trade power with the EU. The electrification of heating and transport can and must take place in parallel to this expansion of renewable energy sources.

DOABLE, BUT CHALLENGING Yet putting this strategy into practice won't be easy. Electricity use will increase significantly over time due to the electrification of the building and transport sectors, with demand expected to rise from the current level of 60 terawatt hours (TWh) to at least 80 TWh. At the same time, however, efficiency gains will lead to a large drop in overall energy demand. One of the key benefits of this will be a decline in Switzerland's dependence on fossil-fuel imports.

Even if Switzerland's energy system remained unchanged, considerable investment would still be needed over the decades ahead. Extending the operating life of Switzerland's existing nuclear power plants could be a useful stopgap solution. But there's also a clear and pressing need to make major new investments in domestic electricity production. This should include the installation of PV systems on buildings and, ideally, in Alpine regions, as well as the expansion of hydropower. Additional wind capacity would also be helpful, especially in the winter months.

TRADE IS CRUCIAL Switzerland now needs to come up with sensible compromises on landscape and biodiversity conservation: capacity must be increased, but this should ideally be guided by social considerations and experience with pilot plants. Reducing end-user energy consumption is also important, whether through better insulation, smarter energy use in buildings, more efficient transport management or increasingly sustainable forms of

mobility. Politics and society must debate these options now to ensure that whatever solutions are decided upon are quickly put into practice.

Some challenges still lie ahead. For example, electrification is not feasible in certain applications such as long-haul heavy-duty transport and air travel. What's more, seasonal discrepancies in electricity production will need to be carefully balanced. This will be made possible by seasonal storage – whether in the form of hydro, heat or chemical energy carriers such as hydrogen and biomethane – as well as through efficient electricity trade with neighbouring countries. This was already the case in previous decades.

One of the biggest benefits of electricity trade is the ability to leverage synergies: Europe is installing large numbers of wind turbines, which generate more power in winter months, while Switzerland has significant hydropower and photovoltaic capacities that produce large amounts of power in the summer. The availability of production and usage data will play a major role in enabling smart grid solutions and promoting grid stabilisation.

Different countries may have different resources, but they often face similar challenges. Switzerland has a unique opportunity not only to apply its innovative capabilities to its domestic energy transition, but also to export its technologies, expertise and experience to Europe and beyond. ○

Read more blogposts at:
⟶ ethz.ch/zukunftsblog-en

Gabriela Hug wrote this article in collaboration with Christian Schaffner, Executive Director of the ESC.

Combined with existing infrastructure, alpine photovoltaics could play a major role in Switzerland's energy transition. Pictured: the Muttsee dam in 2021.

Images: ETH Zurich / Giulia Marthaler; Keystone / Gian Ehrenzeller

Timber tests in the fire simulator

Image: ETH Zurich / Michael Steiner

The fire simulator tests timber components used in buildings.

House fires develop in different ways. Once a flammable material catches fire, the temperature rises, and the fire grows and spreads. But what happens next depends on various factors, including the size of the space, the fire load, and the temperature and oxygen level in the area of the fire.

To investigate how timber structures behave in different fire scenarios, ETH Zurich recently acquired a new oven for its Institute of Structural Engineering in the Department of Civil, Environmental and Geomatic Engineering. Purpose-built for fire simulations, the oven features a combustion chamber that is 1 metre high, 1 metre wide and around 1.7 metres long. It is fitted with ten gas burners that can heat the oven to over 1,400 degrees Celsius. Several cameras positioned outside the combustion chamber record the tests, and researchers can also analyse the composition of the combustion gases.

Switzerland is currently enjoying a boom in timber construction. A renewable and carbon-neutral resource, wood is also widely regarded as a safe building material: during a fire, steel beams can deform and become unstable, whereas timber constructions may retain their structural integrity for longer. This research by ETH professor Andrea Frangi and his team should help expand the use of modern timber construction. ○

Video of fire simulator:
⟶ youtu.be/LWoyvl_e-3A

Why there are no kangaroos in Bali

Image: Adobe Stock

The red kangaroo (*Macropus rufus*) is well adapted to Australia's dry conditions.

Australia is home to numerous marsupial species, such as kangaroos and koalas. Interestingly, their numbers decline the further west you go. Similarly, Australia lacks many of the mammals typically found in Asia, such as bears, tigers and rhinos.

Biodiversity researchers have long been fascinated by this abrupt shift in animal species along the Wallace Line. Recently, a research team led by Loïc Pellissier, Professor of Ecosystems and Landscape Evolution at ETH Zurich, decided to investigate how this uneven distribution of vertebrates came about and why more species migrated from Asia to Australia than the other way around. Using a newly developed model, they found that the distribution pattern was heavily influenced not only by plate tectonics but also by the climate in the species' region of origin. ○

Why urea may have been the gateway to life

Researchers from ETH Zurich and the University of Geneva have developed a new method that allows them to observe chemical reactions in liquids at an extremely high temporal resolution.

Using their new method, the researchers were able to gain insights into the processes that led to the emergence of life on Earth. Many scientists believe that urea played a pivotal role in forming the building blocks of life. Current theories suggest that urea may have become enriched in warm pools of liquid – commonly referred to as primordial soup – on the then lifeless Earth. As the water in this soup evaporated, the concentration of urea increased. Exposure to ionising radiation such as cosmic rays may then have caused the concentrated urea to form malonic acid over multiple synthesis steps, which in turn could have served as the building blocks for RNA and DNA.

Using their new method, the team from ETH Zurich and the University of Geneva took a closer look at the first step of this long series of chemical reactions by examining how a concentrated urea solution reacts when exposed to ionising radiation. Their results revealed the formation of urea radicals that are highly reactive and very likely to react with other molecules, potentially forming malonic acid. The researchers also showed that the resulting transfer of a hydrogen atom happens extremely quickly, taking only around 150 femtoseconds, or 150 quadrillionths of a second. This explains why concentrated urea solutions produce urea radicals rather than hosting other reactions that would produce different molecules.

ETH professor Hans Jakob Wörner and his colleagues now plan to investigate the subsequent steps leading to the formation of malonic acid and thereby improve our understanding of the origin of life on Earth. Their newly developed method can also be applied more generally to determine the precise temporal sequences of chemical reactions in liquids. Such reactions include not only all the biochemical processes that occur in the human body but also many types of chemical synthesis that are relevant to industry. ○

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Prompt: sculpture of a head-computer-chip on a marble pedestal, hyperrealistic sculptures, pastel colours.

BEING HUMAN

FOCUS | With its ability to write text and generate images, artificial intelligence is making inroads into many areas of life. Perceived as threatening, enriching or just plain gimmicky, AI also raises a fundamental question: what is it that makes us human?

TEXT Corinne Johannssen
IMAGE SERIES The AI software Midjourney generated culptures based on text prompts (see captions).

"What holds the world together" is the title of this issue's series of images, all of which were generated by artificial intelligence, or AI. Using the software tool Midjourney, we transformed text prompts into photographs – with astonishing results. The sculptures depicted on these pages of *Globe* don't exist in reality; the software simply selected an arrangement of pixels that would give the impression of a three-dimensional object. True to its name, generative AI has created something that would not exist without it.

Various software programmes are now capable of generating text or holding conversations with people via chatbots. The best-known of these is ChatGPT. Developed by the US company OpenAI, it communicates using natural-language text generated by AI – and its rise has been nothing short of meteoric. The app crossed the 100-million-user mark in under two months. That's a milestone that took Facebook more than four years to reach – or 75 years in the case of the analogue telephone. Google is now keen to follow suit with its recently released chatbot, Bard.

Criticism of ChatGPT wasn't long in coming. Lawsuits have been filed alleging that the use of data to train the underlying large language models infringes copyright law. Critics also point out the difficulty of knowing whether ChatGPT's output is correct when no sources are cited and there is no way of knowing how the chatbot reached its conclusions.

QUESTION OF ACCOUNTABILITY This is a topic close to the heart of ETH professor Gudela Grote. As a work psychologist, she is interested in the question of when a new technology can be reliably integrated in a work process. "Quality assurance requires a technical system to be certified. But that's just about impossible if you have no idea how it generated its results," she says. When humans and machines work together, the question of accountability looms large. "Employees are obviously concerned about the precise extent of their responsibility," she adds. That's true not only for the emerging technology of generative AI but for any form of automation.

