GLOBE

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Quantum worlds 14

The quest to turn quantum theory into innovative real-world applications

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Paola Bianchi, Data Scientist

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EDITORIAL

THE SECOND QUANTUM REVOLUTION

The first quantum revolution began a century ago, when Max Planck, Albert Einstein and Erwin Schrödinger developed their theories on the mysterious quantum realm. The second has been underway since the end of the 20th century, when we began harnessing the laws of quantum physics in the service of technology. Today, governments and technology companies around the world are investing in a multitude of quantum-based applications, from hack-proof communications to ultra-sensitive sensors and quantum computers. Yet the creation of a truly usable, fully functional quantum computer is proving to be a tough nut to crack.

ETH invested in quantum research early on and now plays a leading role in education, research and development. We very much hope that we can maintain this position – even in today's challenging political climate. Quantum technologies are important to a country like Switzerland, and we aim to stay ahead of the curve. The new Quantum Center established by ETH and PSI is a key part of our strategy, as is the new HPQ laboratory building, which is scheduled for completion in 2025. Equally, the ETH Master of Science in Quantum Engineering is our way of giving the best grounding to the specialists we so urgently need to develop these new technologies.

Despite all our advances in knowledge, much of the quantum realm remains a mystery, and many of its phenomena contradict our everyday assumptions about reality. This is, of course, part of what makes the quantum world so fascinating, as you will discover in this issue of *Globe*.

Read on – and enjoy the journey!

Joël Mesot
President of ETH Zurich

GLOBE – the magazine for ETH Zurich and ETH Alumni

Illustrations: Gwil (cover page); Oriana Fenwick (editorial)

Dare to break new ground with KPMG

It does not make sense to hire chess players, and then treat them like chess pieces

KPMG

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3 / 2021


39


40

Images: courtesy of Sarah Hofer; Daniel Winkler

NEW + NOTED

FOCUS

COMMUNITY

REPORT

PROFILE

NEW + NOTED

Illustration: NASA / JPL-Caltech

An artist's impression of NASA's InSight lander after it deployed its instruments on the surface of Mars.

Beneath the Martian crust

We know that the Earth is made up of layers: a thin crust of light, solid rock surrounds a thick mantle of heavy, viscous rock, which in turn envelops a core consisting mainly of iron and nickel. Scientists had assumed Mars would have a similar structure – and recent insights are helping them build a clearer picture. Researchers at ETH Zurich and the University of Zurich have now been able to look inside Mars for the first time using seismic data. NASA's InSight lander recorded a series of marsquakes which have yielded information about the structure of the planet's crust, mantle and core.

The researchers' findings show that the Martian crust beneath InSight is 25 to 45 kilometres thick. Below this lies the mantle, together with a lithosphere of solid rock: on Earth, this layer is no more than 250 kilometres deep, but on Mars it can reach depths of 400 to 600 kilometres. This could explain why there is no evidence of plate tectonics on Mars. Unlike Earth, with its seven large continental plates, the planet appears to consist of a single plate. This is the first time that researchers have been able to estimate the size of the Martian core using seismic waves. Their findings indicate that the radius of the core is around 1,840 kilometres, which is about half the radius of Earth's core. This means the Martian core is a good 200 kilometres larger than was assumed 15 years ago during the planning of the InSight mission, though the current investigations do confirm the scientists' original assumption that the core is liquid. This large core rules out the possibility that Mars might have a lower mantle similar to that of Earth. Mineralogically speaking, the Martian mantle is a simpler version of Earth's mantle. However, seismologists are also discovering differences in chemical composition, suggesting that Mars and Earth were formed from different constituents. ○

Testing toxicity to protect embryos

Drugs need to be safe – and in the case of pregnant women, they must also be safe for the unborn child. In vitro testing of drug candidates is therefore carried out on embryonic stem cells from mouse cell lines at an early stage of drug development. However, standard cell culture tests are unable to detect substances that harm the embryo indirectly – by interfering with the functioning of the placenta or generating stress responses, for example.

Researchers in the Department of Biosystems Science and Engineering at ETH Zurich in Basel have now devised a lab test for embryotoxicity that also covers the role of the placenta. For this purpose, Julia Boos, a doctoral student in the group of ETH professor Andreas Hierlemann, and her colleagues developed a new chip consisting of several compartments, all interconnected by miniature channels. The scientists combined human placental cells taken from cell lines with microtissue spheroids derived from mouse embryonic stem cell lines. Known as embryoid bodies, these mirror the early development of the human embryo. On the chip, test substances first encounter a layer of placental cells, which they must pass through before reaching the embryonic cells, thereby reproducing the situation in utero.

The goal is to create a new test that is simple to use for the pharmaceutical industry. Being able to detect and eliminate substances that are harmful to the embryo at an early stage of drug development will mean that fewer substances have be tested on animals during in vivo studies. This will help to reduce the number of animal experiments. ○

Illustration: Crafft, Nadja Häfliger

Image: iStock / ae-photos

Forests influence rainfall.

Reforestation to tackle droughts in Europe

Climate models indicate that summer heat waves and droughts are also set to increase in Europe. This will be accompanied by a decrease in precipitation, except in Scandinavia. Based on observational data from Europe, climate researchers have now shown for the first time that forests lead to a rise in precipitation. These findings suggest that reforestation of available agricultural land could increase the amount of precipitation in Europe. The researchers analysed precipitation data from five European regions: Germany, the Netherlands, Sweden, Finland, and the area in and around Great Britain. By comparing pairs of measuring stations in these regions – one station in a forested area, the other on agricultural land – they were able to show that average precipitation in forested areas is considerably higher than in agricultural areas. ○

Image: naaro

3D-printed elegance

STRIATUS ○ Striatus is an arched footbridge made of 3D-printed concrete blocks that are assembled without the use of steel reinforcement or mortar. The additively manufactured blocks are held together merely by means of compression – much in the manner of traditional masonry bridges. In cooperation with partners from industry, the Block Research Group of ETH Zurich has developed a new 3D-printing process in which the concrete is applied not horizontally in the conventional manner, but rather at a specific angle such that the elements are able to absorb and withstand the compressive forces of the bridge. The self-supporting and resource-saving bridge was designed together with Zaha Hadid Architects. It can be viewed until November at the architecture exhibition "Time Space Existence" in Venice. As the bridge is dry-assembled, it can be easily dismantled and reassembled for reuse in other locations – or easily recycled once it has reached the end of its life. ○

⟶ block.arch.ethz.ch

Rethinking the self-sufficiency ratio

Environmental scientist Roman Hüppi believes that the Swiss self-sufficiency ratio is no guarantee of food security.

ROMAN HÜPPI, a postdoctoral researcher in the Sustainable Agroecosystems Group, argues that we should put our basic nutritional needs on more sustainable footing.

The self-sufficiency ratio indicates the extent to which Switzerland can satisfy its food needs from its own domestic production. The most common argument against making Swiss farming practices more sustainable is the concern that this may lead to a decline in food self-sufficiency. Yet issues such as climate change, species extinction and common nutrition-related diseases have turned the self-sufficiency ratio into a dubious benchmark. We urgently need an update to reflect today's challenges.

According to the federal government, Switzerland's gross self-sufficiency ratio over the past few years was around 60 percent. If we consider that about a quarter of animal production is based on imported feed, we are left with a net figure of just 50 percent. In other words, half of the country's food needs are met by imported foodstuffs. Switzerland is highly self-sufficient in terms of animal-based foods, with figures of 115 percent for dairy products and 80 percent for meat. Yet the situation is very different in the case of plant-based foods, where the self-sufficiency ratio is just 40 percent. All these calculations are made on the basis of dietary energy supply, a metric that emerged from the hardships of two world wars, when calorie production was the sole priority.

Due to its high energy content, sugar beet is seen as a key ingredient of food self-sufficiency in Switzerland – but some experts are calling for a rethink.

From a supply perspective, it makes sense to produce as much food as possible domestically, and efforts to intensify farming practices have generally been defended as legitimate steps to boost self-sufficiency. Yet maximising food self-sufficiency is not always a desirable goal, since making agriculture more intensive inevitably causes greater environmental damage, which poses an increasing threat to the very foundations of our food supply.

Image: iStock / Victority

Moreover, analyses conducted by Vision Agriculture suggest that it is not the calories produced in normal times that are key to ensuring food security in a crisis, but rather a country's natural production potential and ability to adapt agricultural practices quickly when needed. In other words, a high self-sufficiency ratio does not guarantee food security, in part because this indicator fails to consider the input required to produce food in the first place.

IMPORTED ENERGY Farmers utilise many different resources to maximise food yields. They harness direct energy in the form of fuels and electricity, and they also use much larger quantities of indirect or "grey" energy, which is hidden in end products such as animal feed, seeds, fertilisers, pesticides, tools, machines and agricultural buildings. According to estimates, Swiss agriculture consumes some two to three times as much external energy as it produces in the form of food. Most of this external energy is imported – yet the self-sufficiency ratio makes the assumption that production resources will continue to be available even in times of crisis.

To evaluate security of supply properly, a suitable indicator should take into account the energy efficiency of domestic production and penalise the use of imported energy. Such an approach would also boost efforts to tackle the climate crisis. As long as imported energy comes from fossil sources and animal feed is grown on cleared land in virgin forests, our imports will continue to fuel climate change and jeopardise domestic yields.

MORE THAN JUST CALORIES From a health perspective, too, the traditional self-sufficiency ratio makes little sense. Low-energy, nutrient-rich foods such as vegetables and fruit carry little weight, while sugar beet gains top marks due to its high energy content. Thus, the production of sugar is encouraged in the name of self-sufficiency, even though it is very harmful in the quantities consumed today. One option would be to gear the self-sufficiency ratio to a balanced diet. Shifting from animal-based foods to a more plant-based diet would also increase self-sufficiency significantly. In the future, farming will need to be sustainable and provide people with reliable supplies of healthy food. It will also need to protect the climate, conserve cultivated land and foster biodiversity. Rethinking the self-sufficiency ratio is essential if we want to adapt it to a multifunctional form of agriculture. ○

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Lighting up tissue formation

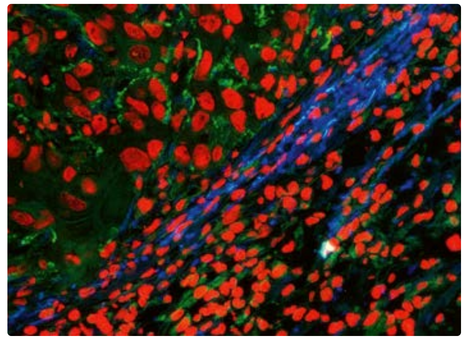

Image: ETH Zurich / Matthew Aronoff

A new marker molecule (blue) shows the boundary of a tumour.

The most common protein in the human body is collagen, responsible for forming skin, tendons, cartilage, bones and connective tissue. Researchers at ETH Zurich have now developed a multi-component marker molecule that highlights any new tissue growth in the body. This can be used to show the boundaries of a tumour. When tumours form or wounds heal, our bodies produce extra collagen fibres. This process requires LOX enzymes, which are responsible for oxidising specific sites in the collagen molecules. This leads, in turn, to chemically modified sites on various collagen strands, which then react with each other, causing the strands to fuse.

Under the leadership of Professor Helma Wennemers, head of the ETH Laboratory of Organic Chemistry, a team of researchers has developed a sensor molecule that fluoresces after reacting with the LOX enzyme. The researchers combined this molecule with a short fibrous peptide similar to collagen and conjugated the peptide with a reactive group that only reacts with collagen if the latter has been oxidised. This molecule anchors itself to collagen fibres wherever new tissue is being formed. It then begins to fluoresce as soon as new tissue starts growing, and the LOX enzyme is produced. ○

Testing Telegram for vulnerabilities

Employing only open-source code and without launching an attack on any running systems, a small international research team recently performed an analysis of the encryption services employed by the Telegram messaging service. Researchers from ETH Zurich and Royal Holloway, University of London, discovered a number of weaknesses in the cryptographic protocol of the popular platform. For the majority of its 570 million users, the immediate risk remains low. Yet the vulnerabilities discovered by the team show that Telegram's proprietary system fails to provide the security guarantees offered by other widely used cryptographic protocols such as Transport Layer Security (TLS).

