ETH zürich
NO. 4/2017

GLOBE

MANUFACTURING REDEFINED

From microsensors to digitalised architecture

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The training device to improve breathing
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Computer science: a taster course for girls
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ETH alumnus Rudolf Bär reaches for the stars
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CREATING THE FUTURE

Sensors so tiny that they can't be seen with the naked eye could soon be used ubiquitously – to further automate industrial manufacturing processes, monitor product quality, or measure our health status. Additive manufacturing methods, such as 3D printing, enable resource-efficient production of complex structures of any size in a single step and with brand new properties.

Lino Guzzella, President of ETH Zurich

These new manufacturing methods and the resulting interconnectivity between components – collectively known as "industry 4.0" – shifts the boundaries of conventional manufacturing processes. Just as in other areas, these new production modes will only succeed if they add value for companies and their customers. ETH Zurich works with both SMEs and large corporations to create "added value" and enduring contributions to the competitiveness of Swiss industry.

You can read more about the "added value" of additive manufacturing starting on page 14

Our Competence Center for Materials and Processes (MaP), for example, promotes interdisciplinary research and development of new materials and manufacturing processes. More than 80 professors and their research groups currently participate.

This issue of *Globe* showcases a small selection of their creations in various dimensions: from a tiny, implantable biosensor that can monitor bladder functions in people with paraplegia and 4D printed objects where "time" represents a fourth dimension, to robotically constructed buildings.

I hope you enjoy this edition.
Lino Guzzella, President of ETH Zurich

Cover image: Alain Reiser; Naida Iljazovic / Editorial: Giulia Marthaler

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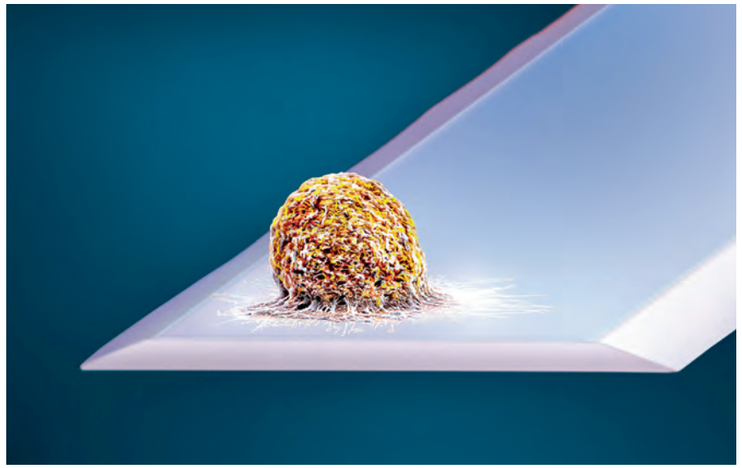
Images: Victoria Loesch & Christian Gerber; Simon Tanner; Daniel Winkler

NEW AND NOTED



Montage of a cell on the highly sensitive weighing arm: the novel cell scale records how live weight changes in real time

A scale for weighing cells

LIVE WEIGHT

Until now, it has not been possible to measure the weight of a living cell. However, ETH research scientists together with colleagues from the University of Basel and University College London have developed a new method of weighing cells. Using this method, they can not only determine the mass of a cell – normally about two to three nanograms – within a very short time, but also measure changes in the weight of the cell in real time, with a resolution of one trillionth of a gram. The patented technology is already available for use under licence.

Stress response

PROTEIN CLUMPS AS TEMPORARY STORAGE

Protein clumps have a bad reputation. When proteins aggregate in nerve cells, this causes the cells to degenerate: a process that has been implicated in many human diseases, especially those of the nervous system, such as Alzheimer's, Parkinson's and amyotrophic lateral sclerosis (ALS). It is no wonder that we have considered such particles first and foremost as pathogenic up until now.

In a study involving yeast cells, ETH research scientists have been able to shed new light on these protein aggregates. They showed that the clumps form in yeast cells when they are subjected to stress factors such as nutrient starvation or heat. If the cells survive this stress, they can dissolve the aggregates and quickly use the individual components in the cellular metabolism again.

The clumps thus have a clear purpose: The yeast cell uses the aggregates as a sort of warehouse for important enzymes, so that these enzymes are not broken down in stress situations and can be reactivated immediately after surviving stress. The protein aggregates protect the individual molecules from being broken down by the cell's own waste-disposal mechanisms. If the cell had to rebuild its metabolic enzymes from scratch after each stress situation, it would cost the cell a lot of time and energy.

Other ETH Zurich research groups have made similar discoveries in the past. They were able to demonstrate that clumps of proteins function, among other things, like a memory and help the cells to store past experiences. This seems to indicate that the clumping of specific proteins is a widespread regulatory mechanism.

The internet of things

A BIOSENSOR FOR FOOD PRODUCTS

Microsensors often contain precious metals that are harmful to the environment and human health. ETH research scientists have now developed an ultra-thin temperature sensor that is both biodegradable and biocompatible, which would make it suitable for monitoring the temperature of food during refrigerated transport.

The ultra-thin temperature sensor is biodegradable

Images: Martin Oeggerli, micronaut.ch / ETH Zurich / University of Basel; Salvatore et al., Adv. Func. Materials, 2017

NEW AND NOTED

Imaging techniques

FLUORESCENT RED IN TWO STEPS

Certain fluorescent proteins can be induced to glow red in a two-stage process, whereby they are stimulated by a blue laser pulse before immediately being exposed to a red laser. Now, an international research team headed by ETH Professor Periklis Pantazis has succeeded in decoding the mechanism that makes this possible. As a result, they were able to extend the two-step method to other fluorescent proteins. This opens up new applications in microscopy and functional analysis in biology research.

In the background of the photomontage, you see two microscopically enlarged proteins of the cytoskeleton: one is an unmodified type of the Eos protein, displayed in blue; the other, a modified type, is displayed in red.

Laboratory of Nano Bio Imaging:
→ www.bsse.ethz.ch/nbi

Light can be used to change the molecular structure of proteins so that they switch their colour

Photomontage: Mohr et al., Angewandte Chemie, 2017, 129, 11786–91, © Wiley-VCH; Crafft

ETH GLOBE 4/2017

Exercise physiology

Respiratory muscle training helps people breathe easy

ETH researchers have developed a special breathing workout that could also help people with age-related mobility problems to improve their health significantly.

Just breathe. Sit still for half an hour and concentrate on your breathing. That's what a training programme co-developed by ETH Professor Christina Spengler is all about. Although it sounds easy at first, it is in fact strenuous and exhausting – but above all highly effective. "A lot of core muscles in the torso are involved in breathing and these are exercised during respiratory muscle training," Spengler says. And it's not just top athletes who benefit from this form of exercise. Spengler believes it also has a lot of potential to help unfit or older people improve their health.

"Many people experience difficulty in breathing. They either have to go at a slower pace when walking or keep pausing for breath when climbing stairs," Spengler explains. Shortness of breath can have a variety of causes; one of them is respiratory muscle fatigue. As Spengler and her colleagues were able to show several years ago, people who specifically worked out their respiratory muscles with the help of such training suffer fewer breathing difficulties over the long term.

Training volunteers use a special device with a mouthpiece through which they breathe in and out deeply. A display shows them how fast and how deeply they should breathe.

To prevent people from breathing out too much carbon dioxide (CO_2) during training and causing the CO_2 concentration in the blood to drop, most of the exhaled air is collected in a sack. This air, which has a higher CO_2 concentration than the ambient air, is inhaled again with the next breath together with a small amount of fresh air. "If the CO_2 concentration in the blood were to decrease, this would cause dizziness or in extreme cases even muscle cramps," Spengler explains.

The device determines how rapidly and deeply users should breathe

For the whole body

Respiratory muscle training is one of Spengler's specialist areas and she has perfected the training programme over the past few years. However, the exercise physiologist admits that doing nothing but breathe intensely for half an hour can be pretty boring. So she and her team have devised a new training programme in which phases of intense breathing alternate with rest phases. During the intense phases, the volunteers also have to overcome an increased resistance. Initial trials with healthy younger volunteers suggest that the less monotonous sprint-interval respiratory training can achieve similar training effects to the previous programme.

Together with colleagues from the Bern University of Applied Sciences and an industrial partner, Spengler is also developing a new device capable of variably regulating the breathing resistance. The device makes it possible to run a performance test based only on breathing, which the ETH professor will use to measure people's fitness levels. Up to now, performance tests have usually been carried out for the whole body. "However, we know that the fitness of the respiratory muscles is also linked to general physical fitness," Spengler says.

Pushing to the limit

One of the most common measurement values for physical stamina today is maximum oxygen uptake. "This parameter is also a significant predictive measure of a person's general state of health," Spengler says. Other scientists have also shown that the lower this value is before an operation, the more likely it is that unfit patients undergoing surgery will develop cardiovascular or respiratory complications.

To measure this value precisely, a person must undergo a performance test to determine their oxygen consumption. This test pushes them to their personal performance limit at which point their maximum oxygen intake is determined. The test is usually performed on a treadmill or a bicycle ergometer, which makes it difficult for people who have joint problems or other mobility issues. The respiratory performance test developed by Spengler on the other hand is designed to measure the maximum oxygen intake in a sitting position.

Hospitals can then use these values to decide whether unfit patients should take a course of breathing exercises – such as the respiratory muscle training mentioned earlier – before certain operations.

Targeted training

Is respiratory muscle training actually better than other sports such as cycling, jogging or swimming? No, Spengler says, adding that not everyone needs specific respiratory training. "Our goal is to determine people's individual performance limits, whether respiratory, circulatory or muscular," the ETH professor says. "This shows where the greatest potential for improving physical fitness lies. People can then target that area specifically in their exercise regime." In addition to measurements relating to fitness levels, personal data such as genetic predisposition are also interesting parameters. In Spengler's opinion, new efforts to gather, collate and evaluate as much personal data as possible therefore show a lot of promise.

Targeted training of the respiratory muscles is particularly interesting for people who do not get much exercise or who easily run out of breath when they physically exert themselves. In the best case, it can help people overcome their shortness of breath and allow them to take up or intensify sporting activities.