Computer science professor Thomas Hofmann is certainly impressed by how fast generative AI is developing. "Although the added value from other forms of automation is probably even greater," he says. Hofmann, whose area of research →

includes language models, agrees that reliability is a thorny issue. Ultimately, all text-based applications share a fundamental weakness: they are based on language models that were trained with a tremendous variety of texts – including fiction.

This makes sense when it comes to learning grammar and spelling. But made-up stories are far from ideal when it comes to factual accuracy. "Language models still can't tell the difference between what's true and what isn't," Hofmann cautions.

A QUESTION OF CHOICE A key concern for Grote is whether people are using a new technology voluntarily as private individuals or whether they are being obliged to do so as employees. As customers, we can choose whether to purchase and use technology giants' products in our private life or not, and companies respond to those choices by improving what they offer. "But as an employee, I'm trapped in a process I don't fully control," says Grote. "I'm faced with whatever technologies my employer has decided to use – and those decisions are rarely made in consultation with staff."

Whether people can work successfully with these new technologies depends on a number of factors. "In my experience, the key is how competent and empowered someone feels," says Grote. For example, those who are less well educated are more likely to worry that their job may be at risk. Equally important is how the company communicates its future technological path. "Employees need a clear idea of how they can adapt and how their employer is going to support them on that journey," says Grote.

Ideally, this process would also address the question of which tasks we regard as fulfilling. Hofmann cites the example of language models that are optimised for programming: "A piece of code that might take me ten hours to write perfectly can be generated by the models in a fraction of a second," he says. That frees up valuable time for other activities. "But if someone used to enjoy spending a full day programming, they're not going to be very happy about that development," he says.

From programming to ChatGPT, language models are making inroads into many areas of society. Grote argues that human language is something quite special. "Spoken language is what makes us unique," she says. "Language is a creative process that expresses thoughts through words." This is the human ability that language models are currently attempting to emulate.

It makes a big difference whether a text has been written by AI or by a human, according to Hofmann: "Whenever we use language, we're also expressing our feelings and experiences. AI doesn't have recourse to that experience, however well written its text may be." During his studies, he also became interested in philosophy and now wonders whether intelligence and being necessarily need to be tied to a biological substrate. Ultimately, he says, it's a question of where we draw the line between artificial intelligence and being human. ○

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Scientifica 2023

Das Spital der Zukunft: Künstliche Intelligenz statt menschlicher Pflege? Panel discussion (in DE).

How artificial intelligence becomes trustworthy. Exhibition stand. AI Center, ETH.

Experience robots and artificial intelligence up close. Exhibition stand. Soft Robotics Lab, ETH.

A CHANGE OF PERSPECTIVE

Strategy games developed by ETH ecologists bring different stakeholders to the table. By shifting people's perspectives, they create a win-win situation for environmental protection.

TEXT Stéphanie Hegelbach

The CHN building on the ETH Zentrum campus is generally a hive of activity, with researchers writing papers and students working on assignments between lectures. Equally buzzing is the basement of the Department of Environmental System Sciences, where some 50 young bumblebee queens are busy establishing new colonies in a climate chamber. On hand to monitor this process is Sarah Richman, an ecologist from the Plant Ecology group led by Janneke Hille Ris Lambers.

Richman hopes the bumblebees will provide clues about how a changing climate is affecting interactions between species – in this case, between plants and their pollinators. Her plan is to simulate global warming by settling the colonies at different altitudes in the mountains and then tracking their fitness and feeding behaviour. In a warming climate, the flowering period of plants often falls out of sync with their natural pollinators – a phenomenon known as temporal mismatch. "Communities that are more diverse are more resilient to these kinds of negative effects," says Richman. "The problem is that biodiversity – like so many other things – is in crisis."

Biodiversity refers to the variety of living organisms at the level of ecosystems, species and genes. Together with abiotic environmental factors such as water, temperature and light, it forms the basis of our ecosystems. "All ecosystems – from the smallest creatures to the global biosphere – are shaped by species and the interactions between them," says Jaboury Ghazoul, Professor of Ecosystem Management.

Depending on their scale and frequency, human activities can have a significant impact on the dynamics of these biological systems. Yet the resilience of ecosystems is astonishingly high. "It was only recently that we discovered that tropical systems – which were previously regarded as particularly fragile – are actually incredibly resilient to disruption," says Ghazoul. Even after severe degradation, many tropical forests can regrow within 100 to 150 years, provided some forest patches remain. Most of the biodiversity, soil organisms and nutrient cycles also recover during this time.

THE IMPACT OF SPECIES LOSS Nonetheless, scientists remain particularly concerned about long-term global impacts such as climate change. "We simply don't know the extent to which species and communities can adapt and recover," says Ghazoul. He suspects that, in some cases, new ecosystems will emerge with a different mix of species. But he argues that we have already lost many important and interesting ecosystems, and that the number of these losses will continue to increase.

"There are certain species that some people won't care about losing – or won't notice when they're gone," says Ghazoul. "But we should be looking at this as a system." Biodiversity loss has far-reaching consequences: as species disappear, ecosystem functions degrade. Soil quality may be affected, leading to erosion and nutrient loss. This, in turn, can transform entire river systems, reshaping the habitat of fish and invertebrates. Silt accumulates in rivers and is washed into the ocean, where it smothers and kills coral reefs, while the influx of nutrients encourages the growth of algae. This depletes fish stocks, thus impacting the livelihood of many coastal dwellers. But how much are we willing to support species conservation if it ⟶

Prompt: sculpture of massive biodiversity on a pedestal, hyperrealistic sculptures, pastel colours.

means giving up other benefits? From agriculture and energy production to the infrastructure that improves our quality of life, every decision we make has an impact on the environment. And each of us has our own picture of what the future should look like. "We need to recognise that everyone's values are equally legitimate, even when they conflict with each other," says Ghazoul. "As a society, the only way we can negotiate compromises is by showing mutual respect and acknowledging the validity of alternative viewpoints."

This is the focus of Ghazoul's work: together with his research group, he develops science-based strategy games that bring different stakeholders to the table. Players are asked to find common goals that take biodiversity and environmental protection into account. "It's pointless talking about species conservation if that isn't even on the other party's radar," says Ghazoul. "What we need to do instead is to pinpoint aspects of the system that are of interest to all stakeholders, such as producing healthy food."

ALL PLAYERS ARE EQUAL The strategy games developed by Ghazoul's group may seem like simple board games, but they still manage to reflect the complex dynamics of whatever socio-economic system they are designed to represent. Key decision-makers and stakeholders are invited to play out a variety of future scenarios. The game format eliminates power imbalances, allowing all the participants to discuss the issues on equal footing – from the farmer and the head of the local water company to the CEO and the politician.

This seemingly offbeat approach has a number of advantages: "For one thing, we can draw on players' local knowledge and practical experience to assess and improve our model," says Ghazoul. And his method also offers opportunities to build trust between environmental activists, scientists and practitioners. "If we're serious about protecting species, we need to build bridges between the people making key decisions," he says.

Games do a great job of highlighting this mutual dependency while also showing how action to foster biodiversity can have downsides that shouldn't be ignored. For example, if a landowner in India improves biodiversity in their forest in order to encourage ecotourism, this may have a negative impact on a neighbouring coffee farm. With more snakes, scorpions and spiders spilling out of the forest, plantation workers may be unwilling to harvest crops, or demand higher wages for doing so. "As the game progresses, these kinds of unexpected consequences provide useful input for political or management decisions," says Ghazoul.

One of the advantages of the game format is that it allows players to view issues from a different perspective. As part of his six-year project on sustainable palm oil production in the tropics, which was funded by the Swiss National Science Foundation (SNSF) and the Swiss Agency for Development and Cooperation (SDC), Ghazoul worked with the governments of Indonesia, Colombia and Cameroon, encouraging politicians to take on the role of smallholders. "One minister told me he had learned more in a single day than during his entire ten years on the palm oil committee," Ghazoul recalls proudly.

So what can we do to improve species protection? First, we need to know how ecosystems work and how they respond to external influences. "Two things are essential if we want to get the full picture: experimental field studies of species-specific responses, such as those of bumblebees, plus analysis of global data sets," Richman. But what's equally important, says Ghazoul, is to understand how people make the decisions that impact biodiversity and greenhouse-gas emissions. ○

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Scientifica 2023

Alpine meadow and forest floor: How species interact. Exhibition stand. Plant Ecology, ETH.

Have we oversimplified our planet? A call for biodiversity. Panel discussion (in English).