As is customary in this area of research, the team informed Telegram developers of their findings 90 days prior to making them public, giving the company time to address the vulnerabilities that had been identified. In the meantime, Telegram reacted to the results and patched the security gaps with software updates.

The project was inspired by research investigating the messenger systems used by participants of large-scale protests such as those seen in Hong Kong during 2019–2020. This showed that protesters mainly relied on Telegram to coordinate their actions – and that Telegram had not yet been subjected to thorough security checks by cryptographers. ○

Illustration: Crafft, Nadja Häfliger

Extracting water from air

Researchers at ETH Zurich have developed a new type of condenser that will extract water from the atmosphere around the clock. It requires no energy input and will even continue to condense water vapour in blazing sunlight. The key component is a glass pane specially coated with silver and a polymer. It reflects the sun's rays and emits thermal energy of its own, thereby enabling it to cool down to as low as 15 degrees Celsius below ambient temperature. As a result, water vapour from the atmosphere condenses into water on the underside of the pane. A conical radiation shield protects the pane to a large extent against airborne heat and incident solar radiation. At the same time, it enables the device to give off its own thermal energy, thereby allowing it to cool passively. This new system may well prove useful in countries where water is in short supply. ○

The pilot condenser on top of an ETH Zurich building.

Image: ETH Zürich / Iwan Hächler

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01

Superposition

Just like the cat here, a quantum system can assume several states at once. Whereas a classical bit is either 0 or 1, a quantum bit – or qubit – can also be both 0 and 1 at the same time, a phenomenon known as quantum superposition.

Qubits remain in superposition only until this state is measured. Measurement resolves the ambivalence of this state, and quantum superposition breaks down.

Quantum

Specific laws

The quantum world is ruled by laws that are beyond everyday experience. Nevertheless, many concrete applications are derived from them.

Quantum technology has given rise to the laser, MRI scanner and transistor.

FOCUS

ETH was quick to recognise the potential of quantum science and is now a world leader in research and education in this field. Yet many mysteries of the quantum world remain to be discovered.

ILLUSTRATIONS
Gwil

ART DIRECTION
Crafft AG

TEXT
Corinne Johannssen,
Florian Meyer,
George Tudosie

Worlds

In crude terms, our digitally driven information society is based on a simple binary opposition: 0 or 1. But what happens when other alternatives exist alongside these polar opposites? Might this give rise to a whole raft of different states and enable us to process complex information much faster?

It is precisely the prospect of going beyond conventional methods of data processing that has inspired such high hopes in the field of quantum physics – not only on the part of scientists in basic and theoretical research, but also among the CEOs of major corporations. Were this vision to materialise, and computers behave in accordance with the laws of quantum mechanics, it would open the door to a whole new world of applications. For example, such a powerful system would be able to determine the mechanism of proteins at a radically faster rate than a conventional computer could ever hope to achieve. This, in turn, would massively accelerate the development of new medicines.

A ROCKY ROAD Given such prospects, it is little wonder that quantum physics should exercise a fascination far beyond its immediate circle. Yet the road that will take us to a quantum computer capable of answering everyday questions is a rocky one – and much longer than many are prepared to admit. "We're talking about decades, not years, before we reach that point," says Jonathan Home,

Simplifying quantum systems

If only it were less prone to error, quantum physics might already be giving us instant solutions to seemingly unsolvable problems. ETH researchers are therefore working to develop systems that are more robust.

TEXT Felix Würsten

Professor of Experimental Quantum Optics and Photonics at ETH Zurich. And Professor Home is one of those working in a field in which quantum research is relatively far along. He uses individual atoms as qubits. These are the basic units of information used by a quantum computer to perform calculations. Home uses beryllium and calcium atoms held in special electrical ion traps. These are then manipulated with a laser according to the laws of quantum mechanics. "Atoms are great systems for information processing because they can be isolated – and because, provided they remain isolated, they can store quantum information for a couple of seconds or even minutes," he explains.

In order to be able to use this information, however, these fragile quantum objects have to be reconnected with the everyday physical world. During this step, even the slightest anomalies can corrupt the entire system. The question is, therefore, how to reduce this susceptibility to error and, at the same time, increase the number of qubits.

SIMPLER AND MORE ROBUST An obvious approach is to equip the systems with a degree of redundancy, i.e. to link several physical qubits to a single logical qubit. But this has a major drawback. Although redundancy renders the system more stable, it also makes it exponentially more complex – and, in turn, much more susceptible to error. "In fact, our principal aim is to build systems that are simpler and more robust," Home explains.

This requires not only sophisticated control technology and a lot of engineering know-how but also a better understanding of the physical correlations. According to Home, the development of quantum computers has already yielded concrete benefits, even if today's technology is still far removed from being able to investigate protein structures: "In essence, our experiments pose an endurance test for the physical theories. The results then provide us with new insights as to how the quantum world works." One of ETH's big strengths is that researchers here are working on very different approaches. The ion traps used by Home are just one of a number of routes that could deliver a breakthrough. Superconducting circuits are another promising option. "It's highly unusual for one university to be pursuing so many different approaches," says Home.

HIGHLY SPECIALISED INFRASTRUCTURE In common with his colleagues, Home has big hopes for the planned physics building on the Hönggerberg campus. Funded by an endowment from Walter Haefner, this will feature highly specialised laboratories that are exceptionally well isolated from outside interference. It is here that scientists will attempt to push back the boundaries of quantum research. In so doing, they will also explore ideas that are still very much in their infancy.

> "We spend a lot of time just on the peripheral technology around the actual quantum systems."
>
> Yiwen Chu

One potential route is the use of free electrons in semiconductor materials. These are able to move freely of the influence of the crystal lattice structure and exhibit quantum mechanical properties that can be used for processing information. "But for this purpose, the semiconductors have to be extremely pure," explains Werner Wegscheider, who as Professor of Solid State Physics has experience in producing these specialised materials. He uses a vacuum chamber to build customised semiconductors atom by atom. "We make the world's purest semiconductors," he says with pride. Such materials can exhibit completely new properties. When cooled to a very low temperature and exposed to a magnetic field, the free electrons condense to form a quasiparticle. In other words, they collectively behave in the manner of a single particle and can therefore be described mathematically. Researchers have good reason to believe that such topological quantum systems are more resistant to perturbation than other quantum objects – which is precisely why they may be less prone to error.

A WORTHWHILE EFFORT Topological quantum systems offer an especially neat example of how, in physics, theory and experiment can be mutually enriching. The basic quantum Hall effect underpinning these systems was discovered experimentally. This effect was then described theoretically. The resulting theory subsequently led to the prediction of the topological states about which researchers are currently so excited. It has yet to be experimentally verified whether these theoretically predicted states actually exist in practice. If experimental physicists can demonstrate this, they may soon be returning the problem for additional theoretical elaboration.
Like Home, Wegscheider warns it will take ⟶

some time before a quantum computer can solve practical problems beyond the realm of quantum physics. "Three years ago, I was still sceptical, but now I'm pretty confident that we'll get there," he says. "When you think about the truly fundamental problems that systems like this will be able to solve, then all the effort that is now taking place around the world is definitely worthwhile."

At present, it is still unclear which of the various approaches will ultimately prevail. The answer may well lie in a mix of different solutions – semiconductors with superconducting circuits, for example. "When these two options are combined, you get quasiparticles known as Majorana fermions, which are thought to be less susceptible to error," says Wegscheider. Yiwen Chu, Assistant Professor of Hybrid Quantum Systems, is investigating combinations of different quantum systems. "There's a whole range of quantum objects, such as photons, ions or even superconducting circuits," she explains. "All have their specific strengths, but also disadvantages. The question is how to bring these elements together in a way that combines their strengths."

BRIDGING THE GAP Her model is the classic computer, which uses, for example, a silicon chip to process information and optical fibre to transfer the data. By analogy, a quantum system might use superconducting circuits to process data, which would then be transferred by photons. "But it turns out that these two quantum objects are not particularly compatible," says Chu. What is needed, therefore, is something to bridge the gap. Chu and her research group are currently investigating the use of small crystals for this purpose. As mechanical objects, they are able to communicate with both sides by means of acoustic vibrations.

At the same time, it may well be that these crystals themselves are capable of storing and processing quantum information. "The crystals use acoustic vibrations, which are much slower than light waves, so we could use them to build smaller qubits," she explains. Yet her chief aim here is not to accommodate as many qubits as possible on a given surface. The advantage is rather that these crystals can be isolated from one another much more easily than, for example, superconducting circuits. The greater degree of isolation prevents an unwanted loss of information, which in turn helps reduce the susceptibility to error. Yet the greatest challenge of all is that as more and more qubits are connected together, the system itself has to become increasingly complex. "We spend a lot of time just on the peripheral technology around the actual quantum systems," Chu explains. Yet it would be wrong, she says, to look upon the quantum computer as purely an engineering problem. "There are also a lot of unanswered questions on the physics side of the equation." One of these is whether the transition between the worlds of classical and quantum physics is continuous or abrupt. "We don't yet have a definitive answer to this problem," says Chu. "But either way, it's going be an exciting time for us physicists!" ○

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02

Teleportation

Entanglement

The state of one quantum particle may become entangled with that of another. When one particle changes its state, so does its entangled partner.

ALBERT EINSTEIN described entanglement as "spooky action at a distance".

QUANTUM COMPUTERS

Quantum teleportation plays an important role in quantum computing. This does not involve, however, the teleportation of matter.

Infinite distance

Computer scientists take on the quantum challenge

For a long time, the development of quantum computers was concerned with theoretical and hardware aspects. But as the focus shifts towards programming, software and security issues, the classical computer sciences are coming back into play.

TEXT Florian Meyer

Physicists had long nurtured the ambition to build a quantum computer. In the early 1980s, one of the most famous among them, Richard Feynman (1918–1988), questioned whether it would ever be possible to efficiently compute and simulate quantum physics phenomena using a conventional computer. He argued that digital computers couldn't compute fast enough to calculate and simulate the quantum effects that typically occur within atoms and molecules and between elementary particles – at least not within a reasonable period of time.

Initially, he proposed building a quantum computer based not on digital coding but rather on a direct imitation of quantum systems. His core idea, which continues to inspire the development of quantum computers to this day, was that certain properties of quantum mechanics could be harnessed for computation. Specifically, this would mean taking advantage of two quantum states of particles: superposition and entanglement.

The principle of superposition, for example, can be exploited by quantum computers to carry out faster calculations. While digital computers use binary bits that can only take on the states of one or zero, quantum computers use quantum bits, or qubits, to process information. Qubits can be one or zero, and they can also be both one and zero at once, a state we call superposition. This crucial difference enables a huge leap in computing speed for certain computational problems.

In future, quantum computers promise to perform ultra-efficient calculations that normal computers cannot solve in a reasonable period of time, a milestone sometimes referred to as quantum supremacy. Although scientists have yet to find conclusive proof of the existence of quantum supremacy, recent technical advances have been impressive. In 2019, Google claimed to have achieved quantum supremacy for a specific computational problem for the first time, having built a quantum computer that required only 200 seconds to solve a problem that would have taken a conventional computer 10,000 years.

ENCRYPTION COULD BE CRACKED Right now, quantum computers are too small and error-prone to pose any serious threat to today's digital computers, which are capable of performing billions of computations per second. Even Google's quantum computer was only able to prove its supremacy in a single, specific task. Nonetheless, quantum technologies have now reached a stage where their development lies in the hands of more than just physicists. Today, many computer scientists are "quantum curious", according to ETH Computer Science Professor Kenneth Paterson. He conducts research in the field of cryptography and works on ways of securely processing, transferring and storing information. "We've been 'quantum aware' in my area of research ever since quantum computing started to become a bigger issue in cryptography about ten years ago," says Paterson. "As soon as someone builds a quantum computer that is sufficiently large-scale and reliable, the current encryption framework of the internet will cease to be secure, because quantum computing could be used to crack that encryption."