The regime can also benefit people with weight problems. A few years ago, Spengler and her team conducted a study with people who wanted to lose weight by following an exercise programme and making changes in their diet. To prepare for the programme, half of the study participants did breathing exercises for a month, while the other half didn't. "We were able to show that the test subjects who had done the respiratory muscle training performed better over the programme as a whole," Spengler says.

— Fabio Bergamin

Exercise Physiology Lab:
→ www.epl.hest.ethz.ch

Image: Victoria Loesch & Christian Gerber

Formed from the magma of a volcanic super-eruption: The Wheeler Monument in Colorado

Supervolcanoes

SPONGY MAGMA CHAMBERS

Supervolcanoes continue to baffle researchers. Up until now, experts have been divided as to whether magma chambers in the Earth's crust under supervolcanoes consist of molten or completely solidified magma. Now ETH researchers have shown that the truth lies somewhere in the middle. Supervolcano magma reservoirs contain a mixture of both molten and solid magma – and are somewhat like soggy sponges.

Medical diagnostics

RAPID ANALYSIS IN DOCTOR'S SURGERY

Infections and metabolic disorders can be detected in blood or urine by means of complex tests in specialist laboratories. Now, scientists at ETH Zurich and the healthcare company Roche have jointly developed an innovative analytical process based on the way molecules on a small chip diffract light. This technique has the potential to revolutionise diagnostics: in future, it may enable doctors to carry out sophisticated tests easily and quickly in their own surgeries.

Just like established diagnostic procedures, the new method also uses the lock-and-key principle for molecular recognition. To determine the presence of a particular protein (the "key") dissolved in the blood, for instance, this protein must dock on to a suitable antibody (the "lock"). In traditional immunological tests, researchers then employ a second "key" marked with dye to make the "key in the lock" visible. This step is redundant in the new process, however, because laser light makes the "key in the lock" visible immediately.

In order to achieve this, the scientists use a chip with a specially coated surface. If they direct laser light along the chip's surface, the light is diffracted by the lock-key combinations and focused onto a point below the chip – where a dot of light appears.

The researchers call their new diagnostic technique "focal mology-raphy". It is substantially faster than previous analytical processes, and it is ideally suited for measuring proteins in bodily fluids or conducting analysis in real time. This opens up a vast range of potential applications.

Generates ultra-pure green light

Light-emitting diode

FOR THE PUREST GREEN

TV displays need to have the purest base colours possible. In the case of green, however, technology is being stretched to its limits. Using an ultra-thin and bendable light-emitting diode (LED), engineers at ETH Zurich have succeeded in generating ultra-pure green light for the first time. This could lead to visible improvements in the colour quality and sharpness of high definition displays for TVs and smartphones. A patent application has been submitted.

Images: Flickr / John Fowler; Sudhir Kumar, Jakub Jagielski

Rapid imaging

A LOOK INSIDE GRANULAR MATTER

Even in today's high-tech world, we still can't really predict when rockslides or earthquakes will occur – nor can we know exactly how they will evolve. This is partly due to the fact that scientists have only a basic understanding of the way gravel and sand behave, particularly when mixed with water or gases. Researchers at ETH Zurich and the University of Zurich, together with colleagues at Osaka University in Japan, have now developed a technique that could make it much easier to study such phenomena in the future.

Granular systems – a generic term for anything that resembles grains or powders – are important not just in nature but also in practical applications, such as the chemical industry. Here, production flows are frequently interrupted by unforeseen jamming or de-mixing of the granular materials used.

To overcome such obstacles, researchers at ETH reintroduced into physics research an imaging technology that is mainly used nowadays in medicine: magnetic resonance imaging (MRI). They added a number of radio antennas to a commercial MRI device, which they used to analyse what happens when gas flows through granular systems. This allowed them to capture images of the inside of agitated granular systems ten thousand times faster than had been possible before.

The gas flow causes the granular medium, which is usually solid, to behave like a fluid. This makes it possible for gas bubbles to rise, split up, or merge. Previously, it was impossible to study such processes in real time.

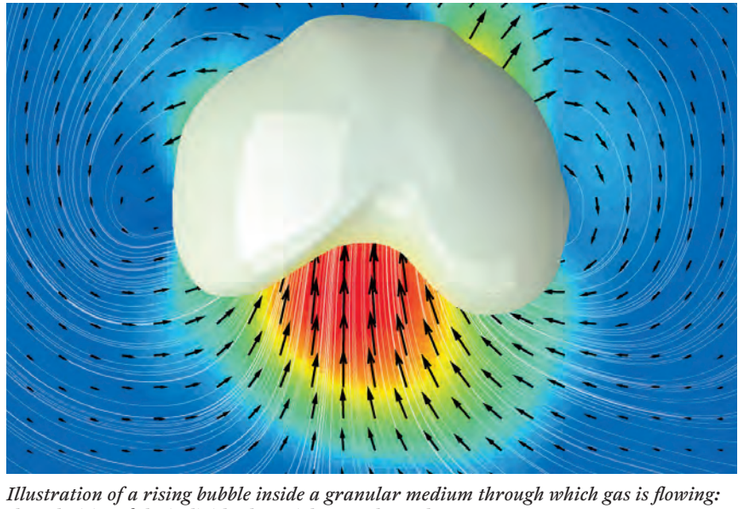


Illustration of a rising bubble inside a granular medium through which gas is flowing: the velocities of the individual particles are shown by arrows

Image: Alexander Penn

Computer working memory

FAST MAGNETIC WRITING OF DATA

For almost 70 years, computers have stored data magnetically on tapes and hard disks. To date, however, magnetic storage technologies have been considered too slow for use in the working memory that computers use to process data. Researchers at ETH have now tested a process that makes magnetic data writing significantly faster and more energy-efficient.

In traditional magnetic storage technologies, current-carrying coils produce a magnetic field that changes the direction of magnetisation in a small area of the data carrier. It would be much more efficient to change the magnetisation direction directly, without any recourse to intermediary magnetic coils.

This is exactly what the ETH researchers have now succeeded in doing. An electric current passing through a specially coated semiconductor film inverts the magnetisation in a tiny metal dot. The process lasts less than one nanosecond, and it produces precise and repeatable results. That makes it potentially suitable for use in magnetic working memory. Magnetic RAM like this would, among other things, make the loading of the operating system obsolete when booting a computer – because programmes would remain in the working memory, even when the power is switched off.

For more information on this and other research news from ETH Zurich, please visit:
→ www.ethz.ch/news

Nano – micro – macro Manufacturing redefined

From the lab to the production floor: *Globe* shows how new technologies like digital fabrication and additive manufacturing are creating new possibilities.

TINY METAL COMPONENTS

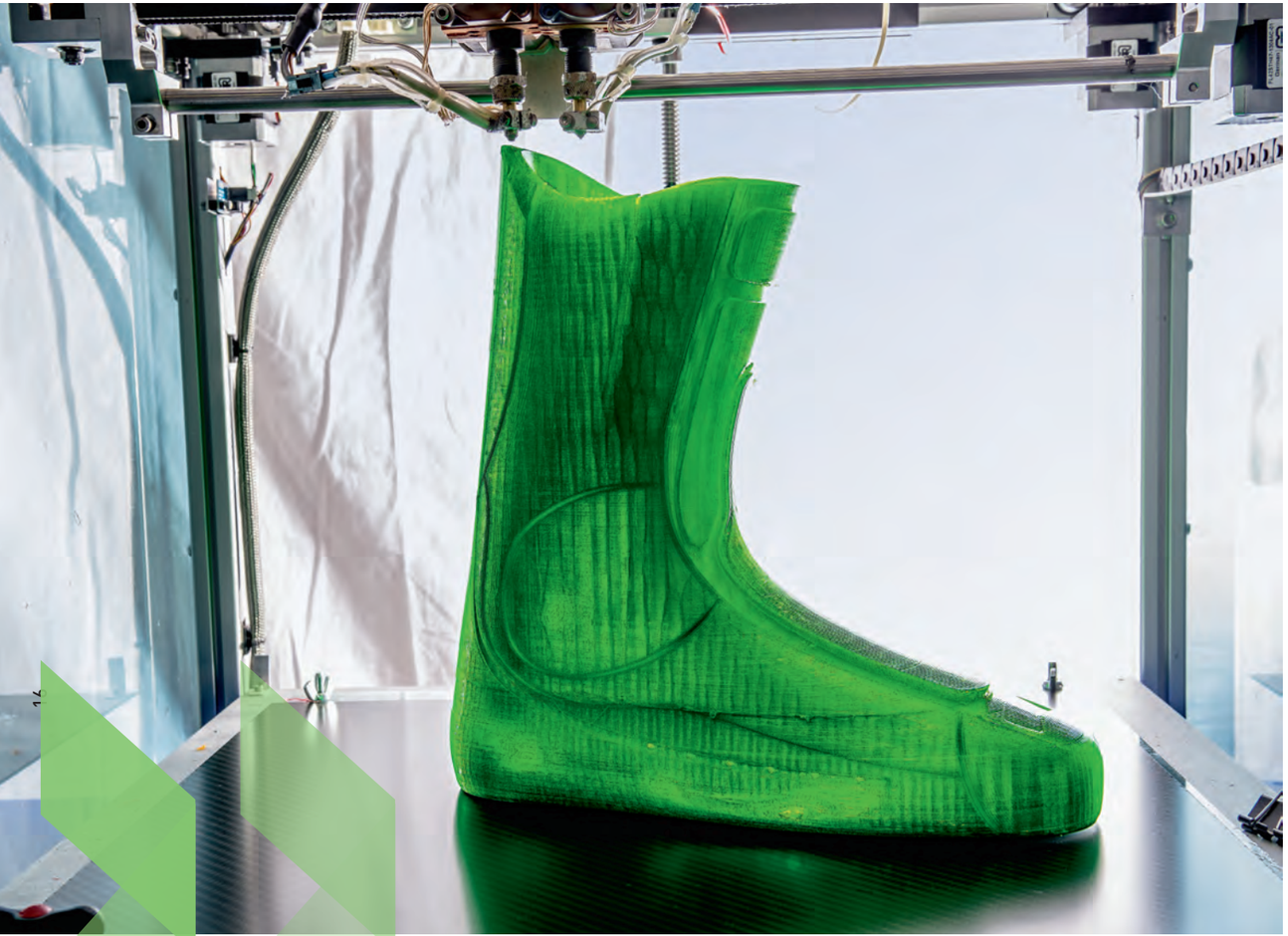
Thanks to a novel 3D microprinting process, it is now possible to manufacture complex metal components in the sub-micron and micron range, easily and in a single step. ETH Zurich researchers originally developed FluidFM technology for use in biological research. It has since been further developed for a different application, 3D microprinting. The ETH spin-off Cytosurge Ltd aims to make this technology accessible with its FluidFM µ3Dprinter and, together with partners from industry, is testing possible applications in areas such as the semiconductor and medical device industries.