A CONTRADICTION

Quantum mechanics describes the forces that hold the world together on the smallest scale. The theory of relativity explains the world at the cosmic level. The two seem incompatible – and a unifying theory is nowhere in sight.

TEXT Christoph Elhardt

Without quantum mechanics, many of the technologies that we take for granted would be inconceivable. These include lasers, electron microscopes and atomic clocks, as well as medical imaging, electronics and semiconductors. It is difficult to think of another scientific theory that has been confirmed so frequently and so consistently since it was first elaborated 100 years ago. Of the four fundamental forces in physics that hold the world together on the atomic and subatomic level, three are based on concepts derived from quantum physics: electromagnetism, which is responsible for everyday phenomena such as light, electricity and magnetism; the strong nuclear force, which binds atoms together; and the weak nuclear force, which causes atomic nuclei to decay.

Yet the fourth fundamental force of physics, gravitation, which holds our universe together and explains the behaviour of planets, is notoriously hard to reconcile with quantum mechanics. This is because quantum mechanics is exceptionally good at explaining the interaction of particles at the atomic and subatomic level, but it rapidly runs into problems when tackling larger objects, which are subject to gravity. "Despite many attempts by luminaries such as Albert Einstein, Richard Feynman and Stephen Hawking, no one has yet been able to explain gravitation in terms of quantum physics," explains Renato Renner, Professor for Theoretical Physics at ETH Zurich. Meanwhile, in the macroscopic world, Albert Einstein's general theory of relativity continues to hold sway – another theory that, like quantum mechanics, has been confirmed by numerous experiments over the past 100 years. Without it, neither GPS devices nor watches would function accurately.

It might seem as if all this slots neatly into place in the world of physics – but, unfortunately, nothing could be further from the truth. The problem is that this description of the atomic and subatomic world doesn't fit in with our picture of the cosmos. As Renner explains: "General relativity is incompatible with the principles of quantum mechanics." For years now, physicists have been dreaming of combining the two theories to produce a unified picture of the physical world.

THE CURVATURE OF SPACE-TIME In 1915, Albert Einstein published his general theory of relativity, which rocked the established view of the physical world. Einstein departed from the received explanation of gravity as a force dependent on the mass of and distance between two planets, as formulated by Isaac Newton almost 200 years earlier. Instead, he introduced a new concept: space-time. "Einstein takes the

AT THE HEART OF PHYSICS

familiar concept of three-dimensional space and fuses it with time to create a four-dimensional mathematical construct. He then explains gravity geometrically in terms of the curvature of space-time," says Renner.

According to this schema, massive objects like planets create a dent in space-time. In turn, the geometry of this dent determines how objects move within the space-time continuum. In simple terms, space-time is like a trampoline upon which a heavy ball then creates a depression. If a tennis ball is placed at the edge of this depression, it will roll down towards the heavy ball. The concept of space-time serves to explain why, for example, clocks run faster on an airplane than back on Earth. Einstein's theory was even able to explain why Mercury has such an eccentric orbit around the Sun.

QUANTUM FUZZINESS Around the same time as Einstein, physicists such as Werner Heisenberg, Nils Bohr and Erwin Schrödinger were doing their best to upset our picture of the atomic and subatomic world. They posited that the realm where electrons, protons and other elementary particles are in constant motion, attracting and repelling one another, is subject to different laws. But whereas Einstein's formulas can be used to calculate the orbit of the planets as precisely as if they were on rails, the objects of the quantum world cannot be described with the same precision. In the microcosm of atoms and particles, there are no such fixed orbits. There, the determinism of classical physics gives way to probabilistic statements. "An electron or proton can be in several places at the same time," explains Professor Anna Soter, who conducts experimental research at the ETH Institute for Particle Physics and Astrophysics. "It is only through the act of measuring them that they acquire a determinate location. Beforehand, the best that we can do is to draw up a probability distribution."

The general theory of relativity makes no provisions for such fuzziness. Were a particle to be in several places at one and the same time, it would no longer be possible to calculate the precise location where it makes a dent in space-time. Nevertheless, it is universally accepted that even the very smallest objects bend space-time and thus influence gravity. After all, they, too, are endowed with mass, just like larger objects. And since the earth is composed of particles, many physicists think it must be possible to incorporate general relativity into quantum mechanics. Yet, to this day, it remains unclear how gravitational force arises from these particles and their irregular movements.

GRAVITY AS INFORMATION Several theories have been proposed to explain gravitation on the basis of quantum physics. These include string theory and loop quantum gravity. A more recent approach, also being pursued at the chair of Professor Renner, is known as "It from Qubit". This theory is based on the premise that the properties of space-time can be described in terms of entangled qubits – the basic unit of information in quantum computing. Unlike Einstein's theory of relativity, this new approach is no longer purely geometrical in nature. Instead, it is based on the sum of qubit entanglements. ⟶

Prompt: sculpture of watch curvature of space-time on a pedestal, hyperrealistic sculptures, pastel colours.

"Contrary to existing theories, ours isn't concerned with what qubits are made of," Renner explains. "What we're interested in is how they are entangled with one another. These entangled qubits correspond to curved space-time in the macroscopic world." For Renner, the search for quantum gravity is primarily about discovering the right patterns of entanglement between qubits. To illustrate this, we might think of space-time as the taut fabric on a trampoline, with each fibre representing a relation between qubits. An indication of how seriously this approach should be taken is that it delivers the same results as other theories when explaining theoretical quantities such as the entropy of black hole radiation.

NEW EXPERIMENTS As Professor Soter explains, the problem today is not a shortage of grand theories but rather a lack of experiments that might provide insight into how gravity affects elementary particles. At present, there is no way of directly testing either It from Qubit or any other of the theories in this field.

Her research has therefore taken another tack. When physicists say that particles have mass and that they should therefore cause a curvature of space-time, they are assuming that the inertial mass of these particles corresponds to their gravitational mass. Inertial mass is a measure of an object's resistance to a change in motion; gravitational mass is a measure of the force that gravity exerts upon an object. The assumption that there is no difference between the two is a key plank of general relativity and is known as the equivalence principle.

For Soter, however, this is by no means proven in the quantum world. "We can certainly measure the inertial mass of atoms, but no one has ever observed a falling particle that consists only of leptons and is therefore not affected by the strong interaction," she explains. She hopes to change this with an experiment that aims to observe whether a horizontal beam of muonium atoms is subject to the pull of gravity and will therefore fall downwards like a jet of water from a garden hose.

If this turns out to be the case, it would be further proof of the need to unify quantum mechanics and general relativity. "But if we discover an anomaly here, and the muonium atoms do not fall as expected, then we have a big problem," she says. This would create a minor sensation in the world of particle physics. Yet it would not be the first time an experiment had caused us to rethink our picture of the physical world. ○

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Vom Versuch, das Grösste mit dem Kleinsten zu vereinen. Short lecture (in DE). R. Renner, Theor. Physics, ETH.

Ein Tanz von Licht und Materie. Short lecture (in DE). Martin Frimmer, Photonics Laboratory, ETH.

Mission Nano-MRI. Short lecture (in DE). Alexander Eichler, Laboratory for Solid State Physics, ETH.

A computer made of light and sound particles. Exhibition stand. Hybrid Quantum Systems, ETH.

MORE RESPECT FOR PEOPLE WHO THINK DIFFERENTLY

Polarisation seems to have increased in recent years, whether between right and left, urban and rural, or the supporters and opponents of vaccination. We talked to two experts about the cracks in society – and the glue that binds us together.

INTERVIEW Vinzenz Greiner und Christoph Elhardt
IMAGE Désirée Good

Open a newspaper, visit a website or switch on the TV, and it's easy to feel that society is more polarised than ever. Is that true?

NADIA MAZOUZ: To start with, I think we need to distinguish between two types of polarisation. Affective polarisation is where individuals or groups show a high level of antipathy towards the members of opposing groups, even to the extent of revelling in their misfortune. Social media has made this form of polarisation not only more visible, but also more common – that's the prevailing view among sociologists as I understand it.

What's the other type of polarisation?

MAZOUZ: Something we call ideological polarisation, which is when all the various attitudes, opinions and values that people have are no longer spread along a continuum but are bunched

Philosopher and physicist Nadia Mazouz and sociologist Christoph Stadtfeld.

up at the extremes. There's some debate about whether this form of polarisation has increased or not. But there are certainly some voices saying that the political middle has shrunk and that the fringes are getting stronger, more outspoken and better organised.