The encryption and security protocols that run behind the scenes whenever we log on to social media, make an online purchase, use online banking or send an email are all based on integer factorisation and related problems that are vulnerable to Shor's algorithm. Integer factorisation is the process of breaking down a large composite integer into its prime factors. This requires huge computing power, which is why there is still no algorithm – that is, no calculating procedure – that a digital computer can use to efficiently solve a factorisation problem. Back in 1994, however, mathematician Peter Shor created an algorithm specially designed for quantum computing, which can find the prime factors of composite integers significantly faster than classical algorithms. Shor's ideas can be used to crack the other forms of public key cryptography in use today.

Today's quantum computers are too small and error-prone to run Shor's algorithm. In principle, however, it is clear that any quantum computer that is powerful and reliable enough to do so would be able to perform factorisation within a reasonable period of time. The moment this situation occurs, factoring-based cryptography and related techniques currently in widespread use will no longer be secure. Not all of cryptography will be affected, of course; for example, quantum computing won't seriously affect the security of encryption methods that rely solely on secret-key cryptography. But public-key cryptography – which currently forms the basis for securing over 90 percent of web traffic – will definitely be at risk.

> "The current encryption framework of the internet will cease to be secure if we have large-scale quantum computers."
>
> Kenneth Paterson

TRANSLATING IDEAS According to Paterson, a quantum computer would need millions of quantum bits to crack a security key. Scientists at ETH Zurich are currently running quantum computers with up to 17 qubits. On the development side, researchers are on the brink of reaching a new phase of mid-sized quantum computing systems with 50 to 100 qubits, though these are still susceptible to errors. "But we might see a sudden breakthrough in the power of quantum computers, and it could take at least ten years to modify today's public key cryptography. That's why we're getting ready now," says Paterson. His group has co-developed a new quantum-safe algorithm that is being evaluated in an on-going worldwide competition to select new, quantum-secure algorithms.

People sometimes ask Benjamin Bichsel whether he feels his research will have been in vain should large-scale, reliable quantum computers ⟶

eventually turn out to be unfeasible. "I think that's the wrong question," he says. "But I do wonder what we'll do if quantum computers end up working brilliantly and we don't have a clue how to programme them efficiently!" Bichsel works in the research group led by computer science professor Martin Vechev, whose group developed the first intuitive high-level programming language for quantum computing in 2020.

It will take special programming languages to properly exploit the potential of quantum computers. "Quantum programming languages are essential to translate ideas into instructions that can be executed by a quantum computer," wrote Microsoft researchers in 2020 in the science journal Nature. The authors included Bettina Heim and Matthias Troyer, who had previously worked as researchers at the ETH Institute for Theoretical Physics.

Today's quantum programming languages are tied closely to specific hardware. These "hardware description languages" focus on the behaviour of circuits and how to optimise them. In contrast, the Silq programming language developed by Martin Vechev's group abstracts from the technical details. "Silq is the first high-level quantum programming language that is not tailored primarily to the design and functionality of the hardware, but rather to the mindset of the programmers who want to solve a problem," Bichsel explains.

Over a year has passed since Silq was launched; as the first high-level quantum programming language, it has already won acclaim for its elegance and internal coherence. Martin Vechev and his team have also earned praise for their innovative contribution towards reducing errors in quantum computing. In a further article about Silq, *Nature* explicitly refers to the "uncomputation" feature that enables Silq to automatically reset temporary values "rather than forcing programmers to do this tedious work manually".

A computer processes a task in several intermediate steps, creating intermediate results or "temporary values" in the process. In classical computers, these values are erased automatically to free up memory. This task is a lot more complex in the case of quantum computers, however, since the principle of entanglement means that previously calculated values may interact with current ones and jeopardise the calculation process. That makes the ability to automatically clean up temporary values a key part of quantum computing.

A HOLISTIC VIEW OF COMPUTING The question of whether Silq can hold its own against the quantum programming languages developed by technology giants Microsoft, IBM and Google – Q#, Qiskit and Cirq, respectively – is still very much up in the air. But, in the meantime, Vechev's team have also succeeded in transferring automatic uncomputation to Qiskit. "It's very encouraging to see that we can transfer key Silq concepts to other languages – especially since automatic uncomputation improves the efficiency of quantum computing with Qiskit," says Martin Vechev.

In the long run, there will be less of a focus on computer scientists writing languages and software for hardware developed by physicists. Instead, the emphasis will shift to developing programming languages hand in hand with quantum algorithms, quantum hardware, quantum software, quantum applications and workflows. "If we genuinely want to make quantum computing a reality, we will need to make this new approach part of a fully fledged computer system in which multiple components combine to solve specific problems efficiently," says Paterson. Martin Vechev nods in agreement: "This is where ETH Zurich has a real advantage, because we have quantum physics, quantum technology and quantum computer science all under one roof." ○

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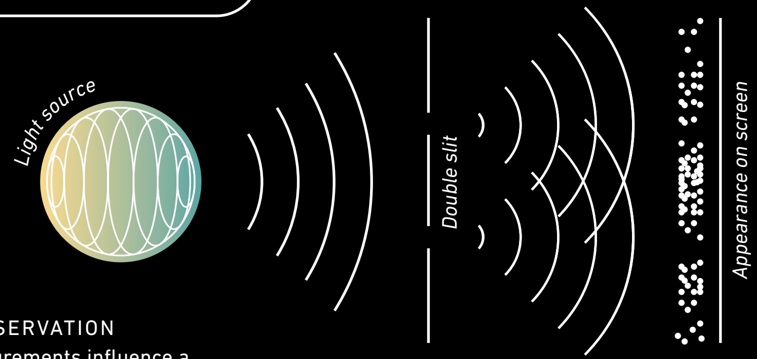
Double-slit experiment



UNDER OBSERVATION
Direct measurements influence a quantum system, because the observer becomes part of the system.

03

Duality

If quantum objects are fired through a double slit one after the other, each one of them hits the screen at random. The resulting interference pattern on the screen reflects the wave nature of the quantum particle.

WAVES + PARTICLES The double-slit experiment shows that a quantum object can behave both as a wave and as a particle – two properties that are mutually exclusive in classical physics.

Mastering the unknown

Two years ago, ETH launched the innovative Master's degree in quantum engineering. Now the first cohort of students is nearing the end of the programme.

TEXT Martina Märki

Companies and research centres around the world are ramping up to explore the potential applications of quantum mechanics. To train the required experts in this field, ETH Zurich launched a Master's degree programme that has won worldwide recognition for its interdisciplinary approach.

The Master of Science in Quantum Engineering (MQE) is a joint programme offered by the Department of Information Technology and Electrical Engineering and the Department of Physics. Its goal is to fuse quantum physics with engineering disciplines. "We might not have been the only ones to come up with this idea, but we were definitely one of the first to do a credible job of bringing these two fields together," says MQE Programme Director Lukas Novotny. "Now our Master's course is seen as a model for others to follow."

Novotny is Professor of Photonics at the Department of Information Technology and Electrical Engineering. As Programme Director, he is responsible for ensuring that the Master's course lives up to its promises. These are nothing if not ambitious: quantum engineering is a new field at the interface of quantum physics, electrical engineering and IT. It exploits the laws of quantum physics to develop technologies that outperform classical engineering approaches. Quantum technologies will fundamentally change the classical engineering paradigms of computing, information processing and measurement techniques – and future quantum engineers will need the skills to develop these new technologies and put them into practice.

WEARING TWO HATS One of these budding quantum engineers is Anja Ulrich. She is part of the first cohort of students who embarked on the new Master's programme two years ago – in her case, on the heels of a Bachelor's degree in electrical engineering. She is currently on an internship at imec in Belgium, after which she intends to start her Master's project. Imec is a research centre that specialises in nanoelectronics and digital technology and also conducts research into quantum technologies. "The group I'm working with here is made up mostly of physicists," she says. Right now, the big challenges of quantum technologies lie in the field of engineering rather than physics, so her internship has required her to step up a gear. "It's been a steep learning curve for me," she admits frankly. "But that's probably true for everyone who makes the transition from academia into the real world."

The Master of Science in Quantum Engineering gives engineers like her the tools they need to understand the language physicists use. "It teaches us to wear two hats." She admits that she sometimes wishes the degree programme had taken a more hands-on approach to the physics components, but overall she's pleased with the course: "It has definitely met my expectations. Obviously I come from an electrical engineering background, but I've always had a huge interest in physics. So my goal was to learn more about physics without losing that connection to engineering." The programme content is carefully tailored to reflect what students have studied in the past. "Students from an engineering background get a slightly bigger dose of quantum physics in their first year, while students coming from the physics side start off with more of an electrical engineering focus," says Novotny. The goal by the end of the Master's course is that students not only understand the principles and language of the other subject area but are also able to transform them into something new with real-world applications.

When it came to designing the course, there was broad agreement that they couldn't simply create a double degree with double the workload. "We chose to focus on areas that are genuinely relevant to quantum engineering, on both the physics and the engineering side," says Novotny. But that doesn't mean the Master's isn't challenging. "Obviously this degree programme is a big step out of our comfort zone," says Ulrich. "But quantum engineering is uncharted territory for all of us – and that's what makes it so exciting!" She says it feels inspiring to work in a field that could spark a technological revolution, a point that Novotny echoes: "The course is hugely demanding, but the students can handle it. They're motivated by the recognition that they're blazing a new trail." The bond between the students is another big advantage in Ulrich's eyes. Right from the start, she's been heavily involved in the newly established student association, which now offers everything from support with exam preparation to professional networking, industry contacts and social events.

PIONEERS ON THE RIGHT PATH The first cohort of quantum engineers is approaching the end of their Master's degree, while the third will be starting the programme this autumn. The number of students opting for the Master of Science in Quantum Engineering has almost doubled since it was first introduced – a clear indication that the course has struck a chord. "It shows we're on the right track," says Novotny. It's also a challenge, especially on the organisational and administrative side. Careful consideration must now go into transitioning the programme from the start-up phase to a steady state, Novotny argues, and that includes enlisting the support of a network of industry partners. "I want quantum engineering to lay down some roots," he says.

"Quantum engineering is uncharted territory for all of us."

Anja Ulrich

Graduates from the course can certainly look forward to good job prospects, he adds, though he cautions that the success of the programme will only become clear once the first graduates have spent some time in the working world. Anja Ulrich is optimistic: "I think it will give me all sorts of opportunities, especially since the number of people with proper qualifications in this field is still fairly low." She also sees significant potential for making a difference, making exciting discoveries, and paving the way for change: "We might actually get the chance to make something new happen rather than just tinkering away in the background." And what could be more motivating than that? ○

ANJA ULRICH is one of the first cohort of students to take the ETH Master of Science in Quantum Engineering.

LUKAS NOVOTNY is Programme Director of the Master of Science in Quantum Engineering and a professor in the Department of Information Technology and Electrical Engineering.

Master's programme in Quantum Engineering:
—› master-qe.ethz.ch

"It increasingly feels like a high-tech race."

Could quantum technologies really be the next gold rush? ETH Vice President Vanessa Wood and quantum researcher Andreas Wallraff discuss how close we are to putting quantum promises into practice.

INTERVIEW Martina Märki and Corinne Johannssen

ETH spin-off Zurich Instruments was recently acquired by German technology group Rohde & Schwarz. What was so significant about this deal?

VANESSA WOOD: Zurich Instruments has gone from being a niche manufacturer to attracting the interest of a major electronics company. That's fantastic news! It shows that demand for quantum technology devices has now reached a broader market, and it confirms the more general trend we're seeing in investments in this area.

ANDREAS WALLRAFF: Rohde & Schwarz is a big corporate group. Their decision to snap up Zurich Instruments will certainly have been motivated by that company's success in carving out a position for itself in the market for quantum technology instruments over recent years. Although Rohde & Schwarz has some products that can be used in related fields of application, they had never really targeted this particular area before. So buying an ETH spin-off was a good opportunity for the company to get into this market. We've been collaborating with Zurich Instruments on joint projects for the past eight years, so it's also an exciting development for us as a lab.