Image: Cytosurge Ltd

ARCHITECTURE

Robots that build walls, and 3D printers that print entire formworks for ceiling slabs – digital fabrication in architecture has developed rapidly in recent years. At the Empa and Eawag NEST building in Dübendorf, eight ETH Zurich professors are collaborating with business partners to build the three-storey DFAB HOUSE. It is the first house in the world to be designed, planned and built using predominantly digital processes.

Image: NCCR Digital Fabrication



CLOTHING Tailored Fits AG manufactures tailor-made insoles for all ski boots. The way it works is by scanning the inside of the boot and the skier's lower leg. Based on the personal biometric data and information about skiing style, unique software defines individual pressure zones on the feet. This allows comfort and the distribution of force to be perfectly matched to every skier. After scanning, the insole is 3D printed in a single step using fused deposition modelling technology.

Image: Tailored Fits AG

"Innovation is a balancing act"

New manufacturing technologies will transform the way we produce things. So can we expect everything to come off a 3D printer? Mirko Meboldt, an expert in product development, talks to management expert Torbjörn Netland about the potential – and reality – of the situation.

INTERVIEW Martina Märki and Nicole Kasielke

Do you have anything 3D printed at home?
MIRKO MEBOLDT – I made an attachment for my milling tool. It's cheaper than buying it and I can tailor it to my own needs.
TORBJÖRN NETLAND – I have some tracks for a toy train set. It's something of a metaphor for where 3D printing stands at the moment – which is in the hobby room. Something to play around with.

Play around? Enthusiasts are calling additive manufacturing the disruptive technology that's going to change everything…
MEBOLDT – It's a rather absurd situation. I don't think we've ever had a situation where a production technology enters children's playrooms and company board rooms at one and the same time. Never before has a technology been so over- and underestimated.

Why is that?
NETLAND – Often people get the wrong idea in their head. Yes, you can buy a 3D printer right now for just a few hundred Swiss francs. But it's only going to print toys. It's not suitable for industrial applications.

MEBOLDT – You have to remember that 3D printing isn't a singular term, but instead encompasses the entire range of additive – that is to say, layer-based – production techniques. These form a whole category of their own, bringing together more than two dozen different process technologies, and a whole plethora of different properties and materials.

"Companies need some sort of sandbox to experiment in."

TORBJÖRN NETLAND

So how do we do it all?
MEBOLDT – These days, there are 3D printers for ceramics, metal, plastic, wax, plaster, sand, and concrete – and for every scale. I can just as well print shapes that you can thread through the eye of needle as I can print an entire building. In other words, it's a technology with a great many fields of application, even in medicine, where it can ›

TORBJÖRN NETLAND
is Assistant Professor of Production and Operations Management. His research focuses on increasing productivity in companies in industry.

MIRKO MEBOLDT
is Professor of Product Development and Engineering Design. His research concentrates on the use of new technology in the next generation of products and development processes.

Images: Giuilia Marthaler (2)

be used to manufacture artificial limbs or tissue replacements. It's a huge range of techniques we're talking about, and that is really grabbing people's attention.

So it is a disruptive technology after all?
MEBOLDT – With new technologies, it's all about the accompanying vision as well. In my opinion, technology itself is not disruptive. The disruption lies in its application, and how I as the user employ the technology within my value creation chain to generate added value for the customer or to optimise my production operation.

Could you give us a specific example?
MEBOLDT – I could point to the invisible "aligners" offered by Invisalign, a company founded in San Jose, California in 1999 that now has sales exceeding 1.3 billion dollars. The founding principle of alignment treatment, the patent, goes all the way back to 1945. However, it was only with the advent of 3D printing and digital technology that it actually became efficient to produce the aligners. Today, treatment begins with a mould of the patient's teeth, which is subsequently scanned and digitalised. The orthodontist can then digitally manipulate how they want the teeth to shift over the course of the treatment. An exactly fitted aligner is printed for each stage of the treatment – 12 in all, and all for a cheaper price than one traditional set of braces – and a much better match with what the customer needs.
NETLAND – Probably the best-known industry example is the injector for the LEAP engine for General Electric's Boeing Dreamliner. It's a relatively complicated component made up of many different individual parts. Before, it required up to 20 suppliers to manufacture. But if you produce the nozzle in one piece using additive techniques, suddenly all you need is one single supplier for the metal powder. It all goes to show that disruption isn't about the technology itself, but rather how the techniques are used for extremely specific applications.

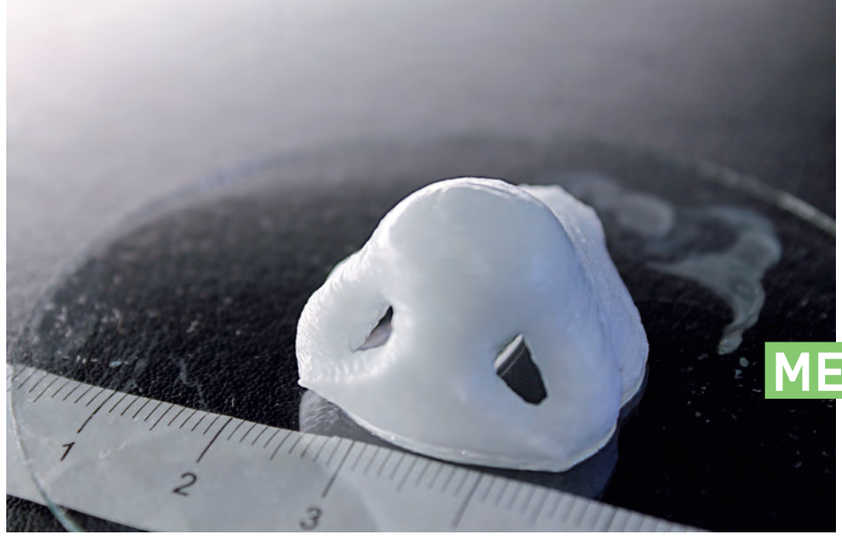
You're saying that it requires specific conditions?
MEBOLDT – Exactly so. It's good if I can automate value-creation processes relating to design, production and distribution, or if I need structures that I can't manufacture with any other technique. The truth is that additive manufacturing techniques are still expensive and time-consuming. I have to find the niches where the added value of the application justifies the high price of the technique. One really good example is the company Schunk, which manufactures gripper systems. Thanks to digitalisation and 3D printing, today the company can deliver each gripper – which must fit exactly to the specific component – much more easily than in the past. It's been able to eliminate 90 percent of its previous design work while significantly reducing delivery times. This makes it all worthwhile even if producing the grippers might be more expensive.

What about in 20 years' time? Can we expect these techniques to become cheaper in the foreseeable future?
NETLAND – Personally, I think that traditional processes will keep a cost advantage over additive manufacturing for most manufacturing processes over the next 20 years. However, additive manufacturing will keep getting cheaper and better, and thus gain more and more market share. Right now, for instance, 3D printing isn't suitable for mass production – it can't compete.
MEBOLDT – For companies, the critical question is how they get started with the technology and manage the learning process. It's not about putting everything on the table all at once. The technology first has to be successfully implemented in suitable pilot projects to allow it to become a sure-fire success. The key thing is to keep on pinpointing where the added value is within one's own value-creation chain, what the current limits are, where the costs arise and what the business model will look like. Working through these points is a learning process, and hard work.

"We have to be able to try out something new and imperfect once in a while."
MIRKO MEBOLDT

Professor Meboldt, you are one of the leading figures in the Manufacturing, Processes and Materials initiative, which encourages precisely these learning processes. What's been your experience with industry partners?*
MEBOLDT – There are Swiss firms that have been manufacturing using additive techniques for years. They've come a long way – Sonova with its hearing aids, for instance. They know what they're talking about and have quite specific research questions for ETH. Others are still a little more naive about the topic. They want to get into 3D printing because it's fancy. However, the first question should not be "Can we print a part in 3D?", but "Does it make commercial sense and where do we start?" On the Bosch Packaging project, we analysed which of the 800,000 replacement parts they handle from Switzerland have a viable business case for introducing 3D printing. Following that analysis, we went on to implement additive techniques in two component families – you have to take it one step at a time.

* ETH Zurich launched the Manufacturing, Processes and Materials initiative in 2014, encompassing the Competence Center for Materials and Processes (MaP) and the Manufacturing Partnership Council. ABB, Alstom, BASF, Bombardier, Bühler, EMS, ETEL, Hilti, Huber+Suhner, National Instruments, Oerlikon Metco, Ruag, SABIC, Sulzer and Swisscom are among the main sponsors.

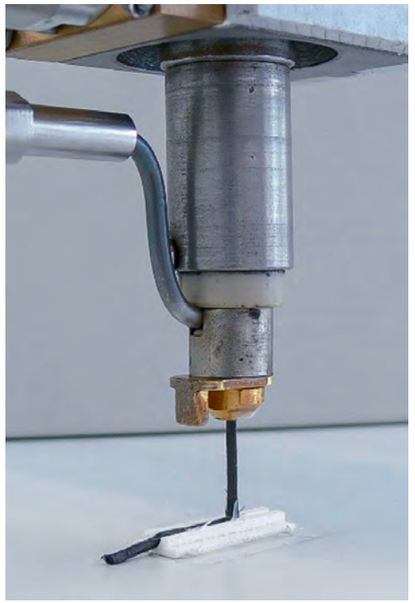


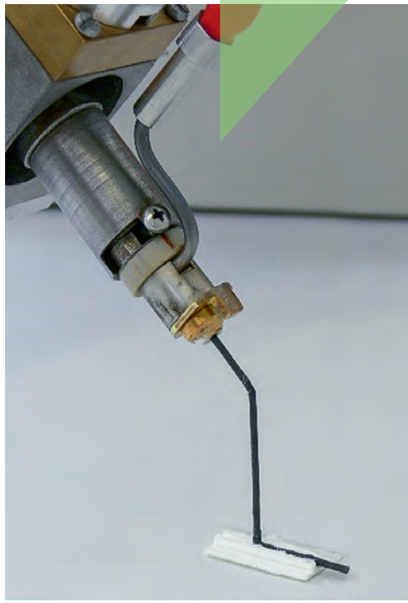
MEDICINE

Marcy Zenobi-Wong's research group at ETH prints cartilage transplants from endogenous cells, like this nose for example. They are customised and can grow with the patient.