CHRISTOPH STADTFELD: Affective polarisation is also linked to what we call the internet paradox: the World Wide Web was supposed to create a global village square and broaden access to information; yet, far from fulfilling that dream, the internet has become a place where disinformation flourishes and people isolate themselves in echo chambers. I would argue, though, that affective polarisation is not a new phenomenon: social media and other media may have raised its profile in the attention economy, but it also fulfils a basic psychological need that we all share.

Which need is that?

STADTFELD: The feeling of wanting to belong to a group, to divide the world into "us" and "them". In recent years, we've seen a proliferation of specialised niche groups that increasingly regard mainstream politics as their common enemy. Before the internet era, people with unconventional or extreme political viewpoints had little choice but to adapt to the norms of their immediate social environment if they wanted to avoid being completely excluded. But now things are different. People on the fringes can easily find like-minded individuals on the internet to form a group and create a community.

MAZOUZ: Exactly. It's a combination of both processes: the fragmentation of society into different niches and the gradual erosion of moderate positions that mediate between the two ends of ⟶

> "Current events make a farce out of one of the central tenets of the Enlightenment – namely, that people should use their own capacity for reason."
>
> Nadia Mazouz

the political spectrum. Our society has traditionally thrived on dissent, but this new trend is making it more segmented and simultaneously less complex.

That seems counter-intuitive. Surely a more fragmented society would become more complex?

MAZOUZ: Individuals belong to various groups, and these groups are becoming increasingly alike and therefore more homogeneous. The problem comes when certain lifestyles are automatically tied to specific political ideologies; that impoverishes our society and, ultimately, our democratic discourse.

STADTFELD: We sometimes talk about portfolios of identities, ideas and lifestyles. As a sociologist, I find it intriguing that certain portfolios are becoming more dominant, while the overall number of portfolios is shrinking. For example, it's increasingly uncommon that individuals identify as liberal and left-leaning, while holding conservative views on family issues. In other words, people's lifestyles are becoming more homogenous and more politicised.

Can you give an example?

STADTFELD: One US study found that you can get a fairly good idea of someone's political affiliation from their coffee preferences – essentially by asking them whether they would order a pot of black coffee or a flat white to go. It turns out that the flat-white drinkers are very likely to vote Democrat!

MAZOUZ: These are the kinds of lifestyle choices that people adopt to identify with their own group – and there's a real concern that this sense of identification is getting stronger. For example, if my group tells me that climate change doesn't exist, then I, as a member of the group, will adopt that position. So, we're not only dealing with polarisation, but also with politicisation in the sense of people developing a blind allegiance to their own group.

Is this increasing polarisation also creating new lines of conflict?

MAZOUZ: Yes. Researchers are now seeing a new fracture line that goes beyond the traditional left/right divide – namely, a cleavage between cosmopolitan attitudes and communitarian or even nationalist attitudes.

A disintegrating centre plus increasing fragmentation and the politicisation of lifestyle choices: just how stable is society if we keep splitting into smaller groups?

STADTFELD: Just like any other group, a society needs norms and a narrative to maintain its cohesion and to make people want to be a part of it. For example, Switzerland takes great pride in its ability to solve conflicts through consensus and compromise. The search for compromise is a norm, but it's also part of the shared narrative that holds the country together.

MAZOUZ: What keeps a society stable is a willingness to cooperate. In order to cooperate, we need some idea of how we want to live together. The problem with affective polarisation and fragmentation is that they chip away at the number of people who can actually agree on the basic requirements for coexistence, such as the need for mutual respect. ⟶

> "As a society, we need to create opportunities for people to build relationships that span different groups and communities."
>
> Christoph Stadtfeld

Prompt: sculpture with two faces on a marble pedestal, hyperrealistic sculptures, pastel colours.

That's something politicians often seem to struggle with, too…

STADTFELD: Many of them – those who are on the fringes, for example – obviously have a vested interest in feeding divisions in society.

MAZOUZ: Right. People like that are eager to further undermine whatever mutual respect we have left. But democracy can only thrive if we accept each other as free and equal individuals, and not as enemies. That's why I find the current state of affairs so alarming.

Respect is clearly important. But in the age of "alternative facts", it seems we can't even agree on a common ground for discussion.

MAZOUZ: Current events are making a farce out of one of the central tenets of the Enlightenment – namely, that people should use their own capacity for reason. The reality is that more and more people are getting most of their information from platforms that cast doubt on the very legitimacy of traditional epistemic authorities such as science.

How can we counter this increasing polarisation?

STADTFELD: As a society, we need to create opportunities for people to build relationships that span different groups and communities, because it is these relationships that ultimately give rise to new groups. I'm thinking in particular of housing and education policies that encourage diversity, or sports clubs that bring different people together and get them talking. But any group or institution, however small, can have a positive impact – by encouraging us to engage with others, for example. Here at ETH, I think we should be fostering social networks that include students from every group. Networks like these sometimes emerge when students meet in seminar or mentor groups that are put together at random.

If I, as an individual, want to change my attitude towards people who think differently from me, what specific steps would you recommend?

STADTFELD: Living life with curiosity and without inhibitions. Often, it's only when we talk to people with opposing views that we realise how much we actually have in common. It's also good to develop a thicker skin and not to immediately fly off the handle when someone comes out with an opinion that conflicts with our own.

MAZOUZ: A bit of self-reflection would also be helpful. We may consider ourselves to be cosmopolitan individuals who support diversity and are always open to hearing different opinions, but I've also noticed a tendency to show real disdain for people we think of as intolerant. That, in itself, is a form of affective polarisation. If we really believe that people should stop fuelling division, we need to practice what we preach. ○

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Konflikte in Freundschaften und in der Familie bewältigen. Science Café (in DE). Dept of Psychology, UZH.

How do we consume information in digital times? Exhibition stand. Fög and IKMZ, UZH.

Brennpunkt Monte Verità. Short lecture (in DE). Linda Schädler, Head of the Graphische Sammlung, ETH.

THE STRENGTH OF NATURE'S WEAKEST FORCE

Gravity keeps our feet firmly on the ground and Earth in its orbit around the Sun. Meanwhile, satellites in space measure the acceleration caused by the Earth's gravitational pull.

TEXT Barbara Vonarburg

When a Falcon 9 rocket took off from Vandenberg Space Force Base in California in May 2018, a spellbound Benedikt Soja was there on the ground to see it. Back then, the researcher was employed by NASA, which had joined forces with the German Research Centre for Geosciences (GFZ) to launch two satellites into space. Today, Soja is Assistant Professor of Space Geodesy in the Department of Civil, Environmental and Geomatic Engineering at ETH Zurich, where he and his team analyse data from this satellite pair. "The GRACE Follow-On mission, or GRACE-FO, is designed to map Earth's gravity field with unprecedented accuracy," he says. "With its help, we can track the changing pull of gravity at every point on Earth."

It is gravity that makes objects fall to the ground and holds the Earth at a distance from the Sun that is conducive to life. Yet the pull of Earth's gravity actually varies from place to place: our planet is not a perfect sphere, and areas of greater mass exert a stronger gravitational pull. By measuring gravity, GRACE-FO can therefore determine how mass is distributed around the planet.

KEEPING AN EYE ON CLIMATE CHANGE "We're very interested in tracking changes in Earth's mass distribution," says Soja. "And that's especially true in regard to water, now that climate change is such a major issue." Using satellite measurements, researchers can monitor melting ice sheets in Greenland or Antarctica and dwindling levels of groundwater in parts of California or India. "Even heavy rainfall is enough to cause a perceptible change in the local gravitational field, because you suddenly have all this water accumulating in one place," Soja explains. "We've seen some significant changes in mass redistribution over the recent years due to climate change."

Earth's gravitational field can also be measured from the ground, but only in certain places. "Trying to use ground-based methods to cover the entire planet, including its oceans, would be impossible," explains Soja. That's why measurements taken from space are so important. A satellite's orbit is partly determined by gravity, so Earth's gravitational pull can be calculated by simply determining the precise position of each satellite along its orbit. "This method works, but the results aren't detailed enough for scientific purposes," says Soja. Fortunately, more accurate information is now available from the twin satellites of the GRACE-FO mission, a follow-up to the GRACE pair of satellites that launched in 2002 and have since burned up in Earth's atmosphere. GRACE-FO's twin satellites follow each other in orbit around the Earth, separated by about 220 kilometres. Measuring devices on board each spacecraft constantly monitor the distance between them. As they pass over areas →

of greater mass concentration, the gravity anomaly causes this distance to change. On the previous GRACE mission, a microwave ranging system calculated changes in intersatellite distance with a micrometre-per-second precision. But the follow-on mission has taken this tracking performance to a whole new level: by using a laser ranging interferometer, which uses superimposed light waves of a shorter wavelength, it delivers measurements in the nanometres-per-second range.