Should we see this as part of a wider trend in this field?

WOOD: The acquisition of Zurich Instruments reflects broader efforts we're seeing by big-name computing and electronics companies to make the right investments to establish a presence in the field of quantum technology.

WALLRAFF: Interest in this area has been huge over the past five years, with big investments in both new and not-so-new start-ups. We've also seen tremendous expansion in the field itself. As a result, there are now far more opportunities to find a job in quantum technologies, both here in Switzerland and internationally.

Have we now reached the point where you would say we're transitioning from quantum theory to real-world practice?

WALLRAFF: We've witnessed a number of transitions since quantum physics first emerged over 100 years ago. Things like transistors, lasers and MRI would never have been conceivable without quantum physics. So you could argue that many applications of quantum physics are already here. The late 1980s produced various theories on how quantum physics could be used for information technology, computers, secure communication and enhanced sensor systems. In the late 1990s, researchers began experimenting with ways of making such systems a reality, and the first successful implementations led to a period of experimental advances and a surge in expectations. Today, we really are in a transitional phase between fundamental physics and real-world applications.

How close are the ties between ETH and the private sector?

WOOD: We're already cooperating with industry partners on numerous Innosuisse and EU projects. At the same time, we're working with the recently founded Quantum Center, which is headed by Andreas. The idea is to set up a Partnership Council, which will help industry partners, ETH researchers and students benefit from ever-closer cooperation.

Which specific industries do you have in mind?

WOOD: We hope to attract the interest of major international technology companies such as Google, IBM and Microsoft as well as start-ups such as Rigetti Computing and IQM. We'll also be looking at potential users of quantum technology, such as the cyber security sector.

WALLRAFF: I'm also very interested in applications in the chemical, pharma and biotech sectors, such as the development of catalysts, biologically and chemically active substances, and medicinal drugs. These may be a long way off – a bit like quantum computing itself – but they're definitely areas in which quantum computers could offer major benefits. Calculate the properties of a complex molecule, for example, and you're essentially solving a quantum physics problem.

It all sounds very interdisciplinary! Does the Quantum Center involve many different branches of knowledge?

WALLRAFF: We currently have 28 founding members from six academic departments – Physics, Chemistry and Applied Biosciences, Electrical Engineering and Information Technology, Computer Science, Materials Science, Mechanical and Process Engineering – and from the Paul Scherrer Institute. It's important to promote an interdisciplinary approach, because we really are in the process of transitioning from basic research, where there's still an awful lot to do, to real-world quantum technology applications. And these applications are certainly not confined to the realm of physics; in fact they may even turn out to be predominantly in other areas such as chemistry, materials science and ⟶

ANDREAS WALLRAFF is Professor of Solid State Physics and head of the Quantum Device Lab at ETH Zurich. He is also the founding director of the recently established Quantum Center at ETH Zurich and leads efforts to build superconducting quantum computers at the ETH Zurich – PSI Quantum Computing Hub.
⟶ qudev.phys.ethz.ch

VANESSA WOOD has been Vice President for Knowledge Transfer and Corporate Relations at ETH Zurich since 2021. She is also full professor and chair at the Institute for Electronics (IfE) at ETH Zurich.
⟶ ethz.ch/vp-knowledgetransfer

Images: Giulia Marthaler; Markus Bertschi

“ETH has made targeted investments in the quantum space.”

Vanessa Wood

computer science. That’s why we also need to address students outside the physics bubble – with courses like the Master of Science in Quantum Engineering, for example.

How competitive is Switzerland in the quantum sphere?

WOOD: Very competitive indeed. The Swiss NCCR programme “QSIT – Quantum Science & Technology”, which brings together researchers in this field from across Switzerland, has been running since 2011. Switzerland’s success is also reflected in the record number of professors taking part not only in Horizon 2020 projects but also in numerous projects funded by third countries such as the US, where ETH and other Swiss research groups have been invited to participate. At the same time, however, the failure to reach a Swiss-EU institutional framework agreement leaves us in a quandary. It means we’ll have to find ways of ensuring that Swiss research remains an attractive option for partnerships in these research programmes.

WALLRAFF: Switzerland may be a small country, but it has a big influence on the development of quantum technologies. The whole theory and practice of quantum technology increasingly feels like a high-tech race, so our task now is to identify ways of maintaining our competitive edge in the future.

How did ETH establish such a strong position in the quantum sciences?

WOOD: ETH has long striven to gain a good strategic position in this field. We do that by investing in people as well as in the latest and most cutting-edge infrastructure and equipment. We’re very fortunate to have professors at ETH who rank among the world’s best in all the major quantum computer technologies, including superconducting circuits and photonics, to name just two. ETH ploughed significant support and funding into the creation of a Master of Science in Quantum Engineering, the first programme of its kind in Europe. Financing for the Quantum Center came from the ETH+ initiative and the ETH Foundation. ETH also joined forces with PSI to back the creation of the Quantum Computing Hub, a cutting-edge laboratory that aims to address the challenges of scaling up quantum computers.

WALLRAFF: There was a moment in 2005 where I was able to choose which direction my career should take – and I knew I wanted to go somewhere that would allow me to turn theory into practice. Quantum research is a high-tech field, so you can’t get anywhere without seriously complex infrastructure and the right resources. ETH has managed to keep that impetus going and deliver steady growth over all these years, and now it’s reaping the benefits. I’m sure we’ll continue to enjoy this momentum for many years to come. ○

FUNDING FOR THE QUANTUM CENTER
To reinforce its leading position in quantum research and help translate theory into practice, ETH Zurich teamed up with the Paul Scherrer Institute (PSI) to establish the new Quantum Center. Donor funding supports the ongoing development of a technological base to enable the manufacture of quantum computers as well as a doctoral programme and new professorships.

⟶ ethz-foundation.ch/en/quantum

To find out more about this topic, check out our exciting videos of quantum researchers at work:
⟶ ethz.ch/en/globe-21-03

Videos: Nicole Davidson

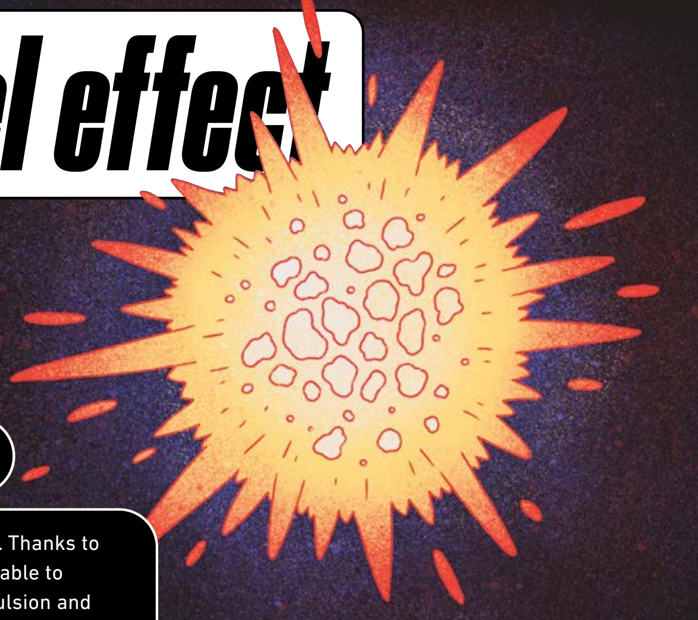
Potential well

Trapped! Classical particles can only make it to the top if they possess sufficient energy.

Quantum particles can overcome insurmountable barriers – almost as if they were tunnelling through them like superheroes. Yet the probabilities for this can be extremely low.

04

Tunnel effect



Nuclear fusion

Protons repel one another. Thanks to the tunnel effect, they are able to overcome this mutual repulsion and fuse. This releases enormous amounts of energy – just like in the Sun.

The whole is the truth

Quantum physics opens our eyes to the holistic nature of reality. Nothing can be observed in isolation – and everything is governed by chance.

TEXT Christoph Elhardt

We generally assume that the objects around us exist independently of us and of other objects. We can observe a glass as a well-defined object and investigate its chemical or physical properties in the lab. We can even predict its behaviour at any point in time as long as we know all the external factors acting on it. Science encounters a reality made up of clearly delineated objects: a reality that can be measured by scientific instruments and ultimately even be controlled. From the steam engine to the light bulb, many examples of scientific progress are based on this notion, all condensed by classical physics into verifiable laws of nature such as Newtonian mechanics, electrodynamics and thermodynamics. The realm of classical physics is ruled by determinism.

In the early 20th century, however, this deterministic view of the world began to crumble. Physicists such as Max Planck, Albert Einstein and Nils Bohr showed that classical physics could not describe phenomena at the level of atoms and elementary particles. The world of microscopic particles, it appeared, was governed by fundamentally different rules.

THE END OF DETERMINISM "Quantum physics breaks with the idea of a deterministic reality that breaks down into subsystems," says physicist and ETH professor Hans Christian Öttinger. He conducts research in quantum field theory in the Department of Materials and specialises in the philosophical and epistemological implications of quantum theory. "In the subatomic world, we can no longer observe things in isolation, because quantum physics tells us that everything can be correlated," says Öttinger.

If we measure or observe a system of electrons, photons or other microscopic particles, we inevitably interact with the system and become part of a larger holistic system. Viewed in this way, we are investigating not an independent reality but also all the changes that are unavoidably triggered by our measurements or other interventions. Moreover, while in classical physics seemingly random behaviour occurs only as a product of insufficient information or measurement error, quantum theory elevates randomness to a fundamental principle. "Our quantum physical representation of the world clearly implies a genuine randomness in the universe," says Öttinger.

THE DOUBLE-SLIT EXPERIMENT This is powerfully illustrated by the well-known double-slit experiment. If we fire photons from a light source onto a detector screen, they appear on the screen at random points spread over a wide area, even though they were fired under identical physical conditions. No pattern can be discerned; randomness prevails. Yet if we were to fire multiple bullets from a pistol, all under exactly the same experimental conditions, we could be confident of them all hitting the same spot. If we now position a plate containing two identical, parallel slits between the light source and the detector screen and then repeat the photon experiment, a pattern of alternating bands appears on the screen. This striped interference pattern can be represented mathematically by a wave function, which enables physicists to determine the probability of particles hitting a specific spot on the screen. In the quantum world, these kinds of probabilistic statements replace the determinism of classical physics. And the experiment has another surprise in store: if we place a particle detector at each slit so as to determine which of them each photon passes through, the pattern changes once again.

According to ETH professor Öttinger, this is only to be expected: "The moment we add the double-slit plate and the detectors to the experiment, we alter the world we were hoping to observe, because each interacts with the photons and affects their behaviour." This also applies to other elementary particles: neither whole atoms nor individual electrons can be measured without regarding them as part of a larger holistic system. But if everything is correlated, how is it possible that we can observe a glass and other large objects in isolation? Öttinger and other theoretical physicists argue that decoherence effects are at work: "Mutual correlations quickly decay in the case of large objects. That's why we can study a glass or a stone in isolation without having to consider its interactions with its surroundings."

COMPLEMENTARITY AND CONTRADICTION Öttinger's explanations on the holistic nature of quantum systems and decoherence certainly sound convincing. Yet they contradict the dominant reading of quantum theory originally proposed by Nils Bohr. Known as the Copenhagen interpretation, Bohr's version states that quantum mechanics does not describe reality itself, but rather a state of knowledge about reality. Bohr worked on the assumption that every object in quantum physics always exhibits properties of both a wave and a particle. Scientists refer to this as the complementarity principle, or wave-particle duality. In this interpretation, the light and dark bands of the interference pattern in the double-slit experiment are taken as an indication that photons really do pass through the two slits as waves. Measuring their motion with a detector causes a collapse of the wave function, which is why the photons subsequently appear on the screen as discrete particles. Öttinger and other physicists argue that this reading raises more questions than it answers. Why should we assume that particles travel in a wave-like manner? Doesn't this assumption contradict the notion of wave-function collapse? How exactly should we interpret the concept of a particle in quantum physics anyway? And can these particles really travel along paths?