COMPOSITE MATERIALS

Continuous lattice fabrication (CLF) is a patented technology developed at ETH Zurich's Laboratory of Composite Materials and Adaptive Structures. It is the first 3D manufacturing process for continuous fibre-reinforced thermoplastic composite materials not based on classic layer-by-layer build-ups. CLF allows strategic orientation of the fibres in all spatial directions. The combination of high fibre content and continuous fibres makes it possible to produce not just prototypes, but also mechanically robust high-performance structures.





Images: Group Tissue Engineering and Biofabrication; Martin Eichenhofer, Composite Materials and Adaptive Structures Lab (2)

FLYING OBJECT

Conventional quadcopters are not very efficient at forward flight. The blade profile of this quadcopter – developed by ETH Zurich's Institute for Dynamic Systems and Control and Product Development Group Zurich – provides additional uplift. The rotor blades are manufactured using additive techniques and covered by an ultra-light foil. In addition to cost-efficient production for small volumes, 3D printing enables targeted optimisation of the structure and integration of features such as connectors.

NETLAND – We're still at the trial and error stage. Basically, what companies need is some sort of sandbox to experiment in alongside their bread and butter business. ETH is an excellent partner for that. 3D printing is well established in the design process – think rapid prototyping. But it is new to manufacturing, and still somewhat of an exception. More than 99 percent of the things we produce over the next 5 years will be produced using conventional techniques.

Are smaller companies more open to innovation than big ones?

NETLAND – Not necessarily. All the big companies I know, including ABB and Siemens, are thinking about 3D printing and testing where they might be able to implement it.

MEBOLDT – In my opinion, the big companies have more problems integrating new technologies within their organisation. Small or start-up companies are much more agile. The founder of a start-up I know (Tailored Fits) worked for many years at one of world's biggest ski boot manufacturers. While he was there, he repeatedly failed in his attempts to implement additive manufacturing technology. So, in the end, he founded his own start-up, and they've just brought out the first tailor-made 3D printed ski boot.

NETLAND – That fits well with Clayton Christensen's theory that big companies are incapable of disruptive innovation. Start-ups spring up and improve, and end up taking market share from big business.

So it's an opportunity for start-ups right now then?

NETLAND – Yes, but not only for them. General Electric is probably the biggest 3D printing company. They're trying everything they can. It's been a priority at the company for more than ten years.

What's the situation in Switzerland? Are we too cautious and missing out on opportunity?

NETLAND – We're no more cautious than Norway, Germany or Sweden. Switzerland has the advantage of having ETH, lots of start-ups and a spirit of entrepreneurship. I have no worries about Switzerland lagging behind any other countries, including the US.

Big change is coming to industry, whether it's additive manufacturing or industry 4.0. How do you prepare people for innovation?

MEBOLDT – When Torbjörn Netland is in his lectures or at his desk thinking about how drones might transform production processes in the future, then that's exactly what's happening.

NETLAND – Of course we conduct research into and talk about the future at ETH. Virtual reality, the internet of things, additive manufacturing, drones, machine learning, and artificial intelligence are all things that we teach and develop here. However – and this is an important point, I think – we always remain realistic. This isn't only about visions of the future.

MEBOLDT – As an educator, I see my task as being to equip people with the skills they need to develop the future themselves. That means helping them to see and implement things before they are obvious. It's not just a case of developing technologies; they must also have the ability to take their knowledge and transform it into value for business and society.

What does industry 4.0 have in store for our economy and how well equipped are our companies?

NETLAND – Digitalisation is on the way, that's for sure, and additive manufacturing depends heavily on that. However, I also think that there won't be any massive changes for most companies in the next five to ten years. Of course I would love to be visionary about this, as many technology enthusiasts are. But when I visit companies, I see a different world. Quite apart from the technologies themselves, there are still other essentials to consider, like process organisation and marketing, not to mention the human component. If you get those things right, a company can prosper for a long time.

MEBOLDT – What makes Swiss companies successful? Most often, it's the fact that they excel in a very specific area, are efficient and effective in implementation, and work hard to keep optimising their process. However, if I am always thinking about what I'm best at and nothing else, then it's hard for me to think differently. And when people no longer want what I can do best, then I have a huge problem. We need that ability to think differently – even if all too often it is hardly embraced because it impinges on well established processes. That's where the challenge is and where companies run the risk of missing crucial trends.

NETLAND – We're always talking about change, and how that is a positive thing in itself. But there are some very successful companies that thrive on stability. It's another way of thinking that certainly has its value. I greatly admire companies who do something really well, and are able to trade on Swiss quality and stability long term. There's a lot to be said for continuous improvement as opposed to radical innovation.

I'm sure Swiss companies will be delighted to hear that…

MEBOLDT – I agree with the sentiment for certain sectors. But when I think differently and break new technological ground, I just can't be a professional straightaway and I remain a long way from perfection. We have to unite our obsession with perfectionism with a new culture that allows for failures and allows us to try out something new and imperfect once in a while. It's a tricky balancing act, but one that we absolutely have to master. ○

Smart manufacturing with ETH spin-offs

Additive manufacturing is developing rapidly – even if it still has a long way to go before it becomes standard everywhere. Perhaps this is precisely what motivates ETH spin-offs to venture into this technology.

ADDITIVELY The possibilities offered by 3D printing are practically inexhaustible. Many technologies and materials are available, which makes it quite challenging to choose the right printing technique. Help with finding the ideal solution for various applications comes from ETH spin-off Additively. The young company offers an online platform for professional 3D printing. It connects companies with 300 suppliers, all 3D printing technologies, more than 250 different materials and over 100 different machines. The aim is to make better use of additive manufacturing's potential, despite its high level of complexity.

→ www.additively.com

SCRONA Print an ultra-thin mobile phone display? ETH spin-off Scrona develops print heads that do just that based on its proprietary NanoDrip printing, a groundbreaking ink-jet technology that achieves a printing resolution which is up to 1,000-fold finer than the width of a human hair. The vision is to use this 3D printing technology for nano-electronic components to create greener and less costly electronic products than those available today.

→ www.scrona.ch

Image: Rajan J. Gill, Institute for Dynamic Systems and Control

Nanosensors for industry, heart and bladder

The digitalisation of our daily lives and workplaces would be inconceivable without progressively smaller and more affordable sensors. At ETH Zurich, several research groups are working on new sensor concepts. Some of these might revolutionise medical technology.

TEXT Samuel Schlaefli

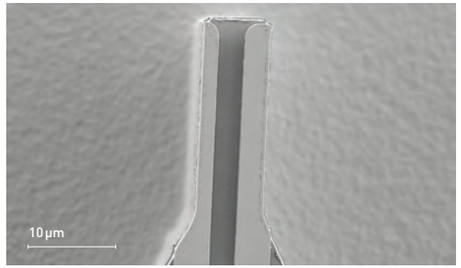
Christofer Hierold has been working in the field of microsystems technology and sensor integration for 30 years. The advances promised by Industry 4.0 don't really sound like anything new to him. "One of the goals is to enable the seamless monitoring of industrial production processes, but the semiconductor industry has been doing that in process technology for years," the ETH Professor of Micro- and Nanosystems says. After all, it requires hundreds of process steps over several weeks to construct a silicon wafer with integrated circuitry – and a great many sensors are already employed to monitor the machines as this takes place. "The new and exciting thing about the ideas for Industry 4.0 based on digitalised processes is that we are increasingly seeking to achieve uniformly high quality for very small batch sizes, possibly even for batch sizes of one." That means being able to guarantee that a single customised item can be produced to the same high quality standards as mass produced components.

Such flexibility in production is made possible only by the smart linking of sensors in conjunction with the use of sophisticated algorithms. These algorithms are required so that the data recorded can be translated into information that is useful for process control. Hierold is convinced that factory floors will therefore become increasingly filled with sensors. Going forward, this might even apply to the goods produced. "In future, it's probably not just machines that will be fitted with additional and smaller sensors," the researcher says. "Some day, the products, too, might have sensors on them to monitor quality during manufacturing." Temperature or pressure sensors would then transmit data in real time about the current state of the product and potential faults in the production process. Production would certainly be more comprehensively monitored than it is today.

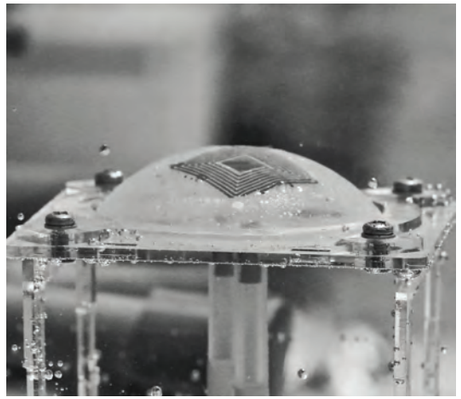
> "Production will be more comprehensively monitored."
>
> CHRISTOFER HIEROLD

Superior sensitivity

If the above scenario is to become a reality, it will be underpinned by sensors that are smaller, cheaper and more efficient. That's exactly what Hierold is working on. One section of his research group is focusing on the development of nanoelectromechanical systems (NEMS). Sensors based on these are no longer visible to the human eye. Instead of using semiconductors, as is standard in sensor technology, Hierold builds his NEMS using carbon nanotubes. These are tiny tubes, typically two nanometres in diameter, which are made of graphene and very robust. They are characterised by their large surface area, which makes for highly efficient interaction with other molecules. Gases such as nitrogen oxides, which contribute to smog and ozone formation, can therefore be detected at very low concentrations. If single carbon nanotubes are used as a gas sensing material, only three microwatts of power are needed to take a measurement instead of the one to ten milliwatts previously required. "We can take measurements using a thousand times less power," Hierold explains. As far as he is concerned, this opens up completely new possibilities. The sensors could use what is known as an energy harvester to derive the energy needed from their surroundings – by taking advantage of a temperature gradient, for instance, or by converting kinetic energy. "That would be especially practical for mobile applications such as smartphones, or for taking environmental measurements with widely distributed sensor networks," Hierold says.