ELIMINATING INTERFERENCE However, not all the variations in a satellite's orbit are caused by Earth's gravity field. At an altitude of about 500 kilometres, space is not a perfect vacuum, and satellites are constantly being slowed down by atmospheric particles. Variations in solar wind can also cause changes in orbit. The decision was therefore made to equip the GRACE-FO satellites with accelerometers. "These high-precision measuring devices enable us to determine all the non-gravitational effects, so we can be confident that we're only measuring accelerations caused by gravity," says Soja.

He and his group are investigating the best method of processing data from the accelerometers to ensure all the unwanted signals are removed. Artificial intelligence has proved to be a great help in this context. "Using traditional methods, it's hard to find correlations in huge volumes of data, because you may only have a sketchy knowledge of the physical processes," says Soja. "But methods such as machine learning can spot patterns in data and therefore extract the most important information much more efficiently." The algorithms developed by the ETH researchers have so far yielded results that are up to 20 percent more accurate than those achieved by NASA using conventional methods.The acceleration due to gravity (*g*) is a measure of the strength of Earth's gravity field, while G is the gravitational constant used in Newton's law of universal gravitation. "Big G is the least well-known natural constant," says Jürg Dual, Professor Emeritus of Mechanics at ETH. Scientists have been able to measure the other natural constants, such as the speed of light, with much greater precision. "The problem is that gravity is much weaker than all the other fundamental forces," says Dual. "So it's very difficult to determine the gravitational constant by experimental means."

EXPERIMENTS WITH RESONANCE Working in what was once a military fortress in the Swiss Alps, where they are shielded from noise and variations in temperature, Dual and his research group are developing a new method of measuring the gravitational constant. "Unlike previous experiments, ours relies on a dynamic system rather than a static one," he says. The experimental setup consists of two vacuum chambers that are mechanically isolated from each other. In one chamber, two rods rotate at a defined frequency, causing a beam in the second chamber to vibrate due to the gravitational force. Central to this experiment is the phenomenon of resonance, which amplifies the vibrations to such a degree that they can be measured by a laser interferometer. Drawing on a wealth of theoretical knowledge, the researchers can use these tiny oscillations to calculate the gravitational constant.

Conventional experiments still have the edge in terms of accuracy, but since the first attempts the researchers have been able to increase the precision of their measurements by a significant degree. "This is where it gets exciting, because our dynamic system allows us to explore new kinds of questions that static experiments are unable to answer," says Dual. Contrary to expectations, might there also be some kind of mutual interaction between gravity and the other fundamental forces? And is the generally held assumption that we can't shield gravity actually true? The ETH researchers hope to put this to the test by suspending large metal plates between the two vacuum chambers while leaving everything else unchanged. "If we see any effect, that would be pretty revolutionary," says Dual. Indeed, such a discovery might even require us to rethink some of the models we use to describe the universe and its evolution. ○

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Scientifica 2023

Exploring gravity: mysteries from space. Exhibition stand. Institute of Geodesy and Photogrammetry, ETH.

Prompt: sculpture of an apple, hyperrealistic sculptures, pastel colours.

Image: ETH Zurich

Thomas Zurbuchen took over as head of the ETH Zurich Space initiative in August 2023.

Former NASA science chief joins ETH

Recognised as one of the world's most influential researchers, Thomas Zurbuchen has played a major role in advancing space science. He recently returned home to Switzerland after spending more than 20 years in the US. In August 2023, he took charge of the ETH Zurich Space initiative as Professor of Space Science and Technology. Launched in October 2022, this initiative aims to expand space research and teaching at ETH and to strengthen cooperation with partners from science and industry and with space agencies. "Thomas Zurbuchen's expertise and global network make him the perfect candidate to take the helm," says Vanessa Wood, Vice President for Knowledge Transfer and Corporate Relations.

From 2016 to 2022, Thomas Zurbuchen was Associate Administrator for the Science Mission Directorate at NASA, the US space agency. In his new role, he aims to take space research to the next level, not only at ETH Zurich but also throughout Switzerland and Europe. "The space sector is growing worldwide at a tremendous pace. We're determined to ensure that Switzerland and Europe make the most of these new opportunities, remain competitive and increase their visibility on the international stage. ETH Zurich is the ideal place to turn that vision into reality," Zurbuchen says. His work as an ETH professor will be firmly focused on teaching. Zurbuchen has set himself the challenge of creating a top global interdisciplinary Master's programme in space science and technology in order to provide training for the next generation of space leaders. ○

ETH Zurich takes seventh place in QS rankings

Year after year, ETH Zurich performs strongly in numerous rankings, and the latest Quacquarelli Symonds (QS) World University Rankings show its standing is as strong as ever. ETH Zurich now appears seventh on the list, having risen two places since last year. This confirms the university's top position in continental Europe, based in particular on its outstanding academic reputation and output of scientific publications.

Three additional metrics made their debut in this year's QS rankings, with sustainability, employment outcomes and international research network all appearing for the first time. ETH Zurich gained particularly impressive scores in the second and third of these new categories. ○

Biomedicine benefits from collaboration

ETH Zurich and Roche are to collaborate more closely on two new research and training programmes. Their focus will be the development and application of new bioengineering methods and new human cellular and genetic model systems. The two partners are confident that these cutting-edge technologies will enhance their ability to study, understand and influence the molecular mechanisms of both healthy and diseased human organs.

This collaboration will be based primarily in Basel, home to ETH Zurich's Department of Biosystems Science and Engineering and to Roche's Pharma Research and Early Development unit as well as its new Institute of Human Biology. ○

ETH Alumni Association appoints new president

Image: ETH Alumni Association

Left to right: Hana Disch, Jeannine Pilloud – newly elected president of the ETH Alumni Association – and Felix Graf.

Jeannine Pilloud was elected as the new president of the ETH Alumni Association in May 2023. Pilloud, who studied architecture at ETH Zurich, has served on the association's board since 2021. She holds various positions on boards of directors and advisory bodies both in Switzerland and abroad. She also acts as a consultant and advisor on change processes to a number of organisations. Pilloud replaces Walter Gränicher, a member of the ETH Alumni Association board for the past 12 years, 10 of which were in the role of president.

The board also welcomed two new members: Felix Graf, CEO of NZZ, and Hana Disch, a self-employed consultant. Working closely with the board and the administrative office, Pilloud intends to continue developing the ETH Alumni Association progressively over the next few years. ○

Read the ETH Alumni Association's 2022 annual report:
⟶ ethz.ch/alumni-annualreport

Chemistry Olympiad at ETH Zurich

In July 2023, ETH Zurich hosted the International Chemistry Olympiad (IChO) – the first time the event has ever been held in Switzerland. Open to students aged between 16 and 19 from all over the world, the annual competition requires participants to demonstrate their knowledge of chemistry in a five-hour theoretical examination and put their skills to the test in a five-hour practical. Almost 350 young chemistry aces from around 90 countries took on the challenge, hoping to win one of the coveted medals and learning more about Switzerland and ETH Zurich in the process.

Their efforts were rewarded at the closing ceremony, which was held at the Tonhalle concert hall in Zurich. A total of 217 gold, silver and bronze medals were handed out, while a further 27 candidates received an honourable mention, including Vivian Huber from the canton of Basel-Stadt. ○

Image: ETH Zurich / Luca Ferrari

The 2023 Chemistry Olympiad welcomed almost 350 young participants from around 90 countries.

Image: Fred Merz / Lundi13 / EPFL

ETH President Joël Mesot (right) and EPFL President Martin Vetterli (left) launch a green energy coalition.

Green energy coalition with EPFL

ETH Zurich and EPFL are looking to join forces with partners from politics, science and the private sector to drive the development of innovative storage and transport solutions for renewable energy carriers. The goal is to build a flexible, climate-neutral energy system for Switzerland. Around 20 partners and businesses have already voiced an interest in taking part.