QUANTUM FIELD THEORY According to Öttinger, such questions compel us to abandon classical terms such as particle, wave and motion. He regards quantum field theory as the most promising starting point for a fundamental explanation of quantum phenomena, even though its robust and graphic formulation throws up some major problems. In quantum field theory, new particles can appear and disappear at any time. Rather than focusing on individual particles, Öttinger prefers to talk about particle clouds or particle swarms, in which individual particles can only be discerned once a certain resolution is reached. Below this threshold, they are blurred or "smeared out", much like a picture in which individual pixels only become visible when you zoom in, and where the exact pixel resolution is not important to the picture as a whole.

Whether this interpretation of the quantum world will ultimately prove more convincing is likely to remain a matter of debate for some time to come. Nonetheless, the applications of quantum theory have long since become part of our day-to-day lives, even if it seems we do not fully understand the mathematical formalism on which they are based. Taking that step would require a willingness to broaden our current range of experience by incorporating new insights. ○

HANS CHRISTIAN ÖTTINGER is Professor of Polymer Physics in the Department of Materials at ETH Zurich.
⟶ polyphys.mat.ethz.ch

An unusual encounter: ETH President Joël Mesot chats with Digital Einstein.

Image: Nicole Davidson

Conversations with Einstein

When ETH President Joël Mesot lowered himself into an armchair in ETH's biggest lecture hall, he was faced with an unexpected guest. Sitting opposite him was one of the most famous personalities of the 20th century, instantly recognisable by his moustache and dishevelled hair. The surprise guest at this year's Rössler Prize ceremony was Albert Einstein , and he had come in a very unusual guise: as a digital human, who asked questions, gesticulated wildly and bluntly informed Mesot that he couldn't imagine a worse job than being ETH President.

It was ETH professor Markus Gross and his team who came up with the idea of Digital Einstein. "To mark the centenary of Einstein's Nobel Prize in Physics, we wanted to show that we have the technological know-how to bring our most famous alumnus to life as an animated character," says Gross.

A SPIN-OFF SUCCESS ETH spin-off company Animatico developed Digital Einstein in cooperation with researchers at ETH. Swiss comedian Karpi provided Einstein's voice, devised the content and collaborated with a digital artist on the digital figure's 3D appearance.

"Digital humans like Einstein who can see, hear and interact with the person in front of them are driven by complex algorithmic systems," says Christian Schüller, one of the three founders of Animatico. Key technologies include natural-language processing and dynamic rendering of the individual's expressions and body language. To help Einstein identify interlocutors and ask them questions, a small camera is used to scan people's movements and reactions. Whenever someone addresses Einstein, microphones filter their voice out of the ambient noise. Their words are then converted into text and analysed by language-processing software. The program uses machine learning to determine what they wish to say and then employs a dialogue algorithm to choose the most appropriate answer along with expressions and gestures from a finite universe of possible reactions.

EINSTEIN STILL HAS A LOT TO LEARN Currently, Digital Einstein can only select from a predefined set of answers and responses programmed by the developers. This means the dialogue can be guided along predetermined narrative paths, though it also limits the flow of conversation. "We'll definitely see conversations opening up more in the future," says Gross. "But that will require digital humans such as Einstein to have access to a knowledge base and become self-learning. They'll also need a working memory and emotions, but current machine-learning and language-processing applications are not yet mature enough to achieve that."

Digital Einstein and other digital characters offer an opportunity to make interaction between humans and machines more intuitive and more accessible to people who are less tech-savvy or who have disabilities. Digital humans might be deployed at ticket counters and hotel check-ins to make these processes more convenient. They could also provide product advice and act as virtual coaches in healthcare settings. And these are just a few examples of what's possible. — Christoph Elhardt ○

MEET DIGITAL EINSTEIN Digital Einstein will be taking up his post in the ETH Zurich Main Building at the start of the semester on 22 September 2021. Students, staff members and visitors to ETH have until mid-October to strike up a conversation with Einstein and find out more about his time as a student and professor at ETH.

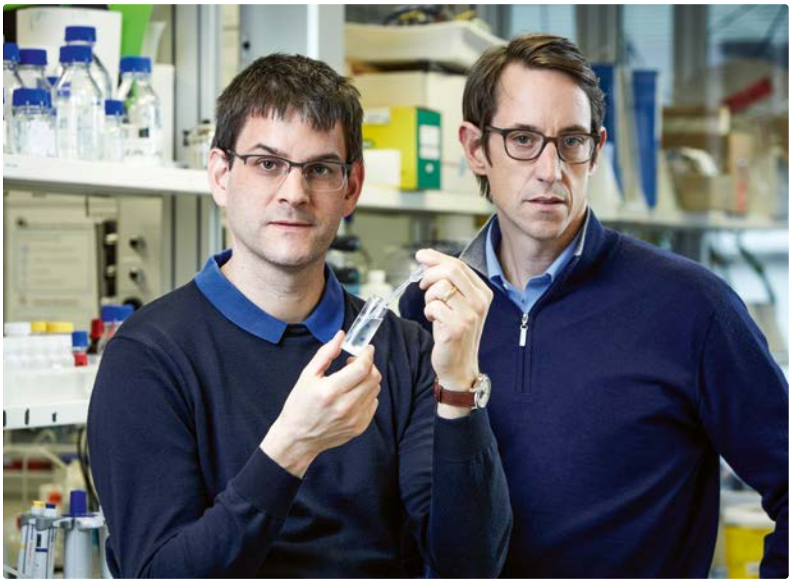
Image: Florian Meyer

Andreas Krause (left) with prize donor Max Rössler.

Mastermind of machine learning

Andreas Krause is Professor of Computer Science at ETH Zurich and one of Europe's leading researchers in machine learning. He is also the winner of the 2021 Rössler Prize, which honours groundbreaking achievements and is ETH Zurich's most generous research award. This year's Rössler Prize was presented at the ETH Foundation's thanksgiving event. "Andreas Krause is a stellar researcher and a dedicated lecturer. For someone at such an early stage of his academic career, he has already earned a notable number of merits in one of the most impactful technologies of the 21st century," said ETH President Joël Mesot in his speech.

ETH alumnus Max Rössler gifted 10 million francs to the ETH Foundation in 2008. The interest from this capital is used to fund an annual prize worth 200,000 Swiss francs for ETH professors who are rising stars in their area of research. ○



Wendelin Stark (left) and Robert Grass, winners of the European Inventor Award 2021.

Image: EPO

European Inventor Award

ETH professors Robert Grass and Wendelin Stark have won the 2021 European Inventor Award in the category of Research, as presented by the European Patent Office (EPO). The two scientists are pioneers in DNA encapsulation, a groundbreaking technique in which data stored in genetic code is enclosed in tiny glass beads. To illustrate the huge potential of this technology, they staged a number of demonstrations, including the DNA encoding of the opening season of the Netflix series Biohackers. Haelixa, an ETH spin-off, is now marketing DNA encapsulation as a method of data storage. With this development, DNA can be used to label gemstones, gold and even organic cotton, thereby ensuring they remain traceable along the entire supply chain. ○

Eight consecutive years in the top ten

ETH Zurich has been awarded eighth place in the QS World University Rankings for 2022. This is the eighth consecutive year that ETH has featured in the top ten of the QS ranking list, which includes 1,300 institutions from all over the world. The university's overall score actually increased this year from 95 to 95.4 (out of 100), though the competitive nature of the rankings saw ETH Zurich slip from sixth to eighth in the 2022 list. It was overtaken by the University of Cambridge and Imperial College London and now shares eighth spot with University College London. ETH Zurich remains continental Europe's best university for the 14th consecutive year. ○

New affiliate organisations

The ETH Alumni Association has a new affiliate organisation in China. The Chapter Shenzhen Alumni was founded by Claire Zhang and Hanyu Qin. Claire graduated with a Master's in Energy Science and Technology, while Hanyu completed his doctorate in the Department of Biosystems Science and Engineering. Both now live in Shenzhen, China's innovation hub.

Caya Gharibian, Alessandra Pfister and Leonie Perren are among the first students to graduate from ETH with a Bachelor's degree in human medicine. They are now continuing their studies in Basel, Lugano and Zurich to graduate as doctors. They have set up Human Medicine Alumni to provide a shared platform for ETH graduates of the Bachelor's programme in human medicine. ○

TRANSFER

Technology for a safer ride

Motorcyclists are much more likely to suffer a fatal accident than people using other vehicles, particularly when riding around bends in the road. Simon Hecker, Pioneer Fellow 2019, and other ETH researchers are hoping to improve this situation with the use of smart safety technology.

Aegis Rider Technology draws on the latest advances in computer vision, mapping and control theory to improve cornering safety for motorcyclists. It uses a combination of cameras, machine learning and digital map processing to calculate the safest trajectory. The result is sent to an augmented reality display integrated within the motorcycle helmet, helping to guide the rider along the ideal line through the bend. The system also warns riders if they are going too fast and indicates the correct bike tilt and position when cornering.

A start-up company is now working on the further development and commercialisation of this potentially life-saving product. ○

Aegis Rider Technology: Start-up
Founded: 2020
Product: Safety technology for motorcycles

⟶ aegisrider.com

Illustration: Carolin Eitel

"Our researchers shouldn't be the ones who suffer."

Image: Markus Bertschi

Detlef Günther, Vice President for Research at ETH Zurich

The termination of negotiations on the EU-Swiss institutional framework agreement has real consequences. The EU will now treat Switzerland as a non-associated third country when it comes to applying for project funding.

As participants from a non-associated third country, Swiss researchers and innovators can continue to submit applications in response to calls for collaborative projects in which third countries are eligible to participate. Instead of being financed by the European Commission, the Swiss contribution will now be funded directly by the State Secretariat for Education, Research and Innovation (SERI). However, participants from non-associated third countries cannot take on coordination roles in collaborative projects. Similarly, participation in mono-beneficiary projects is not allowed for researchers from non-associated third countries, with the exception of 2021 calls for ERC Starting Grants and ERC Consolidator Grants. Researchers who have been awarded an ERC Starting or Consolidator Grant will receive direct funding from SERI. Yet these changes to research funding are only one aspect of the new reality. Detlef Günther, Vice President for Research at ETH Zurich, is particularly concerned about Switzerland's future standing in the international research community.

Detlef Günther, Switzerland will now be treated as a non-associated third country in Horizon Europe. What does this mean for ETH Zurich?

Switzerland's full-association status in the world's largest research funding programme is of crucial importance to ETH Zurich. Since 2007, ETH researchers have received over 500 million Swiss francs from the European Research Council (ERC) to advance their research projects. Personally, I find it incomprehensible that ETH should now be excluded from so many of these funding programmes. It really is deeply regrettable.

Is ETH now short of research funds?

We will have to rely on additional support from the Swiss government. But the finances are only one aspect of Horizon Europe – even more important are the international collaborations and competition among Europe's best universities. We're already seeing a huge drop in our researchers' ability to compete, and this will ultimately make Switzerland a less attractive place for leading researchers to work. Put simply, we've been thrown out of the Champions League and relegated to playing in the Swiss League.

If this were football, some players might be thinking of changing clubs…

That's exactly what we're worried about. If we're only allowed to play occasional matches for the foreseeable future and have no chance of getting to the top of any league, then top-flight researchers might leave Switzerland or not come here at all. We will lose vital know-how – and that will inevitably have a negative impact on Switzerland's economy.

What effect will this decision have on international research collaboration?

Around half of our international research cooperation is currently with EU countries. Europe is the most important international partner to us and all the other Swiss universities. Collaborating with other European universities will now become a Herculean task. Having to draw up individual contracts for each project will be time-consuming and delay research – and that will significantly reduce the attractiveness of Swiss universities as research partners.

What do you think will happen in the future?