TINY BUT EFFICIENT
Function module for carbon nanotube sensors to detect gases



BIOSENSOR
The bladder sensor stretches along with the bladder and sends a signal to indicate the urine level

Nanosensors for health

Tiny, efficient and affordable sensors will also play a key role in the health system of the future. This is demonstrated by the vision of an "internet of humans". Under the leadership of EPFL, ETH Zurich and a number of other universities are promoting the vision of a personalised, sensor-based healthcare and disease-prevention system in Europe. EU research funding is to be sought for such a flagship initiative. The aim is that, in future, sensors worn on the body will continuously record and evaluate health-related data such as blood pressure or heartbeat. In this way, it would be possible to recognise and treat symptoms of illnesses at an early stage. Those behind the initiative see digitalised prevention not just as a contribution to long-term health, but also as a potential means to reduce healthcare costs.

Microsensors will also play a central role in the inter-university Zurich Heart project. At present, researchers are developing new concepts for artificial hearts that can be used as an alternative to human heart transplants. Hierold's group is working on the system integration of a microsensor for monitoring and controlling such artificial hearts. "The performance of the heart must be able to adapt automatically to a patient's age, health and level of activity," Hierold explains. To achieve this, his team is working with a standardly available pressure microsensor. However, they have to use biocompatible materials to protect the sensor because it starts to "drift" (i.e. its signals fluctuate over time) when it comes into contact with blood and other physiological fluids. Some day, they aim to integrate the pressure sensor into the in-flow cannula of the newly developed heart pump.

Stretchable bladder sensor

Researchers at the Laboratory of Biosensors and Bioelectronics (LBB) are also working on biosensors. As part of a collaboration with the University of Zurich and other partners, Professor Janos Vörös' group has recently developed a flexible sensor that one day might be used by patients with spinal cord injury to control the level of urine in their bladder. "For many patients, not being able to control their bladder is a more serious impairment than not being able to walk," says Vörös. If patients have an overfilled bladder without being aware of it, urine flows back into the kidney and can cause devastating damage there.

Vörös' group is developing stretchable sensors, which are enclosed in a soft shell made of a biocompatible rubber (polydimethylsiloxane). The sensor is attached to the surface of the bladder, and, when the bladder fills with urine, it is able to stretch along with it. Stretching the sensor results in a measurable change of its electrical properties, which can be measured using RFID technology from outside the body, meaning that the sensor inside the body does not need its own battery. Researchers are currently testing the system on pig bladders, and testing ›

Images: Sebastian Eberle, Micro- and Nanosystems Group; Laboratory of Biosensors and Bioelectronics

on live animals (incontinent dogs) is planned before applying the system in humans. In future, patients themselves should be able to use an app to monitor whether their bladder is full.

The "smart cable"
Vörös' work on sensor development gave rise to an unexpected by-product: unbreakable cables. In 2016, members of his group founded nanoleq, a spin-off which takes the stretchable, conductive polymer composites and adapts them for commercial use.* "Cables like these are particularly in demand for automated manufacturing processes – where robots repeat the same movement thousands of times every day, and the wear on cables is very high," Vörös says. He adds that nanoleq is already in contact with several major cable manufacturers. The young entrepreneurs want to take it a step further: they are thinking of a "smart cable", which will be in a sleeve fitted with microsensors so as to detect problems with materials in real time. Vörös still collaborates closely with the spin-off, and he says that the first prototypes are under development.

In the future, micro- and nanosensors might do more than oversee the way single items progress through the production process, as Hierold predicted. It may be that these sensors will soon monitor every single cable involved in that process. ○

Micro- and Nanosystems Group
→ www.micro.mavt.ethz.ch

Laboratory of Biosensors and Bioelectronics:
→ www.lbb.ethz.ch

*The founders, Vincent Martinez and Luca Hirt, are Pioneer Fellows. Pioneer Fellowships are funded from donations to the ETH Zurich Foundation.
→ www.ethz-foundation.ch/pioneer-fellowships

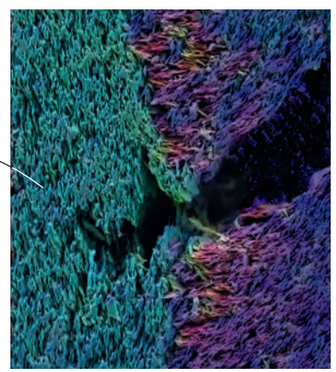
3D printing unlimited: From tooth enamel to 4D printing

ETH scientists are constantly pushing the boundaries of additive manufacturing processes. They are mimicking production concepts found in nature and adding a fourth dimension to 3D printing technology.

TEXT Peter Rüegg

When asked which natural material he finds most fascinating, there's no hesitation in André Studart's reply: "Bone." He is Professor of Complex Materials, and he explains his fascination with bone by saying that it is tough and extremely durable, yet it also remains dynamic over the course of a whole lifetime since fractures or cracks always heal by themselves. Studart would love to replicate bone in his laboratory: he and his group specialise in biomimetic materials, which he prefers to produce using additive manufacturing processes (i.e., 3D printers).

In some ways, additive manufacturing processes simulate production concepts found in nature. "Basically, 3D printing and living cells construct material in the same way," Studart says. He explains that cells are constantly secreting organic or inorganic material, thereby building up a composite material layer by layer. In doing this, they produce materials in which the properties of individual layers change gradually.



ARTIFICIAL TOOTH USING ADDITIVE MANUFACTURING
(cross-section) Ceramic platelets are aligned vertically in the enamel, but diagonally to horizontally in the dentine

That is the way intervertebral discs are constructed, for example. These soft, gelatinous structures between the vertebrae allow for spinal mobility and act as shock absorbers. They have a tough outer shell that becomes softer as it goes in. "Additive manufacturing can replicate material gradients like this in a way that traditional processes just cannot do," the ETH professor emphasises.

He has already used additive manufacturing processes in his laboratory to simulate all kinds of natural materials, from mother-of-pearl to pine cones. One of the big successes is biomimetic tooth enamel, which Studart's colleagues produced using a combination of additive manufacturing and traditional casting techniques.

The researchers filled the plaster cast of a tooth with a suspension containing magnetised aluminium oxide platelets and glass nanoparticles as mortar. Using a magnet, they aligned the platelets perpendicular to the surface of the tooth. Once the first layer was dry, the scientists poured a second suspension without glass particles into the same mould. The platelets in this second layer were aligned horizontally to the surface of the tooth using the magnet. As a result, the researchers managed to produce an artificial tooth with the same layered structure as a natural tooth.

Studart's research group puts its success down to precise observation of natural models, an eagerness to experiment, and special printer inks. "We put our effort into developing print-ready inks, not machines," Studart says, and the 3D printers in his laboratory are commercially available machines. The researchers have recently adjusted this strategy, however, to include the development of new printers. This allows the group to fully exploit the potential of the unique inks that they have developed – which include a special ink that Studart has used for the 3D printing of extremely porous ceramic material. The ink is a ceramic suspension full of air bubbles or oil droplets, which is extruded using traditional direct ink writing techniques.

This approach enabled the material scientists to print a multi-layered and close-meshed lattice structure, and so to produce a foamy yet robust ceramic material. This material could some day be used as a catalyst in the chemicals industry, in biomedicine, or indeed in the energy sector.

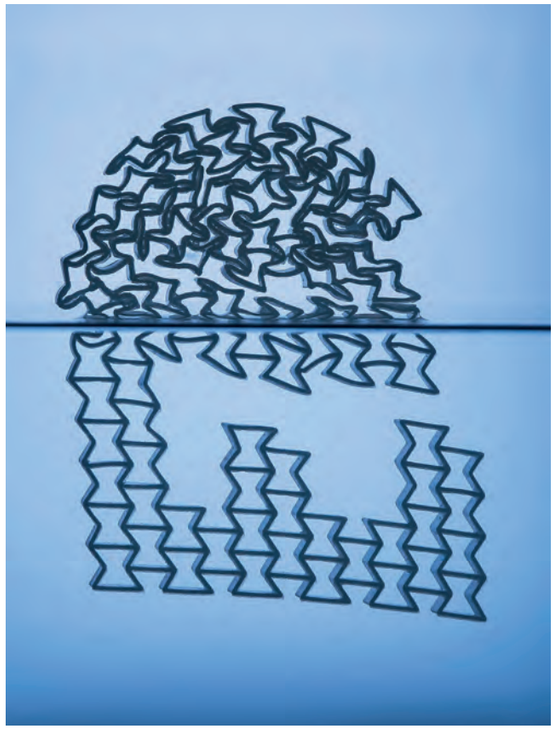
Enabling self-repair
Yet even with additive manufacturing processes, replicating bone has remained a hard nut to crack. "It's one of my greatest ambitions to produce a bone with a 3D printer," the professor says.

He also says that one problem with imitating bone is that, unlike the genuine article, artificial structural materials usually do not contain any living cells – cells like osteoblasts and osteoclasts that are responsible for the exceptional ability of bone to heal itself. One possible remedy is to incorporate microcapsules into the ink. These could contain a solution that leaks out when exposed to high pressure and repairs any structural damage. Unfortunately, this approach only works once. That is why Studart is conducting experiments with special inks capable of releasing "healing" substances in the printed material more than once. However, he is still a long way from having found a solution to the problem posed by bone. "The challenge is enormous," he says.