Drawing on innovative technical solutions, the coalition plans to develop new ways of using energy storage to exploit seasonal differences in electricity production in Switzerland and Europe. This will improve Switzerland's security of supply and diversify energy trade with European and international partners, giving rise to new sectors and creating opportunities for tech start-ups and Swiss industry. ○

Adam Aleksander Korczak and Patrycja Kucharczyk, co-founders of the start-up Treeless Pack, in the Student Project House at ETH Zurich.

Upcycling waste, saving trees

TEXT Nicole Davidson, Corinne Johannssen

Pulp is normally produced from wood fibres – but why not use an entirely different source of cellulose? This was the intriguing idea that led Patrycja Kucharczyk and Adam Korczak to found Treeless Pack, a start-up that produces micro-organism-based natural fibres by feeding bacteria on nutrients found in organic waste. Producing cellulose from wood is extremely polluting and energy-intensive. By contrast, Treeless Pack's method helps protect our forests. What's more, thanks to the fully automatable vertical farming technology currently being devoloped, it's highly scalable and energy-efficient. The two young entrepreneurs began their journey in the Student Project House at ETH Zurich. There, they received coaching and numerous other benefits, including access to a network of like-minded creators, industry partners and start-ups at a more mature stage of development. It didn't take long for them to turn their concept into a product: Treeless Pack now offers a resource-friendly alternative to wood-based cellulose that can be used for paper, packaging and even composites for the construction industry. ○

STUDENT PROJECT HOUSE This creative thinkspace and makerspace is open to ETH students from any discipline. The support they receive in developing and implementing their own project ideas helps the students learn about the different stages of the innovation process.
⟶ sph.ethz.ch

Video: Treeless Pack
⟶ youtu.be/iyCMYXhLzM0

Image: Nicole Davidson

New space for clinical research

By combining healthcare and research, scientists are seeking to achieve optimal outcomes for patients.

Three ETH chairs are moving into new premises on the Kantonsspital Baden healthcare campus. Together, they aim to make the fruits of basic research available for the benefit of patients.

TEXT Markus Gross

The research group led by ETH professor Viola Vogel recently conducted experiments on mice that reveal how remnants of blood vessels in breast tumours help cancer cells multiply. As well as improving our understanding of tumour growth, these findings could potentially aid in the development of new diagnostic and therapeutic methods.

Yet one important question remains: To what extent can the findings in mice be applied to human patients with breast cancer? In a joint research project with Kantonsspital Baden (KSB), scientists are now investigating whether traces of modified blood vessels are also present in tissue samples taken from breast cancer patients. Vogel's experiments demonstrate how clinical research can play an important role in making the fruits of basic research available for the benefit of society.

SHARED VISION "Our collaboration with the Kantonsspital Baden has opened up fantastic opportunities for ETH," says Christian Wolfrum, Vice President for Research at ETH Zurich. "Over the past few years, we've built a solid, innovative partnership that has spawned joint projects in many clinical areas. Our shared vision is to combine healthcare and research in a way that achieves optimal outcomes for patients." Fired up by their success so far, the two partners have now decided to expand their collaboration. As part of this new development, three ETH chairs will move into the newly built Partner House II on the Kantonsspital Baden healthcare campus.

Image: ETH Zurich / Alessandro Della Bella

"We're proud to see an institution like ETH Zurich choosing to work with one of Aargau's main hospitals," says KSB's CEO Adrian Schmitter, noting that this is the only collaboration of its kind in Switzerland. "Our hospital provides researchers with a practical, hands-on environment. In turn, KSB benefits from ETH Zurich's know-how and capacity for innovation. This partnership also makes Baden even more attractive as a location for healthcare companies and start-ups."

The collaboration began in 2017, when the first cohort of 100 students enrolled on ETH's new Bachelor's degree programme in Human Medicine. Part of the students' induction week was spent at KSB, where they got their first taste of hospital life. Joint research projects soon followed, and in 2018, ETH moved into a suite of offices in KSB's Partner House on the hospital's healthcare campus. Since then, the programme has been expanded to include more extracurricular activities and training opportunities.

DRIVING DIGITALISATION The current partnership extends far beyond purely clinical research and continuing education and training. KSB and ETH are also determined to advance the digitalisation of healthcare data and its use in research. To this end, ETH Zurich has appointed a dedicated data architect to analyse data and interfaces and develop a suitable architecture. In future, this will make it easier to evaluate data and, for example, to search for specific patterns that might indicate disease progression or complications.

ETH's technology and service platform dTIP will also be represented in Baden. The dTIP team includes experts in clinical trials, data management and regulatory issues. It offers scientists a hassle-free, all-inclusive clinical research package that covers every element of a study, from planning and organisation right through to execution. "We want to give people even more of a chance to benefit from our basic research and engineering developments, whether in the form of medicines, therapies, diagnostic procedures or medical devices," says Wolfrum.

Collaboration with Kantonsspital Baden, Switzerland's other university hospitals and additional partners – plus interdisciplinary research in the new GLC building and in the new medical research laboratory in Schlieren – will all help accelerate this process. ○

PHILANTHROPY

BY
Donald Tillman

Inspired by adversity

I have the privilege of meeting lots of people at the ETH Foundation, and some of their stories leave a lasting impression. At this year's "Meet the Talent" – our annual event for sponsors who provide financial backing for ETH Zurich's talent programmes – I ended up chatting to donor Jörg von Ballmoos. His determination to support talented ETH students stems from the challenges he faced in his own early years. After his father died in January 1940, when Jörg was just 11 months old, his mother could barely keep their heads above water. I was particularly struck by his comment that it would have been impossible for him to go to university without a scholarship. That scholarship ultimately led to him graduating from ETH and pursuing a successful career at Ascom, including an assignment in the Chinese city of Guangzhou. From his own experience, he knows there are plenty of young people with tremendous potential who grow up in modest financial circumstances. That's why he's so determined to support them. So, on behalf of all those talented individuals who have received the extra help they needed: Many thanks, Jörg!

—〉 ethz-foundation.ch/talents/eth-scholarships/

Image: Hannes Heinzer

IN PERSON

Work psychologist Petra Schmid studies the effects of social power. She favours an interdisciplinary approach that includes both lab experiments and surveys.

PETRA SCHMID is Professor of Organisational Behaviour in the Department of Management, Technology and Economics at ETH Zurich.
—〉 ob.ethz.ch

You study the effects of social power on human behaviour. What does that involve?

Social power is about asserting control over coveted resources. Not just money or food, but also things like affection or knowledge. Yet it's not enough to simply have control over those resources – you only become socially powerful if someone else desires them.

Which of your findings has surprised you most?

Power was long regarded as something that sets us free, enabling us to do whatever we choose, regardless of social constraints. This gave rise to the idea that power inevitably leads people to process information rapidly and automatically and to behave in uninhibited ways. But my research has shown that people who feel powerful actually do a better job of controlling their behaviour and their cognitive processes, which is why they are more likely to achieve their goals than people who feel powerless.

Are there any situations where you feel powerless?

Whenever my work gets peer-reviewed by "Reviewer 2"! That's the jokey term we use for the kind of arrogant, condescending peer reviewers who deploy a barrage of destructive and biased criticism when evaluating academic papers.

Do we have any control over our own social power?

You can gain social power by climbing the hierarchical ladder. But power is also a psychological state; in other words, people exhibit different feelings of power independently of their social ranking. These feelings are determined by a person's character or mood, but are also influenced by external factors such as the situation or interaction partner.

Do people who feel powerful make better workers?

Power is not intrinsically good or bad. Those who feel powerful get less distracted and find it easier to prioritise things, which could certainly be beneficial in a work context. But my research shows that people who feel powerful are also more likely to stereotype and have prejudices against other groups.

What's the best way to motivate employees?

Show your appreciation. People want their work to be acknowledged and appreciated. ○

INTERVIEW Karin Köchle

Image: Daniel Winkler


IN THE GREAT
OUTDOORS

REPORT | ETH students are mapping the groundwater in an area of forest near Bern. This fieldwork will give them the skills they need for a career in environmental engineering.

TEXT Corinne Johannssen
IMAGES Annick Ramp

The meter emits a series of deafening beeps. Instinctively, everyone covers their ears. Without further ado, course co-leader Matthias Willmann pops the battery out of the device. Exchanging grins, the students continue to carefully lower the cable deeper into the borehole. Today's task is to measure the quality of the groundwater here in Kappelen, a municipality in the canton of Bern.