I'm glad that SERI has introduced transitional measures to help us in the short term, because our researchers shouldn't be the ones suffering from the current situation of political negotiations with the EU. In the long term, Swiss decision-makers should do everything in their power to advance negotiations with the European Union. We need Switzerland to regain full-association status in Horizon Europe so that it can maintain its position as a leading research location. I firmly believe that it is in the interest not only of Swiss universities, but also of all European universities, that Switzerland should maintain full representation in cutting-edge research. We're currently facing huge global challenges as well as increasing competition from international players, so it's more important than ever for Europe to pool its strengths when it comes to research. ○

PHILANTHROPY

BY
Donald Tillman

Intergenerational solidarity, Geneva-style

Solidarity between generations has been very much in the news lately, and I have an inspiring example that I would like to share with you today. The ETH Foundation was recently contacted by ETH alumnus Edwin Zurkirch, long-time president of the GEP Geneva chapter, an alumni group founded in 1910. With many of its members getting on in years, a decision was made to disband the group and start afresh. Mr Zurkirch and his colleagues came up with the idea of donating the remaining funds from the chapter's coffers to support scholarships for ETH students raised in the French-speaking part of Switzerland. Every year, scholarships are granted to numerous students from this region who face challenging financial circumstances. It was therefore a very welcome proposal. This philanthropic gesture by the Geneva chapter will open up access to ETH for young people who meet all the criteria for studying at ETH but would simply be unable to afford it without financial support. It would be hard to find a better example of solidarity that spans generations!

→ www.ethz-foundation.ch/en/eth-scholarships/

Image: Eline Keller-Soerensen

ETH zürich

Master of Advanced Studies in
Management, Technology, and Economics

IN PERSON

SARAH HOFER is researching methods of learning and instruction in STEM subjects. She investigates how intelligence, prior knowledge and gender can affect learning methods and successful learning outcomes.

TEXT Karin Köchle

What's the main challenge involved in teaching mathematical and scientific subjects?

A lot of the material is highly abstract, so the trick is to use illustrative models that help students visualise something they can't normally see. Sometimes, too, everyday experience can interfere with the learning process. Our experience of moving objects, for example, is difficult to reconcile with the principle of inertia. That's why it's so important to make a connection between everyday experiences and scientific concepts.

How can we improve gender equality when it comes to education?

Teachers do sometimes show bias towards students of a particular gender, whether consciously or unconsciously. But we can help tackle that by raising awareness and encouraging teachers to self-monitor. When assessing student performance, the use of standardised or anonymised processes can help them stay as objective as possible. In general, students are more likely to achieve their potential in classes that address their individual requirements and interests – irrespective of their gender.

What led you to study psychology?

I wrote a term paper at secondary school about the behaviour and experience of the protagonists in two dystopian novels. It was so interesting that it made me want to find out more about how people think, feel, learn and act – how that all unfolds and what role the environment and context have to play.

What were the key learning experiences of your career so far?

A big step for me was the realisation that I shouldn't let myself get sucked in by the huge pressure placed on young researchers. Otherwise, it's easy to end up on a hamster wheel and forget what you're actually there for – namely, to produce high-quality, meaningful research and innovative ideas, both of which generally take time, and not just churn out new stuff on a conveyor belt.

What will be your first project as assistant professor at ETH?

In one project, we're going to be using augmented reality in physics teaching. We want to find out if computer-generated teaching aids displayed in AR headsets can help students achieve a deeper understanding of the subject matter. ○

SARAH HOFER is a tenure-track assistant professor of learning and technology in the Department of Humanities, Social and Political Sciences.
—› gess.ethz.ch

Image: courtesy of Sarah Hofer

TRACKING DOWN TRACK BALLAST

TEXT Felix Würsten
IMAGES Daniel Winkler

documenting her findings, she quickly realises that there is a huge difference between constructing geological profiles in theory and recording them in the field.

HIGH DEMAND Lukas and Stefan have good reasons for sending Maira into this rugged and inaccessible gorge. Switzerland is likely to face a shortage of the hard rock aggregate which is used as ballast to support railway tracks. On the face of it, Switzerland has plenty of hard rock to spare – but very little of it is up to this particular challenge. Not only must hard rock ballast be tough and weather-resistant; the broken stones also need to be irregular and angular in shape so as to ensure they interlock properly in the trackbed. Finding the right rock to meet these criteria isn't easy: granite from the Aar massif doesn't come up to scratch, nor does Jurassic limestone – and still less so the platy gneisses from southern Switzerland.

Yet with track ballast being replaced about once every 30 years – on a tight schedule designed to minimise disruption to busy railway timetables – demand is high. A large part of the old ballast can be reused, while much of the rest is repurposed as aggregate for road construction. A steady supply of new ballast material is therefore essential. Yet simply extracting unlimited quantities of rock from existing sites is no longer an option, since quarrying is often incompatible with other interests. Protected landscapes, conservation areas, housing developments and tourist activities all limit the amount of rock that can be taken – a dilemma that also hampers the extraction of other resources like gravel and marly limestones for cement production.

Here in the Chessiloch gorge, the geologists want to study a rock formation that has not yet been exploited. "Most rock ballast is made from siliceous limestone," says Lukas. "But the Hohgant sandstone in this riverbed might also fit the bill." However, quarrying near the Chessiloch gorge is out of the question: not only is it a protected biosphere reserve; it is also far too remote, with no roads or railways to transport the rocks. Nevertheless, this spot is of great interest to the geologists. "What we have here is an uninterrupted rock formation that we can record in its entirety," says Stefan. "It's a great model to help us determine which sections of the formation would be worth quarrying at other sites where this sandstone occurs."

REPORT | Switzerland may soon be facing a shortage of railway ballast. ETH geologists are heading into the wilds to track down new sources of crushed rocks.

After a steep descent through the forest, we finally reach the river. We're in the southwestern part of Switzerland's Entlebuch biosphere reserve, not far from the remote wilderness of the Chessiloch gorge – and right at the heart of Maira Coray's field area. The ETH Zurich geology student is drawing a geological profile along the riverbed for her Bachelor's thesis, recording the details of all the rock strata over a stretch of several hundred metres. This is Maira's third visit to the area. This time she is accompanied by her supervisors, Lukas Nibourel and Stefan Heuberger, from the Georesources Switzerland Group in the Department of Earth Sciences, and by Stephan Wohlwend, a scientist from the Climate Geology group, who advises Maira on the interpretation of her field samples. Together, these three experienced geologists give her the expert support she needs and help her collect samples for more lab analyses.

This project is Maira's first step towards becoming a fully fledged geologist. As well as learning valuable lessons on examining rocks in situ and

FIELD WORK IS HARD WORK Before starting the actual field work, we clamber a little further down the gorge. We're now at the bottom of a waterfall that towers some 10 metres above us, where a massive outcrop of Hohgant sandstone forms a slight overhang. Maira pulls out her tablet and jots down a few notes. She also uses it to measure ⟶

the orientation of the rock strata, and the software plots this data directly into a digital map. "It's a great tool, but for certain types of observations you still can't beat a traditional field book," she says.

Meanwhile, Stefan and Lukas are hard at work, hammering away at the hard rock to break off samples. Ideally, Maira would also like to take a sample from the upper section of the rocky overhang – but that high-hanging fruit proves too much of a challenge even for the climbing skills of the geologists. Their work is interrupted by an enthusiastic Stephan, who comes scrambling up the slope: "There are some pretty big fossils down there," he says. "But I'm not sure if I've found the base of the rock formation yet." The researchers are still uncertain as to where the boundary lies to the rock layer below. We fight our way further through the rugged terrain. The rocks in this part of the stream are polished smooth, so that the large fossils Stephan discovered are now clearly visible. "This might be the boundary between the strata," he says. But he and Maira clearly have doubts, so we press on.

Soon, we find what we're looking for: at the very next rocky outcrop, Lukas spots the boundary between the brown sandy rocks, which include the Hohgant sandstone, and the light-grey Schrattenkalk limestone below. A strip, only a couple of centimetres thick, marks the contact between the two strata. "There's a gap of up to 80 million years here," says Lukas with a grin. "The limestone was deposited around 125 million years ago, but the sandstone layer only came along around 45 million years ago."

That means this spot next to the river spent some time at the Earth's surface 45 million years ago before it was submerged by the ocean. During that period, rivers transported large quantities of quartz sand from the hinterland to the sea, which eventually became part of the Hohgant sandstone. But where exactly did the sand come from? It seems unlikely to have come from the nearby Aar massif, which was still covered by calcareous sediments at that time. It might have come from the Black Forest massif. Yet, the irregular grains in the sandstone would surely be much more rounded if they had travelled such a long distance.

1

COMMISSIONED BY SWISSTOPO This would be a fascinating topic for the scientists to study, but their current brief leaves little leeway to pursue it, explains Lukas. As project manager, he is responsible for keeping everything on track: "We were commissioned to carry out the study by the Federal Office of Topography (swisstopo). Their primary goal is to evaluate potential sites for quarrying suitable hard rock." It may seem surprising that such a meticulously mapped country as Switzerland shouldn't know exactly where to find the right kind of rock in the right quantities, but much of the current data is incomplete. Faced with looming shortages of the necessary materials, swisstopo commissioned the Georesources Switzerland Group to compile an inventory of all potential hard rock occurrences.

Stefan, who has headed the group for around four years, takes a moment during our lunch break to explain its unique role. The group was established in 2018 to replace the Swiss Geotechnical Commission (SGTK), which had been based at ETH Zurich for decades. "We get our basic funding from swisstopo and ETH Zurich, but we still have to fund part of our budget ourselves by conducting studies for industry or government agencies," says Stefan.

The group leads rather a niche existence. "Switzerland's geology is no longer of the main focus of academic research at ETH," says Stefan with a note of regret. "But it's still important to keep this field alive." As well as carrying out projects for federal offices and specialist agencies, the group is also very involved in teaching activities by providing lectures and excursions. "Maira is our first Bachelor's student," Stefan explains. "It's not always easy to find suitable field areas for Bachelor's theses.

Students don't have much time to devote to this work – and if the weather is against us, as it was this spring, then we end up running out of time."

A HEAVY LOAD Climbing back up the hill, we soon find ourselves back where we started, in the middle of the rock section. Maira is keen to take more samples, even though the Hohgant sandstone in this area consists of nothing more than thin layers of rock interspersed with layers of clay, and is clearly unsuitable for quarrying. As Stefan and Lukas get back to hammering, Maira pulls a Schmidt hammer out of a rucksack. This device is normally employed to test the properties of concrete, but it can also be used to measure the hardness of rocks in the field. To build up a reasonably reliable picture, Maira has to measure the rebound of the hammer in various locations, striking the rock in two directions at each of 10 measurement points.