Image: Hortense Le Ferrand, Professorship Complex Materials; Tian Chen, Engineering Design and Computing Laboratory

THE FOURTH DIMENSION
This object is printed flat and can later be reconfigured into other stable and load-bearing forms

4D printing is the next step
How to imitate natural materials is not a research focus for Kristina Shea, Professor for Engineering Design and Computing. Instead, she is looking to add a fourth dimension to 3D printing: time. The objects developed in her laboratory are printed in two dimensions by multi-material 3D printers that can print up to 40 different materials at the same time. Although printed flat, these objects can be reconfigured into three-dimensional forms at a later point. "The objects do not change their configuration randomly, but rather ›



PROGRAMMED RECONFIGURATION A chaotic ball reconfigures itself in warm water to produce an ETH logo consisting of regular, homogenous cells

exactly in the way we have calculated and conceptualised the design on the computer," Shea explains.

Using simulation software that researchers in her group have written themselves, they design objects, compute shapes and forces acting on the structure – and then print the objects, including the elastic joints and hinges, in one run. "The advantage of this is that we can produce the entire object, complete with moving parts, instead of having to assemble individual components into a 3D structure at a later stage," Shea says.

One of these objects is a square that is made up of several triangles. It can assume 128 different forms, one of which is a pyramid strong enough to bear weight. That is unique: "My group is currently the only one capable of printing a 4D load-bearing object like this," Shea says.

One of the factors that can cause 4D structures to change form is a change of temperature. This is what lies behind the current big hit in Shea's laboratory: the ETH logo that automatically changes its shape when it comes into contact with warm water. Once it has been printed, it is heated, deformed, and cooled to room temperature; the result is a chaotic-looking round ball. When it comes into contact with warm water, though, it quickly reconfigures itself and forms an ETH logo consisting of regular, homogenous cells.

In its folded state, it's impossible to guess what shape these cells will form. However, Shea's assistants Tim Chen and Marius Wagner have been able to use a computer to simulate not just the logo-reconfiguration process, but also the way the 3D printer must print the polymer to ensure that the logo can open out like the petals of a flower.

Shea and her group have until now been working on the basics of 4D printing technology. Now, she wants to turn her objects to practical use. Components of this type that change form over time can be used in medicine, for instance, or in space technology, where they could be used for deploying satellite dishes or space instruments. Shea can also imagine developing wall claddings that react to temperature and provide shade for the façades of buildings. She is thinking too of stents that keep narrowed arteries open.

For a while now, Shea has also had a vision of some day producing an intervertebral disc using multi-material additive manufacturing. Studart is pursuing that same distant goal – only the routes taken by the two 3D printing specialists towards achieving that goal are radically different.

Complex Materials group:
→ www.complex.mat.ethz.ch

Engineering Design and Computing Laboratory:
→ www.edac.ethz.ch

Image: Jung-Chew Tse and Marius Wagner, Engineering Design and Computing Laboratory

The smart approach to **digital construction**

At the NEST building in Dübendorf, digitalisation is in the process of revolutionising architecture: robots build load-bearing walls, while algorithmically calculated roofs push the limits of what is physically possible.

TEXT Samuel Schlaefli

As you walk around the new building called Arch_Tec_Lab, it is a bit like taking a journey through the architecture of the future. On the ground level, massive robotic arms glide along ceiling rails across a huge hall, sawing and assembling wood beams to make a room module. One floor up, researchers from around the world sit behind laptops and write the code they use to control small robots. And finally, on the large and spacious top floor, walkways are sometimes obstructed by ornate formwork systems waiting to be filled with concrete. These prototypical formworks have come straight out of an oversized 3D printer. Welcome to the Institute of Technology in Architecture (ITA), which has been based in the Arch_Tec_Lab on the ETH Hönggerberg campus since the end of last year. Here, construction is being reinvented – and digitalisation has a key role to play.

Among the pioneers of an increasingly digitalised architecture are Fabio Gramazio and Matthias Kohler, Professors of Architecture and Digital Fabrication. Since the turn of the millennium, they have been working on the idea of not only designing architecture on the computer, but also using the data directly in the fabrication – to control a robot, for instance. Their group procured its first robotic arm in 2005 and began to experiment. Twelve years later, the team is showcasing how digital manufacturing could revolutionise the construction industry as part of the unique NEST project at the Empa site in Dübendorf.

NEST A computer-generated visualisation of the DFAB HOUSE project

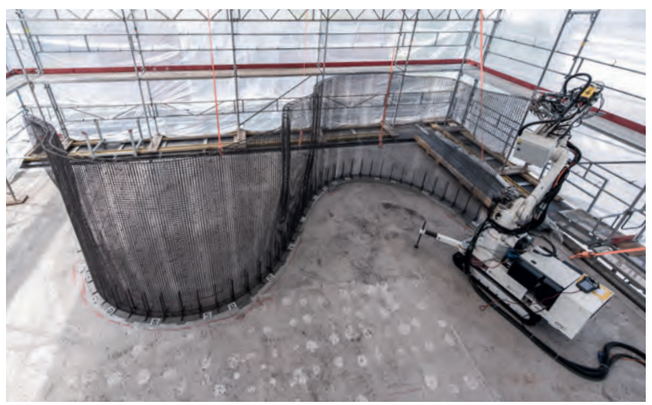
Image: NCCR Digital Fabrication

Implementation in construction

Kohler's group is currently working with research partners to build the three-storey DFAB HOUSE on the top level of the modular NEST building. The new construction is intended to serve one day as accommodation and workspace for visiting academics. "The whole design draws on the new possibilities offered by digital design and fabrication processes," says Kohler. Under the auspices of the National Centre of Competence in Research (NCCR) Digital Fabrication, which he initiated three years ago and presided over until just recently, he hunted out research projects that are ready to be implemented in construction for the first time. These include a robotic slip-forming process used to produce customised and weight-optimised concrete mullions; a digitally generated, two-level timber frame structure that is assembled by two robots on the basis of the underlying algorithms; and weight-optimised concrete ceiling elements that are cast using formwork produced by a 3D printer.

Maybe the best demonstration of the new capabilities, however, is a load-bearing wall that extends right across the open space of the lowest floor of DFAB HOUSE in a long, incomplete S shape. "It's a real milestone," says Kohler. "For the first time, we have been able to demonstrate that digital technologies are not just for pretty structures and ornaments, but can also be applied to the load-bearing core of a construction project." A tracked robotic arm more than two meters high laid the foundation for the double-curved load-bearing wall. ›

HILO PROJECT
A concrete shell with minimum use of materials and maximum stability thanks to the computer-generated form of the steel cable net onto which concrete is poured



IN-SITU FABRICATOR AND MESH MOULD
The In-situ Fabricator robot built the steel mesh for this S-shaped load-bearing wall in the DFAB HOUSE

The "In-situ Fabricator" was developed in collaboration with the Institute of Robotics and Intelligent Systems. Drawing on sensors, floor markings for exact positioning, and smart data processing algorithms, it is largely autonomous. To prepare the wall for concreting, the fabricator produced a fine steel wire mesh on the spot using a wire cutter and a welding tool head – resulting in a mesh measuring 9 metres long, 3 metres wide, and 2.9 metres tall. The digital model input into the robot was calculated by the researchers using an algorithm. "It would have made no sense to plot every point of the mesh using a conventional CAD program," says Kohler.

Soon, industry partners will fill the steel mesh with special concrete. The mesh keeps the concrete in the desired form, serving as both formwork and reinforcement. It might not sound like much, but it is actually an alteration to the entire global concrete construction method as we know it today. "Over a third of the costs relate to the material and work required for formwork," says Kohler. "And once the concreting is done, the more complex formwork usually ends up being scrapped." He also points out that digital fabrication has environmental and economic potential, as engineers would have much more freedom in the design of the load-bearing walls and supports if they were optimised by algorithms and came with robotically produced meshes. In such a scenario, one can use precisely as much concrete as is in fact structurally required – a potential saving of 20 to 30 percent in terms of the amount of concrete used.

Minimal use of materials

This new and improved range of digital tools is revolutionising more than just construction processes, though – there are new possibilities when it comes to design as well. "Ever since reinforced concrete burst onto the scene at the beginning of the 20th century, we've lost a lot of the know-how for building optimised shapes and constructions that look good and conserve resources," says Philippe Block, Professor at ITA and, as of recently, Director of the NCCR Digital Fabrication. "Digitalisation is helping us to reintroduce this lost knowledge into architecture." Block refers to it as "smart load bearing design." He views it as a chance to move away from the resource-heavy, unimaginative, and shapeless architecture that dominates in many places today.

Block's contribution to NEST is the HiLo project, developed in collaboration with Professor Arno Schlüter, which embodies their vision for the future of architecture. Block and his team have designed a spectacular self-supporting concrete shell for the two-storey penthouse. The shell is supported at five points and serves as a roof, interior wall, and facade depending on the exact position. Researchers have employed algorithms to shape the roof structure so that it is extremely stable despite the minimal use of materials. This is the only way it is possible to have a 20-tonne shell – 20 metres long, 10 metres wide, and 6.5 metres tall – that can support itself with concrete between 3 and 12 centimetres thick.

> "We are living in one of the most exciting periods for architecture."
>
> PHILIPPE BLOCK

In addition to the exceptional nature of the shell itself, there is an equally impressive production process to go with it. The fact is that Block's design would have been far too time consuming and expensive to execute using conventional construction techniques. The concreting would have called for a customised wooden or milled foam formwork. Block's design, on the other hand, is based on a reusable stainless steel cable net. This cable net is clamped to a large wooden frame and covered with a textile. Together, they act as formwork for the concrete sprayed on top. The concrete is then reinforced by a carbon fibre mesh. In order to test whether the concept works in practice, Block's group built a full-scale prototype and brought in partners from research and the construction industry to help at the Arch_Tec_Lab. Controlling the geometry of the stainless steel cable net was a task performed in collaboration with the Automatic Control Laboratory and the Institute of Geodesy and Photogrammetry. Motorised theodolites and specialised software and algorithms were used to predict and measure the spatial coordinates of the nodes; this was important to ensure that the cable net deformed safely to its correct target geometry under the weight of the applied wet concrete. Planning and executing the HiLo roof prototype involved a lot of data. Block turned to "compass", the open-source software developed within his group, in order to integrate the data independently of any one computational platform. This was the only way that the necessary modifications could be automatically applied to the overall design.