It's only been a few hours since Carole, Gianna, Raffaele and Robyn arrived. The four ETH students are here to complete a three-day module towards a Master's degree in Environmental Engineering – a course offered by the ETH institute of the same name. Matthias Willmann has been coming to this area of forest for the past 15 years, initially as an ETH employee, recently as an external consultant. All in all, around 20 students are taking part in the module, which aims to map the local groundwater. Willmann has just explained to the group that there are 16 boreholes in the forest. Sunk vertically to over 10 metres, they are permeable below a certain depth. This provides an entry point for groundwater, which can then be analysed by the students.

The group's first job is to measure the water table and the depth of each borehole. For this purpose, Willmann has brought two water-level meters from the equipment tent, which are similar in appearance to cable reels. In this case, however, the cable is a measuring tape attached not to a plug but rather to a thin metal rod – the measurement probe. He instructs the students to lower this carefully into the borehole. "As soon as the rod hits groundwater, current flows and the small display lamp will light up," Willmann explains. Some models even feature an acoustic signal. →

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1
Raffaele, Robyn and Gianna (left to right) prepare the water tank for an experiment with coloured groundwater.

2
Theory first: Matthias Willmann (far left) explains the experiment to Robyn, Gianna, Carole and Raffaele (left to right).

3
Measuring the water table in one of the boreholes.

2

3

A FEEL FOR FIELDWORK It doesn't take long for the four Master's students to get the hang of the meter. Initially, they work as a group. Raffaele slowly lowers the cable into the hole, with Carole lending a helping hand. The battery has been reinserted, and as soon as the lamp lights up and the device beeps, Robyn notes the reading on the tape. At borehole 3.1, the water table is at a depth of 3 metres and 95 centimetres. Gianna records the precise measurement. Raffaele then lowers the cable further until he detects slight resistance, which indicates the bottom of the borehole. "You develop a feeling for this," says Willmann. Once again, Robyn records the reading.

Later, the four students will map the boreholes and plot the level of the water table. This will tell them in which direction the groundwater is flowing. Just like a river above ground, groundwater flows downhill. "The module gives students a feel for the reality of working in the field," says Willmann. "The insights they get out here are really useful." Joaquin Jimenez-Martinez, who co-leads the course with Willmann, nods in agreement.

Jimenez-Martinez works as a group leader at ETH Zurich and the Swiss Federal Institute of Aquatic Science and Technology (Eawag). He recently teamed up with ETH's administrative department for Educational Development and Technology to take a closer look at the role of fieldwork. "The whole teaching process feels different when you have that connection to nature," he explains. "As teachers, we give a quick introduction but then step back and let the students get on with it – taking measurements, trying stuff out, learning in the field." He would love to explain the benefits in more detail, he says, but now he must dash for his train back to Zurich.

Meanwhile, the group is busy using a probe to measure groundwater temperature and conductivity. At a depth of 10 to 12 metres, the water has a temperature of 11 degrees Celsius – exactly as expected. The vertical hydraulic conductivity of the groundwater reveals certain details about its composition. Here in Kappelen, everything is as it should be. But an abnormal reading can also indicate the presence of contaminants. This would be a disaster for a country like Switzerland, where 80 percent of potable water is drawn from groundwater.

BIG SCIENCE With the first experiment now completed, the students join Lucien Biolley, employee at ETH's Institute of Environmental Engineering. Together with Marius Floriancic, he is responsible for ensuring that field instruments remain in perfect working order throughout the year. It's also his job to prepare the equipment required for the present module: two vans and two fully packed trailers are dispatched each year from Hönggerberg campus to Kappelen. Biolley explains to the students how they can use a pressure sensor to continuously monitor the level of the water table. Inside the blue tubes that pass through the borehole caps are cables that transmit the measurements to a data box. This collates all the data and can also be accessed remotely from Zurich. Later on, the students will have a chance to crunch data collected over the past five years. Right now, however, there's more immediate work to be done.

Carole, Gianna, Raffaele and Robyn use a wheelbarrow to fetch a 1,000-litre water tank – still empty, fortunately. They position it next to one of the boreholes and fill it with groundwater using a pump. That evening, marker dye will be added to the water to prepare it for another experiment. "The great thing about fieldwork is that everything's on a big scale, including the equipment," says Biolley. "That makes it much easier to figure out what's going on."

The four students are equally enthusiastic. Robyn and Carole completed a Bachelor's in Environmental Sciences before switching to Environmental Engineering for their Master's. "I'm interested in technical solutions to environmental issues," Carole explains. "I like the hands-on approach." And for Robyn, what counts is not only "what we learn while studying, but also the insight we get into environmental engineering as a profession." ⟶

FOREST OR MEADOW? For the next experiment, the students meet up with Marius Floriancic. His job is to teach them how to measure the amount of water the soil can hold. For this purpose, tensiometers are used. The students take the small tubes, fit a ceramic cap to the bottom and then fill them with water. The drier the soil, the greater the amount of water that passes though the ceramic cap and into the ground. The students insert the tubes to different depths in the forest floor. The readings show the water retention curve, a measure of the soil's ability to absorb water.

A second instrument, shaped like a large fork, measures soil moisture. Floriancic asks where we think soil moisture will be higher: in the forest or in the open meadow? The answer is unanimous: the forest! To our great surprise, the measurements show the exact opposite. Together with the students, Floriancic explores the reasons why: when it rains, the tree canopy and natural debris on the forest floor prevent some of the water entering the soil; also, trees extract more moisture from the soil than grass does; and, finally, forest soil is more permeable than compact meadow soil, which means it lets through more water.

"Computing and modelling – that's something ETH students are good at. But working out here in the field gives them a practical edge to that knowledge," says Floriancic with a grin. "It's an expensive module, but definitely worth the investment," he adds, on a more serious note. As evening falls, the group returns to the water tank in the forest, where Biolley pours in the marker dye. The coloured water flows from the tank through a thick hose into one of the boreholes, where it mixes with the groundwater below. Some 30 metres away, groundwater is pumped to the surface from another borehole and fed through a monitoring device. It will take some time before any coloured water is detected.

The students have completed enough practical work for the day. Later on, they'll be taking a closer look at the data on a laptop. It's precisely this combination of field and desk work that Raffaele finds so rewarding. Gianna, who holds a scholarship from the ETH Excellence Scholarship & Opportunity Programme, also likes the variation. For her, it's "the combination of technology and nature that makes environmental engineering so appealing".

FOSTERING INNOVATIVE TEACHING As of May 2023, courses offered by the Laboratory for Environmental Engineering are being supported by the Innovedum Fund. In collaboration with the administrative department for Educational Development and Technology, a joint project is now underway to simplify the preliminary analysis of data. This will give students more time to devote to advanced data interpretation and the critical evaluation of measurement results. Innovative assessment methods, such as peer grading, also help hone critical thinking.
→ ethz.ch/innovedum-en

4

4
The four Master's students make their way to the last experiment of the day. Later, they will spend the night under canvas.

COMEDIAN WITH A HEAD FOR BUSINESS

TEXT Karin Köchle
PHOTOGRAPHY Gian Marco Castelberg

ETH alumnus Fabian Unteregger is one of Switzerland's most successful cabaret artists. But bringing people together and coming up with solutions is where his passion lies.

"I absolutely adore cake. And, as a food scientist, I have to test desserts on a frequent basis to check they're still up to scratch!" says Fabian Unteregger with a wink as he settles down for our interview at the famous Sprüngli Café in Zurich. Unteregger is a successful comedian and ETH alumnus with a doctorate in medicine – and he happens to consider regular activity much more important than always following a healthy diet.

His early childhood was spent in Bottmingen, a municipality close to the city of Basel. Eventually, a job opportunity led his father to move the family to Zurich. Unteregger soon made new friends, seamlessly switching from the Basel to the Zurich dialect of Swiss German. This talent would later come in handy for his impressions of Swiss celebrities, which have since made him a household name. From the Zurich vernacular of Christoph Mörgeli, a member of the Swiss National Council, to the Basel dialect of tennis ace Roger Federer and the Wallis variety of federal councillor Viola Amherd, he mimics the regional language and vocal mannerisms of his chosen subjects to hilarious effect. As well as having his own stage show and radio programme, he is also a regular guest on television – yet comedy is only one facet of his extraordinarily diverse life.