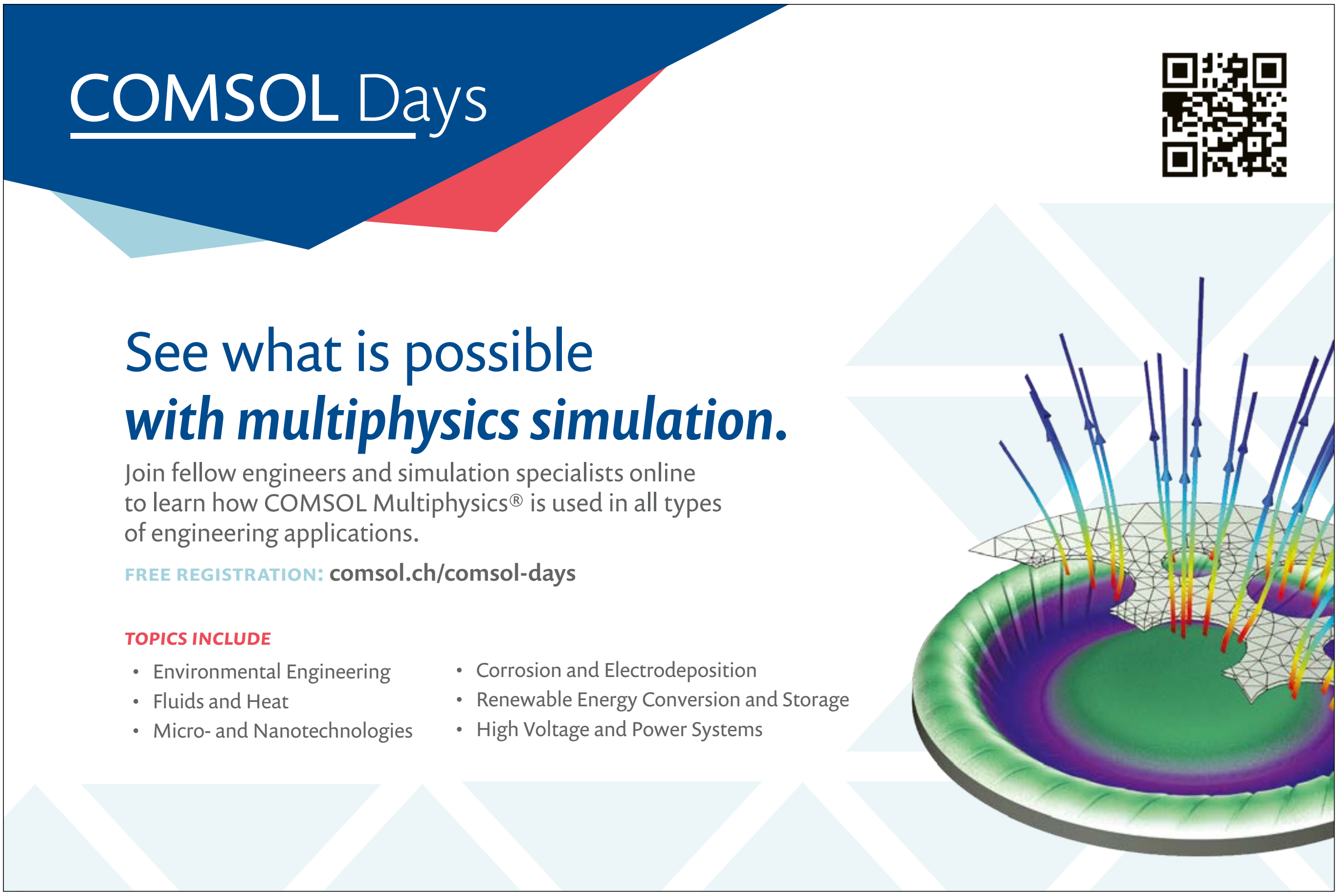
Once Stefan and Lukas have stowed the new samples in their rucksacks, we continue our climb across two more rocky outcrops. Maira also needs samples from the uppermost section, where the Hohgant sandstone again consists of thicker layers. This offers another useful example of how difficult it is to carry out measurements by the book when working in the field: unlike a vertical concrete wall, the surfaces of this rock are not flat and easily accessible. "Conditions in the field are never easy," says Lukas with a shrug.

All in all, Maira and her supervisors have collected some two dozen large pieces of rock. It's been a productive day, and a big step forward in her field work, but right now it's time to carry the heavy load up the slope to the trail and back to the car. Is the Hohgant sandstone hard enough for railway ballast? Only time will tell. Maira's next step will be to analyse the samples back at ETH – this time under clearly defined lab conditions. ○

1
Stefan Heuberger takes a first detailed look at the composition of the rocks while still in the field.

2
Electronic devices may be useful, but Maira Coray also relies on a traditional field book.

2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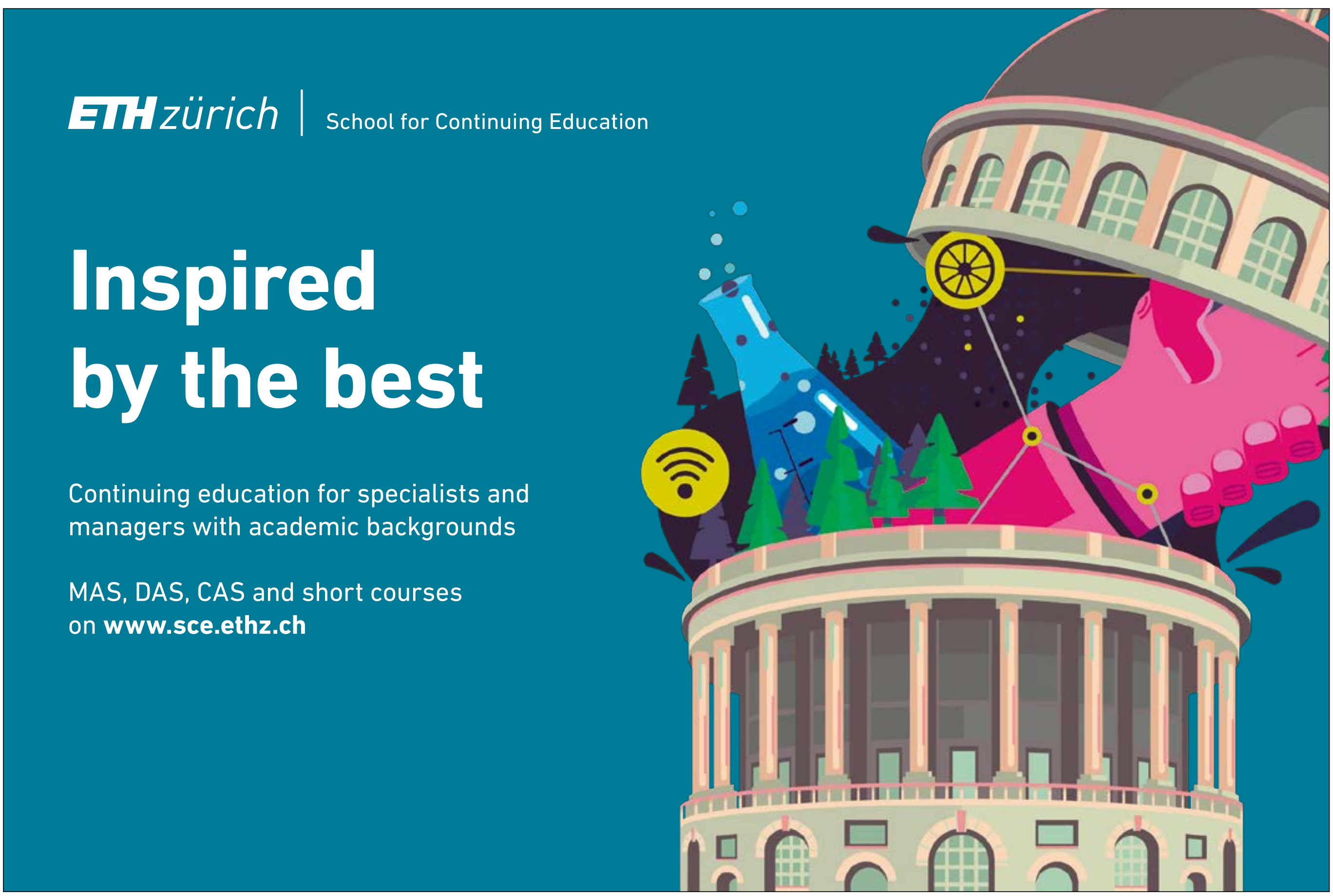
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A HIGHER CALLING

TEXT Leo Herrmann
PHOTOGRAPHY Daniel Winkler

With his zest for life, Manfred Hunziker has never stopped reaching for the heights. A keen mountaineer, he has conquered well over 6,500 peaks. As an ETH graduate in electrical engineering, he followed a career shaped by the dizzying rise of computer technology.

The moment that changed his life, says Manfred Hunziker, came 58 years ago in the winter of 1963 – shortly before 4 p.m. on a Thursday afternoon. The 23-year-old had signed up for a trip to IBM's European research centre in Rüschlikon, an excursion organised by the ETH student association AMIV. The tour of the recently opened centre was impressive – particularly the computer in the basement. But the most memorable moment came over coffee, when an IBM team leader mentioned that the company was looking to fill a programming internship. Hunziker applied and got the job. In the months that followed, he not only gained valuable insights into the world of computers; he also acquired hands-on experience of the employer to whom he would remain loyal until his retirement in 2000 – though he would never have guessed that at the time.

DIPPING INTO THE UNKNOWN After graduating from ETH as an electrical engineer, Hunziker left Zurich and headed across the Atlantic. "Engineers always like to have a goal to focus on," he says. In his case, it was a Master of Science in Electrical Engineering at Georgia Tech, for which he was fortunate enough to receive a scholarship. Hunziker had worked hard at ETH, and he showed the same dedication in Atlanta. This was reflected in his grades, which made a positive impression on industry recruiters who visited Georgia Tech towards the end of the academic year. But what made his CV really stand out was his experience with computers, which was then uncommon and highly sought after. Hunziker was soon invited to interviews at various companies in the US. These included IBM, where the recruiter decided to forward Hunziker's application to their Swiss subsidiary. "They ended up sending me an interesting offer for a job in customer service – right around the time I was starting to feel homesick," says Hunziker. Everything fell into place.

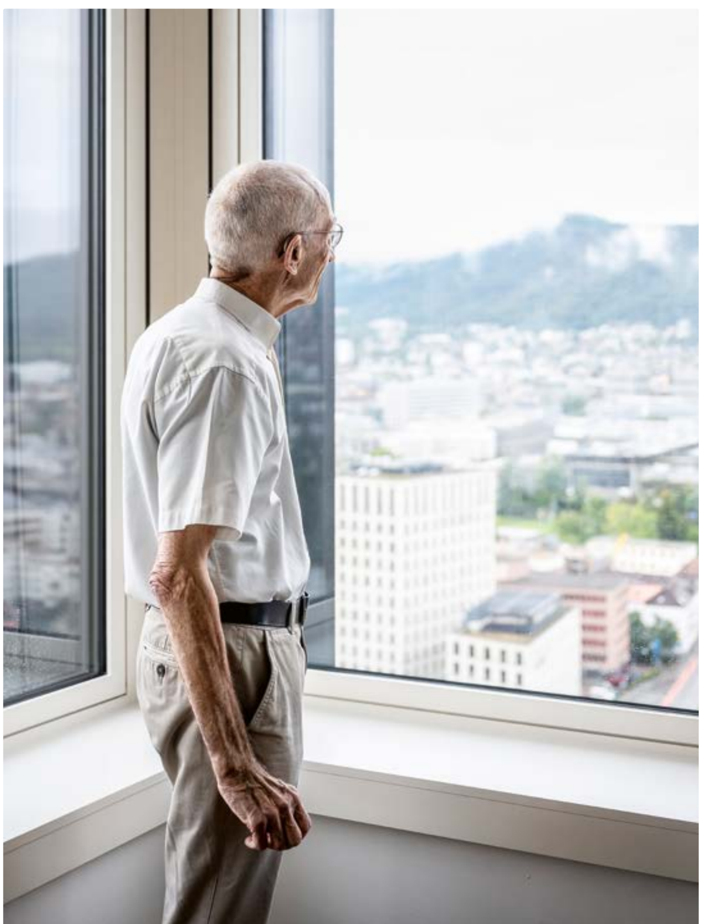
When asked what he learned from his time at university, Hunziker emphasizes the personal aspects: he recalls being something of a country bumpkin, and it was only when he arrived at ETH that he started mixing with more people and finding his feet in different circles. That meant not only Friday-night beers on Bahnhofstrasse, but also working as publishing director in the student association – and even taking the occasional plunge into student activism. When the umbrella organisation of the ETH students' association tried to impose a levy of 6 Swiss francs to fund a mountain lodge in Klosters, Hunziker and his association opposed it. Hunziker produced a leaflet entitled "Where's your money going?", and that, together with a petition, was enough to stop the compulsory levy in its tracks. Today, at 81, he still sees fellow students who were involved in that particular protest; many of them would egg him on to fight for some cause or other, he recalls with a smile. They still meet twice a year for a leisurely meal in a cosy restaurant. The group has gradually shrunk as its members have got older, says Hunziker, but a good dozen of them get together on a fairly regular basis – "to reminisce about the old days". Nowadays, Hunziker provides financial support via ETH Foundation for Excellence Scholarships at ETH, no doubt recalling the time when ETH helped him with a scholarship for his own Master's degree in the US.