The prototype has been disassembled already. The steel cable net has been taken apart into several pieces, and will be reused later at the construction site in Dübendorf. This is where the concrete shell will be assembled as a structural sandwich in two layers, with slightly different proportions and wall thicknesses. Work is due to begin on HiLo at the beginning of 2018. Block can hardly wait. "We are living in one of the most exciting periods in the history of architecture," he says. "Even if we are still right at the beginning and just learning what we can do with digital fabrication." ○

Digital fabrication in construction:
→ www.dfab.ch
→ hilo.arch.ethz.ch

Images: Michael Lyrenmann, Naida Iljazovic; Gramazio Kohler Research

Interdisciplinary teamwork is very demanding

Feedback session with Ingo Burgert, Professor at the Institute for Building Materials, and other ETH experts

Hans Hess, President of Swissmem, and Detlef Günther, ETH Vice President for Research and Corporate Relations, on the opening night

Students on a field trip to InnoRecycling AG

Shaping the future of **manufacturing**

At this year's ETH Week, 180 students from 16 different departments tackled the topic of "Manufacturing the Future". Working in interdisciplinary teams, they learned how to get to the heart of manufacturing systems.

TEXT Editorial Office IMAGE Alessandro Della Bella

ETH Week is an event that helps the university to promote critical thinking and creativity among its students. During the week, students from all disciplines work together on real-world problems, supported by internal and external experts from science, industry and society.

This year, ETH Week focused on examining current and future production methods and developing ideas about how to improve them, all within the context of a wide-ranging discussion that also kept an eye on the possible consequences for society. Key topics included how to make effective use of the new possibilities presented by digital manufacturing, how to design the working relationships between humans and machines and, finally, how we use materials and resources.

"We wanted to put technology in a human context."

STEFANO BRUSONI

In order for the participants to familiarise themselves with the topic, the organisers – the ETH Sustainability Office, the Competence Centre for Materials and Processes, and the Chair of Technology and Innovation Management – put on an extensive programme. Field trips to companies, lectures and expert discussions alternated with project work, with content ranging from engineering and the natural sciences to social sciences, politics and psychology. Central to the programme was the desire to bring students into contact with real-world concerns as early as possible.

As part of the university's Critical Thinking Initiative, ETH Week* has been designed to teach students about interdisciplinary work, communication with all sorts of stakeholders and creative yet rigorous thinking. "This year's ETH Week has deliberately put the focus on relating manufacturing technologies to people and considering the wider social context – with a structure and breadth that is probably unique in the Swiss educational landscape," says co-organiser Stefano Brusoni, Professor of Technology and Innovation Management.

ETH Week continues to have a lasting impact, as confirmed by the fact that four of the student teams continue to develop their ideas alongside their studies as part of the Student Project House. ○

More about ETH Week:
→ www.ethz.ch/ethweek

*The Avina Foundation supports ETH Week via the ETH Zurich Foundation. Avina promotes new approaches in education, training and further education and fosters entrepreneurial initiatives.

The flying robot Skye as an ETH ambassador

Image: Rahel Byland

Festival

IN HONG KONG

ETH spin-off Aerotain caught the attention of locals and tourists alike at Hong Kong's Times Square. Their flying robot, Skye, promoted "Zurich meets Hong Kong", an event presenting the best of Zurich's science, technology, culture, and art to the Asian metropolis from 21 to 29 October 2017. Visitors experienced the magic of augmented creativity with ETH Zurich's Game Technology Center and learned how mobility and energy systems can sustain "smart" cities. The Hong Kong festival created new connections and provided an opportunity to catch up with current partners and ETH alumni in the region.

Digital Day

IT ENTHUSIASM

The first National Digital Day took place on 21 November, with ETH Zurich participating in variety of ways. Organised by the digitalswitzerland association, this major event was backed by numerous companies and organisations. The aim was to demonstrate to people across Switzerland what digitalisation means for them and for the entire country.

Zurich's main train station was one of the main showplaces, with a special exhibition for Digital Day. Here the public could find out about specific aspects of digitalisation divided into different topic areas. ETH Zurich contributed fascinating exhibits which attracted great interest from the public. Researchers also demonstrated in various presentations just how digital transformation will affect things like the building sector and urban mobility.

One of the university's priorities was to underline the significance of computer science by inviting classes of school children from the whole of Switzerland to a half-day programming workshop at ETH. Staff from the Professor for Information Technology and Training gave around 200 students an exciting introduction to the basics of programming. Education Minister Johann Schneider-Ammann was very keen to sit down at the computer to learn about the world of coding: proof that programming can also be fun for older people.

Singapore-ETH Centre

CHANGE OF MANAGEMENT IN SINGAPORE

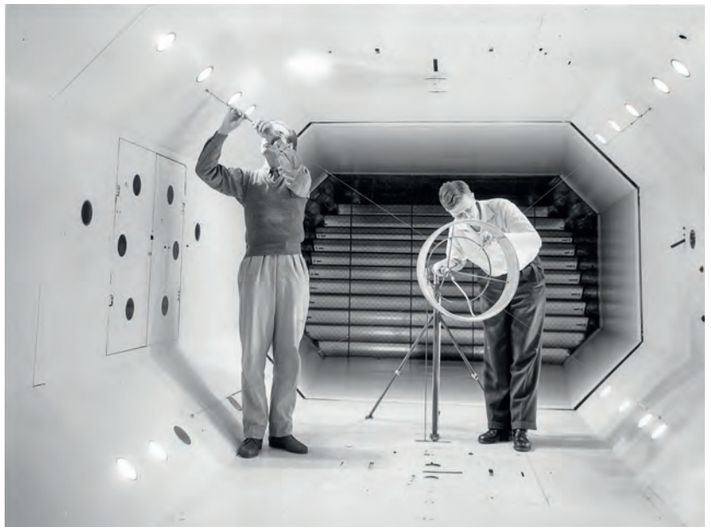
Within the space of seven years, the Singapore-ETH Centre with its Future Cities Laboratory has advanced to become the largest integrated urban research centre of its kind. It provides valuable input for urban and spatial planning in Switzerland and other countries.

In October, ETH Professor of Plant Ecology Peter Edwards handed the management of the Singapore-ETH Centre back to Gerhard Schmitt, Professor for Information Architecture. Schmitt had been in charge of the centre for three years from 2010.

75 years of the ETH Zurich Research Commission

From risky investment to daring research

Seventy-five years ago, in the midst of the Second World War, ETH Zurich made a decision that would shape its research culture right up to the present day: to support unconventional project ideas through its Research Commission.



Working in the wind tunnel of the Institute for Aerodynamics in 1955: from the very beginning, the Research Commission supported projects from all disciplines

Image: ETH Library

Those who want to open up new areas of knowledge must tread risky paths. That is why ETH Zurich channels its funding into individual, daring and open-ended research projects. The ETH Zurich Research Commission plays a particularly important role. "We support application and method development as well as fundamental research from all disciplines," says Uwe Sauer, Professor for Systems Biology and President of the Commission. He explains that the Commission endeavours to support projects that open up new fields of research and can achieve high academic impact, especially those that harness the synergies between work groups. He adds that the Commission evaluates projects based solely on their academic excellence, originality and innovative potential: there are no political or subject-specific requirements, nor must recipients be affiliated with a specific ETH department. "By focusing its own funding on novel research, ETH Zurich can be the first to explore topics and develop new branches of research. The Commission is a piece of ETH's DNA," says Detlef Günther, ETH Vice President for Research and Corporate Relations, who is responsible for the Commission.

The home-turf advantage

The second priority is supporting researchers who are at the beginning of their career. Those who receive initial funding from the Research Commission in the early stages of a project with large innovative potential increase their chances of obtaining grants from national and international funding organisations, for example the Swiss National Science Foundation (SNSF) or the European Research Council (ERC).

When Johannes Bohacek came to ETH in 2009 as an ETH Fellow for postdoctoral work, his area of research – epigenetics, which focuses on the inheritance of acquired behavioural patterns – was a disputed subject amongst brain researchers. "Getting research funding for such a controversial project would have been almost impossible using conventional routes," he says. Today, the importance of epigenetics for heredity is well established and Bohacek himself is an assistant professor at ETH. He says that ETH has a "home-turf advantage" through its internal funding schemes. Kathryn Matlack, an engineer who, like Bohacek, received an ETH Zurich Postdoctoral Fellowship, was able to explore a new area of research and is now an assistant professor at the University of Illinois at Urbana-Champaign. Similarly, the mathematician Sonja Cox obtained a post as an assistant professor in Amsterdam thanks to her ETH Fellowship.

This internal funding is also valuable for scientific staff such as Monica Menendez, who is the group leader of the Traffic Engineering research group at the Institute for Transport Planning and Systems. As she explains, "The high-risk research made possible by the Commission is crucial for the development of cutting-edge mobility applications."

However, established professors also benefit from this funding: "I was able to take my research in new directions," says Dimos Poulikakos, Professor of Thermodynamics. In the case of Beat H. Meier, Professor of Physical Chemistry, two projects paved the way for the ERC grant that he obtained in March 2017. For Klaus Ensslin, Professor of Experimental Physics, what was initially a loosely defined project later became the National Centre of Competence in Research Quantum Science and Technology (NCCR QSIT): "The show of support from ETH strengthened cooperation and led to the founding of the NCCR." Peter Seeberger, Director of the Max Planck Institute of Colloids and Interfaces, was a professor at ETH Zurich and a member of the Research Commission from 2003 to 2009. From his point of view, providing academic "venture capital" gives ETH an advantage in the competition for world-leading researchers: "I know of only one similar system at the Max Planck Society."

Thanks to an ETH grant, the chemist Beat H. Meier was able to create the first atomic resolution structure of a prion protein from the Podospora anserine fungus. He obtained an ERC grant in March 2017

Images: Beat H. Meier; Versantis

Crises open the pocketbooks

The history of the Commission began on 12 December 1942 when the School Council, the highest governing body of ETH Zurich at that time, decided to set up the ETH Commission for Academic Research. The new body was tasked with determining which ETH institutes would be "able to carry out valuable research work in the interest of the national economy". During the economic crisis of the 1970s, ETH President Heinrich Ursprung decided to grant more extensive powers to the Commission and allocate more resources to promising fixed-term research projects in order to counter stagnation. Detlef Günther concurs: "Today, we can allocate a part of each budget on a competitive basis. We share the same goal as our predecessors: providing even better support for the best researchers with the most original ideas." – Florian Meyer

Philanthrophy

INNOVATION THAT SERVES SOCIETY

By Vincent Forster

Together with my business partner Meriam Kabbaj, I founded Versantis, a spin-off of ETH Zurich, in 2015. Today, two years later, our product for the treatment of acute liver disease is on the verge of helping its first patients – thanks to a successful financing round with Swiss and international investors.