FROM ETH TO THE US His chief interests at secondary school were chemistry and biology, a preference for sciences that continued into his university years. In 1997, he embarked on a degree programme in food science at ETH Zurich. "I wanted to study something that's relevant to everyone, and nutrition ticked all the boxes," he says. His time at ETH also sparked an interest in mathematics, and he was particularly drawn to subjects that offered real-world applications. Most appealing of all was the research on ice cream conducted by Erich Windhab, now an emeritus ETH professor, whose findings were readily adopted by industry.

Unteregger also relished the diverse, interdisciplinary nature of his degree programme, and particularly the broad knowledge it gave him of economics and business management. "I never intended to work for a food company," he says. "That's why I looked for a job in marketing after my degree, because I figured that's an important topic for any company." It wasn't long before he was hired by a US multinational as a product manager.

TV OPPORTUNITIES With his wealth of talents, becoming a teacher was still very much an option. An ETH teaching certificate in his pocket, he applied for a post as a biology teacher at the secondary school in Wiedikon, where he had once been a pupil. But his certificate said "food science", not "biology", and the school had to give preference to biology graduates – so he was soon left pondering a new career direction. In retrospect, he feels this was one of the best things that could have happened to him; suddenly, the performing arts became a real option. Alongside his day job, he started getting involved in "theatresports", a competitive form of improvisational theatre, gradually honing his stage presence over the course of a hundred or so shows. It was then that Unteregger tapped into an entrepreneurial streak that seems to have benefited him through much of his career: "After all that group improvisation, I realised that, from a marketing perspective, I needed a standardised product, something predictable that other people would recognise. And that's how I got started as a solo comedian." He quit his job and soon had the Swiss broadcasting company SRF knocking at his door. Before the first episode of the satirical late-night show Giacobbo/Müller even aired, Unteregger was already part of the team. His star has been on the rise ever since. Unteregger became his own boss and successfully turned his comedic talents into a career.

In our conversation, Unteregger is open and articulate, with a keen wit that is never crass or brash. Asked if that combination serves him well

FABIAN UNTEREGGER is a well-known Swiss comedian. He studied food science at ETH Zurich, followed by a degree in medicine from the University of Zurich and a doctorate from the University of Basel. Unteregger, 46, is co-founder and co-president of the organisation Swiss Healthcare Startups and a founding member of the ETH Circle.

in his public appearances, he says that he's not the pushy type. Yet even during his time at ETH, his fellow students were adamant that he should be the one to give the end-of-year speech. "I enjoy watching and analysing people, and I can quickly tell what drives them," he says. As if to demonstrate his sensitivity to people and their moods, he immediately comes up with a pithy analysis of the conversation playing out at the table next to us. When he walks into a room and senses tension in a group, he also uses humour as an icebreaker.

HUMOUR AND LANGUAGES OPEN DOORS Just like humour, Unteregger also sees languages as a useful tool – in his case, as a means of making meaningful contact with others. Learning languages also makes him feel more independent, helps him overcome prejudices and improves his understanding of foreign cultures. He is currently learning Arabic, his eighth language after German, Italian, Swedish, French, English, Spanish and Swiss German.

A trained helicopter pilot who also plays piano, drums, bass guitar and ukulele, Fabian Unteregger is not someone who likes to sit around doing nothing – though he does make sure to get seven hours of sleep every night. After completing his ETH degree programme, his unquenchable energy drove him to study medicine at the University of Zurich, followed by a doctorate at the University of Basel. During the pandemic, he combined his job as a comedian with shifts on an emergency ward, including nights and weekends – an eye-opening experience that taught him a great deal. He also picked up experience in ultrasound scans working as a doctor at Kantonsspital Winterthur, where he completed an accredited sonograph training programme. Working in hospitals has given him an insight into how they are run, and he can't help putting on his entrepreneurial hat to pinpoint how deficiencies in healthcare leadership might be handled in a business setting: "They really are two very different worlds!"

"ETH Zurich is a powerhouse like no other."

Fabian Unteregger

SUPPORT FOR START-UPS Since his stint on the emergency ward, Unteregger hasn't had time to carry out any more medical duties, but that doesn't mean he's left medicine behind. "What interests me now is unearthing potential for innovation," he says. Before finishing his degree in medicine, he founded Swiss Healthcare Startups, a networking platform that aims to bring together established businesses and start-ups. Companies can learn a lot from the start-up mentality and culture, he says, as this often involves working under pressure and embracing the development of risky new products. Unteregger is impressed by the technologies and solutions that emerge from the start-up ecosystem, but he has never seriously considered setting one up himself: "I've had the huge privilege of being my own boss for the past 14 years. My talent lies in mentoring and supporting start-ups on their journey."

And it's not just talented entrepreneurs and fledgling companies that benefit from his work beyond the comedy circuit. To express his gratitude for the education he received, he has also pledged to give something back to his alma mater, ETH Zurich, both as a donor and as co-founder of the ETH Circle, an international network of ETH Zurich ambassadors. He is keen to share the expertise he has acquired from supporting start-ups and working in the fast-paced entertainment industry. He is particularly interested in efforts to extend ETH's reach. "ETH is a powerhouse like no other, and we need to broadcast that around the world," he says.

If Unteregger could give one piece of advice to today's students, what would it be? "Focus on what you're good at and what makes you stand out from the crowd," he advises. "But the most important thing is finding joy and passion in what you do. Life is so much easier when you love your work!" ○

○ *focus*Terra special exhibition

Under the skin

Researchers at ETH's Responsive Biomedical Systems Lab are investigating whether magnetic fields can be used to guide bacteria through human bodies to deliver precisely targeted drugs. Might it then be possible for bacteria to serve as drug mules in the fight against cancer? *The flux under your skin* is an immersive installation that fuses research and technology with the power of the human imagination.

Until 30 November 2023

Find out more:
⟶ focusterra.ethz.ch/en

© Yasai

○ Guided tour

New heights for herbs

Visiting a vertical farm

An ETH spin-off in Niederhasli is looking to grow more from less. Yasai, Switzerland's largest vertical farming company, produces herbs such as basil, mint and dill on vertically stacked beds in a closed-loop system. The tour covers the entire process, from sowing to packaging.

24 October 2023, 6.15 – 7.15 p.m.

Free registration plus other tours:
⟶ tours.ethz.ch/en

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Future sounds: researchers are still a long way off developing robots that can play guitar.

○ Treffpunkt Science City

Artificial intelligence

Is artificial intelligence really all that new? Or is it just another step on the well-trodden path of intelligent programs and smart devices that can predict traffic congestion, forecast the weather and personalise advertising? Visitors to Treffpunkt Science City will learn just how clever the new programs really are compared to us humans. The varied programme of events includes lectures, workshops, demonstrations and guided tours, as well as our highly popular activities for children and young people.

From 29 October 2023

Find out more and sign up:
⟶ treffpunkt.ethz.ch

○ Music at ETH and UZH

Concert of chamber music

Isabel Villanueva is one of today's most sought-after violists. In a concert with pianist Calio Alonso, she will present a programme of Romantic music with pieces by Franz Schubert, Richard Wagner and Manuel de Falla.

24 November 2023, 7.30 – 9.30 p.m.
Auditorium of the University of Zurich

Information and tickets:
—〉 musicaldiscovery.ch

○ ETH climate change conference 2023

From Theory to Practice

The Center for Climate Systems Modeling (C2SM) at ETH Zurich is staging a conference on the topic of "Climate Change: From Theory to Practice".

31 October to 2 November 2023
ETH Zurich Main Building

Registration:
—〉 c2sm.ethz.ch/events/eth-klimarunde-2023

© Nicolas Zonvi

○ Forest lab

Globi's nature trail

Globi's Forest Lab is a free offering, available on request for school classes. Each child will receive a research diary so that they can continue investigating forest lab topics at home.

Information and registration:
—〉 tours.ethz.ch/en

○ Recommended reading

Myriad world of emergence

From single to whole

We perceive the world as a multitude of objects, ranging from extremely small to infinitely large. Yet how attentive are we to the constant interactions between them? The bee sucks nectar from a flower and in the process pollinates it; atoms exchange electrons and thereby create chemical bonds; living beings are in constant interaction with their environment; and we humans share our thoughts

and feelings by means of language.

This work explores how these interactions lead to the emergence of characteristics such as life, community and altruism that can only belong to a system but none of its individual parts. For the author Francis Waldvogel, the complexity of the universe to which we belong is rooted in such emergent phenomena.

Schwabe Verlag
ISBN: 978-3-907106-95-2

Image: Schwabe Verlag

OUT OF FOCUS

What holds the world together, as seen through the eyes of Michael Meister

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