SUMMITS ON THE SIDE Although Hunziker enjoyed working at IBM right up until he retired, it was never enough to keep him fully occupied. His zest for life constantly led him to try new things. Inspired by a work-placement student on his team, he decided in his early 30s to reduce his workload by half and take another university degree, this time in law.

MANFRED HUNZIKER A lawyer and ETH graduate in electrical engineering, Hunziker spent his whole career working in customer service at IBM Switzerland. His passion for mountain climbing saw him conquer over 6,500 peaks and lead some 250 mountaineering expeditions. Originally from Märwil in the Swiss canton of Thurgau, he now lives in Zurich.

"Lawyers and judges follow a similar approach to engineers. They have a case put in front of them and then have to follow clear rules to resolve it," says Hunziker. His previous studies and experience gave him a clear edge, and he delighted in the intricacies of the law – so much so that he decided to crown his degree with a dissertation on the subject of copyright. His newly acquired knowledge proved to be a great asset, particularly in his work for the journal UFITA, for which he reviewed around a hundred academic works on copyright law.

When he wasn't working or studying, he chose to spend his leisure time not by relaxing, but by pushing himself to new heights. His passion for mountaineering seemed like the perfect challenge – but he was determined to set himself a clear goal. True to form, Hunziker decided he would attempt to reach a set list of summits. Inspired by Herbert Maeder's book *The Mountains of Switzerland*, Hunziker, then aged 28, set his sights on climbing all of the 2,400 or so peaks listed in the book. "I put on my engineer's hat and did the maths," he says. "I reckoned I could do it if I climbed 60 mountains a year for 40 years." In the end, it took less time than he had thought. At the age of 65, he only had 97 peaks left, most of which were minor ones that no longer appealed to him. He realised then that the time had come for a new goal. Switzerland had become too small for Hunziker's peak-conquering aspirations, so he widened his focus to cover the entire Alpine range, tackling the highest peak in every mountain region from Nice to Trieste. This project, too, was soon more or less completed – with the exception of a few peaks that were of little interest or, in some cases, simply too challenging. Hunziker is ambitious, but also pragmatic. He recalls being just 50 metres away from a summit in the Dolomites when he turned back. Alone and unsecured, the final stretch looked too dangerous: "One slip and I would have fallen 1,000 metres." Technically challenging climbs had never been his strong suit anyway, he admits. He generally chose the easiest routes and usually enlisted the services of a guide for trickier ascents. To date, he has reached an impressive total of 6,500 summits.



ASCENTS BIG AND SMALL Hunziker's wealth of experience in the mountains served him well for his subsequent involvement with the Swiss Alpine Club (SAC). All in all, he led over 250 mountaineering expeditions in Switzerland and beyond, sharing his enthusiasm with less experienced mountain-goers. But he also cast a critical eye on the association's other activities, echoing the non-conformist spirit he had shown at university. "People didn't always take kindly to my dissenting voice, but they respected me for it," he says. Soon, he was elected to the board of the Swiss Alpine Club's Uto section in Zurich, and he made sure to channel his feedback into real improvements – by, for example, collaborating on seven SAC guide books. His bucket list of summits is pretty much complete, he says, though he still enjoys going on expeditions as much as ever. Fortunately, mountaineering is a sport people can enjoy well into older age. "Even today, I still leave some people behind on the way up," he says. His passion for mountain peaks has even influenced his choice of home: he now lives on the 22nd floor of a high-rise building in Altstetten, which is Zurich's equivalent of Alpine-style heights. From his window, he has a panoramic view of the whole city and the Uetliberg mountain. On a clear day, he can even see the Alps. The building has a lift, which he agreed to use on this occasion for the author's sake, but he often takes the stairs: for someone like him, a 60-metre climb is nothing more than a chance to stretch his legs! ○

AGENDA

Due to COVID-19, events may be cancelled or postponed at short notice. Please check the organiser's website.

DISCOVER

○ 7–17 October 2021

Where the future begins

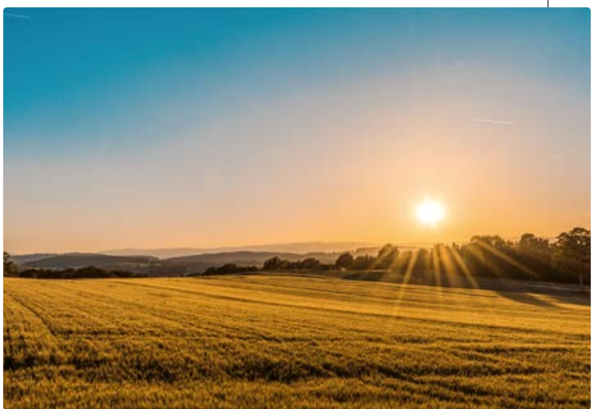


Image:Federico Respini

OLMA, the Swiss agriculture and food fair, will be showcasing how intelligent robots, drones and other digital technology can lead to greater sustainability in farming. Visitors to the ETH stand will gain fun insights into the use of high-tech in modern agriculture.

Find out more:
⟶ olma.ch

○ Monthly, 7–10.30 p.m.

Nightactive

CreativeLabZ is inviting young people between the ages of 16 and 26 to a variety of Swiss museums for an evening programme of "scientainment". Nightactive is a monthly event offering a mixture of entertainment, music and science. September will feature a visit to the FIFA Museum for a taste of eFootball, while October's event will focus on Future Food in Zurich's Mühlerama.

For more information and to sign up:
⟶ nachtaktiv.live

*focus*Terra
○ Until 5 March 2023

Waves – a deep dive!

What paints a rainbow in the sky, sends a song to your ears and warms you up on cold days? Waves! Wherever we go, we are constantly surrounded by waves, even if we can only perceive some of them: water waves, sound waves, light waves. Not only are waves a permanent feature of our lives, they are also used in a wide variety of applications – be it medicine, telecommunications, navigation or the geosciences.

This new interdisciplinary exhibition from *focus*Terra will focus on examples from nature, everyday life, art and research to present a host of phenomena and applications from the world of waves.

ETH Zentrum campus, Sonneggstrasse 5

⟶ focusterra.ethz.ch/en/special-exhibitions

Image: Oculus Illustration

AUDIO

Podcast

The lure of space

This three-part podcast describes one woman's desire to become an astronaut, the investigation of seismic activity on Mars, and the joy of reaching for the stars – including how it feels to win the Nobel prize for the discovery of a new planet.

The podcast is available on all major platforms. It can also be found along with other podcasts at:
⟶ ethz.ch/podcast

○ 14 October 2021, 7.30 p.m.

Piano concert with Emanuil Ivanov

Image: E. Ivanov / musicaldiscovery.ch

The Ferruccio Busoni International Piano Competition is among the most prestigious worldwide. We present the most recent prize-winner, Emanuil Ivanov, and welcome you to a piano recital with a talent who joins the ranks of great performers such as Martha Argerich and Jörg Demus.

Auditorium of the University of Zurich

Information and tickets:
⟶ musicaldiscovery.ch

BOOKS

Draussen ist es anders

New paths towards a science for change

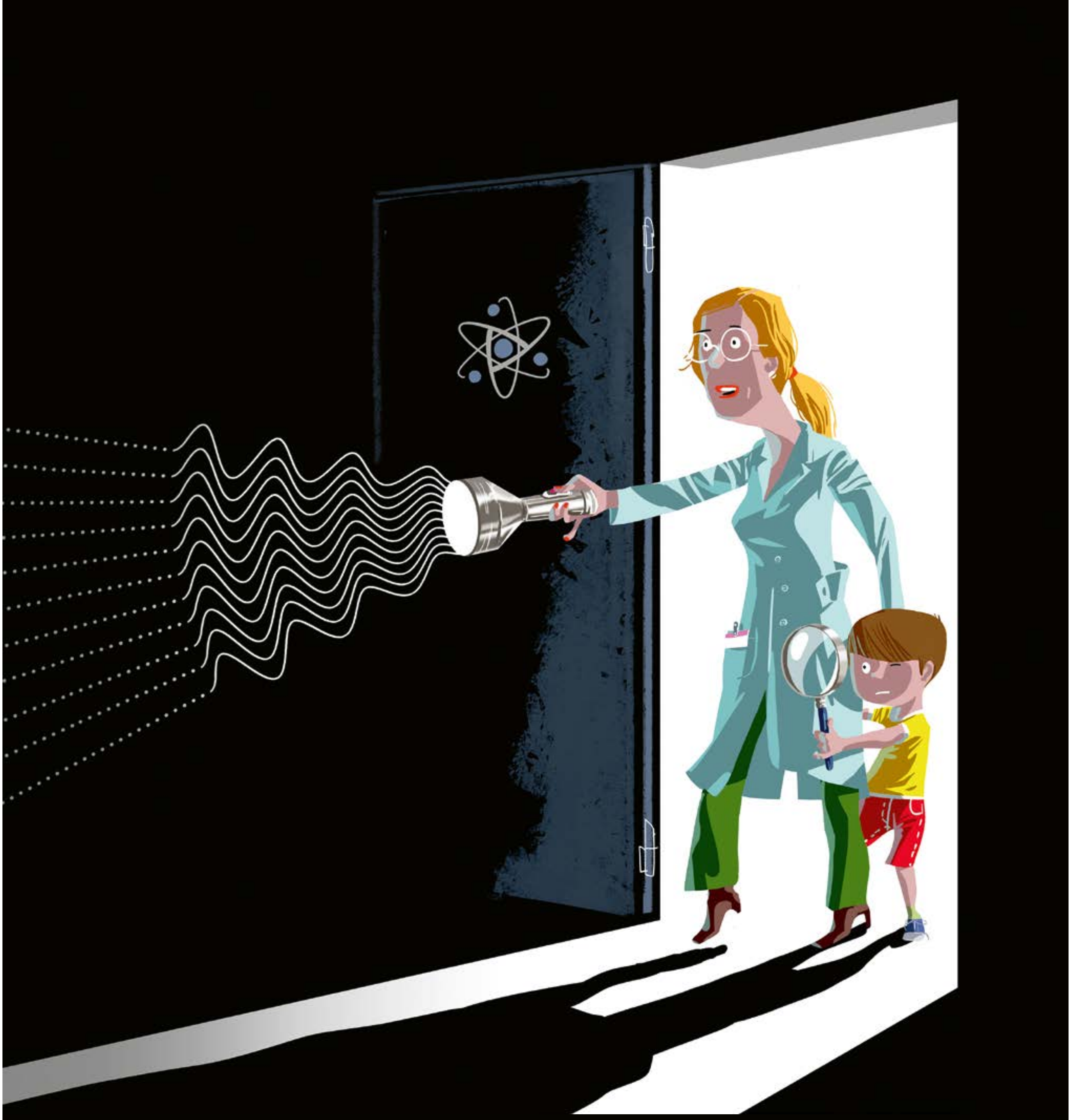
We have reached a crossroads. Radical social change is required if we are to ensure that everyone on this earth can enjoy a good life, both now and in the future. Science has the power to initiate and accelerate this process of change – but only if it can work more closely with industry, the state and civil society. Such is the aim of a transformative science, practised by those who not only analyse change but also play an active, equal and informed role in shaping its development. Yet such a project can only succeed if the scientific community is willing to scrutinise its own practices in the areas of science funding, higher education policy and day-to-day scientific activity.

Image: oekom Verlag

Authored by ETH doctoral student Jan Freihardt, this book presents new approaches and concrete practices that foreshadow the scientific methods of the future. *Draussen ist es anders* ("It's a different world out there") is an honest and encouraging invitation to all those who – blessed with curiosity and a creative will – are involved in study, research or teaching or who hope to be so in the future.

oekom Verlag
ISBN: 978-3-96238-296-4

OUT OF FOCUS



Light in the quantum world, as seen through the eyes of Michael Meister.

Illustration: Michael Meister

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