Versantis has come a long way in a short time, and I owe this to ETH Zurich's Pioneer Fellowship. The funding programme has helped me and many other researchers to develop ideas into marketable products. It is no secret that the path from the laboratory to the marketplace is a rocky one, and difficult to conquer without private support. Now I am confident that our product will be successful and that our sponsors' investment will ultimately benefit the whole of society.

The programme is largely funded through donations to the ETH Zurich Foundation.

More information available at:
→ www.ethz-foundation.ch/pioneer-fellowships

2017 Robert Koch Award

ANTONIO LANZAVECCHIA

Antonio Lanzavecchia (Professor at the Institute for Research in Biomedicine, Università della Svizzera italiana, Bellinzona, and ETH Zurich) is considered one of the most influential modern immunologists. Jointly with Rafi Ahmed, he has now been honoured with the 2017 Robert Koch Award by the Robert Koch Foundation. The Robert Koch Award is one of the most prestigious scientific accolades in Germany. It is awarded annually, under the patronage of the German Federal Ministry of Health, for outstanding and internationally recognised scientific achievements.

ETH Alumni

NEW ACTIVITES

ETH Alumni's Beijing Chapter is active again, and organised its first meeting in October. Members of the chapter met during Beijing Design Week to visit some exhibitions and get to know each other over dinner.

The newly established REIS Alumni section – comprised of alumni from the Spatial Development and Infrastructure Systems degree programme – also met up for drinks for the first time. Despite REIS being a rather new field of study, more than 30 alumni joined the meeting.

Werner Siemens-Foundation

VALUED PARTNERSHIP

The Werner Siemens-Foundation (WSF) has donated 12 million Swiss francs to establish the Centre for Single-Atom Electronics and Photonics.

ETH Zurich and the Karlsruhe Institute of Technology (KIT) are jointly establishing the centre to develop new types of integrated circuits for communications networks. The new centre is expected to start its work on 1 January 2018, and it will be coordinated by ETH Professor Jürg Leuthold from the Institute of Electromagnetic Fields.

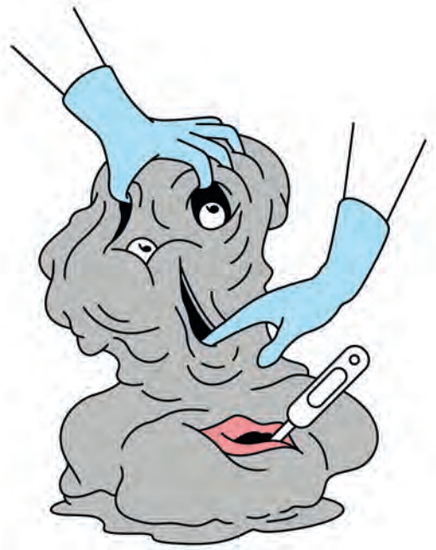
"The generous donation from the Werner Siemens-Foundation provides a unique opportunity to pool the skills of KIT and ETH in the field of electronics and photonics of individual electrons. This will give a boost to basic research and speed up its translation into practice," ETH President Lino Guzzella says.

This is already the Werner Siemens-Foundation's third donation to the ETH Zurich Foundation. The partnership goes all the way back to 2004 and has enabled some important initiatives.

ETH Zurich has paid tribute to its longstanding partnership with the Werner Siemens-Foundation by dedicating a plaque to the organisation. The inauguration ceremony took place at the premises of the Geothermal Energy & Geofluids group, Institute of Geophysics. ETH Zurich is acknowledging in particular the Siemens Foundation's donation of 10 million Swiss francs in 2013 to set up a professorship in deep geothermics.

Oliver Kraft, KIT Vice President for Research, with Oliver von Seidel, Member of the WSF Board, and Lino Guzzella, President of ETH Zurich

Images: Robert Koch Foundation; ETH Zurich Foundation



Column

… and Care crossed the river

Care is a central theme in the writings of philosopher Martin Heidegger. He shares anecdotes drawn from old myths in which a personified Care (*cura* in Latin) crosses a river and moulds the figure of a human being out of clay from the riverbank. As a result, care becomes a central (fundamental) theme of our humanity. This image provides food for thought. The great Basel biologist Adolf Portmann points to how we care for our own, a trait that we human beings with our "physiologically premature birth" are bound to exhibit. A papal encyclical encourages us to "care for our common home". Banks, insurance companies, doctors and social-policy experts all give careful thought to what they should offer in terms of preventative care, after-care or social care. So, they all claim to care for me. How well can they do that, however? Social protection agencies, evidence-based medicine and politics, precision medicine instead of personalised medicine – aren't these all administrative expressions of the fact that individuals are cared for as members of a cohort? This is a far cry from the image of Care moulding a figure out of clay with her own hands, and of a human being thus coming into existence at the bidding of the gods. In a cohort, it's the average that counts. This is determined by statistics, which in turn are determined by measurements. We're good at carrying out measurements because they are part of preventative care. How many base pairs does kale DNA have? How high is the fever or blood pressure? How many steps have I taken today, and how many on average last year?

In cohorts, the "quantified human being" is frequently synonymous with "human being". Care is replaced by care-ful measurements that reduce the lump of clay down to a matter of biology, chemistry or physics (in alphabetical order). This is extremely useful in certain life-threatening cases. However, not every case has symptoms that manifest themselves in terms of these three disciplines. Caring about human beings also means not letting them get into life-threatening situations at all. Continuous measurements and cross-comparisons are helpful for this purpose too – but so are caring human companionship and warmth. In future, we will have to tread carefully along the tightrope between the new totalitarianism of statistical care and care in the form of human warmth. We need to be prepared for a hard economic headwind: it's blowing in the direction of statistical standardisation, and it feeds on our own greed.

The philosopher Hans Blumenberg observes that in the story quoted at the start of this column, there is no mention of a reflection. But what if Care does indeed see her reflection in the river, and fashions human beings "in her own image"? If that's true, we and she might look very much alike.

Gerd Folkers heads the ETH Critical Thinking initiative. He is also President of the Swiss Science and Innovation Council. Prior to that, he spent many years as President of the Collegium Helveticum.

Illustration: Benedikt Rugar; Image: Giulia Marthaler

It's fun to write your own app

"That's right up my street!"

Think girls aren't interested in computers? Think again! *Globe* accompanied schoolgirls for a week as they took part in a computer science taster course.

TEXT Martina Märki IMAGE Simon Tanner

It's 8.30 a.m. on a rainy Tuesday morning. A small group of young girls has gathered in front of the Enge rail station in Zurich. Gradually, the group grows larger. The mood is still somewhat restrained. Most of the girls only met yesterday as they were welcomed to the start of their computer science taster course. Yeara is feeling nervous too. "Twenty girls have registered for the course this time, and I've never had such a big group," she explains.

Yeara Kozlov is a doctoral student at ETH Zurich's Computer Graphics Lab, and she is co-leading the taster course with her colleague Zaheer Chothia, a doctoral student at the Institute for Computing Platforms. They have both done this before. In collaboration with CSNOW (the Network of Women in Computer Science), the Department of Computer Science has been offering girls aged 16 and above the opportunity to attend a week-long taster course for over ten years now. This course is aimed at schoolgirls in their final or penultimate year at school, and at young women who are interested in studying computer science. A varied programme awaits those taking part: women studying or working in the field of computer science share their personal experiences; visits to companies and laboratories; and last but not least, participants take a programming course and complete a small personal project. In his welcome speech the previous day, Zaheer had promised the girls that "by the end of this week, you will have written your own small but fully functional Android app."

In the world of Google

It's now Tuesday morning, and a visit to Google Switzerland is on the agenda. Ten minutes and two mobile phone calls later, all 20 girls have made it to the meeting point. Yeara counts again and, relieved, gives the signal to set off. Google Switzerland's office in the Hürlimann Areal complex looks unpretentious from the outside, but in fact it is Google's largest research and development centre outside the USA and houses 2,400 employees from 85 different countries. Without further ado, the group reaches a small ground-level reception area. They are greeted there by Tahmineh, an Iranian who is herself a graduate of ETH and has worked for Google since 2015 in the privacy department. She has no difficulties at all in winning the atten- ›

Young Google employees in conversation with the schoolgirls

tion of the girls. “In Iran, computer science is more of a woman’s job, and I’ve always been baffled as to why that’s clearly not the case in Switzerland,” she explains. Then she talks the girls expertly through the latest issues in computer science. She asks whether they have heard about augmented reality, the computer as a diagnostic instrument for doctors, conscious robots or driverless cars? “I promise that as computer scientists you’ll be able to have a whole load of fun with all these topics in the future,” says Tahmineh. “There is a huge range of job opportunities in this sector.”

To make sure that things don’t stay on a purely theoretical level, she is joined by four other young Google employees. They too have all studied at ETH. It’s question time, and the young visitors don’t need to be asked twice. They fire questions without any hesitation: How many hours do you work? Do you prefer to work in a team or on your own? What do you like about your work? How difficult was the course at ETH? The young computer scientists’ answers convey a broad picture of their backgrounds and fields of work.

“The visit showed me that computer science involves much more than programming, and I found that very exciting,” a girl named Fabia says on the way back to ETH. She has already done a commercial apprenticeship in a bank and is now completing two years of adult education in Zurich to gain her school leaving certificate. What about going on to study computer science at ETH? Yes, of course! This petite young woman with her calm and considered manner absolutely believes she is capable of that. “We started programming yesterday, in pairs, during our Introduction to Java class,” she says. “Unfortunately, my partner and I had a problem with the login, so we still haven’t got as far as the other girls. I hope that we’ll catch up this afternoon.” Then it’s time for some more work in the computer room. Fabia’s partner, Giuliana, is in her fifth year at the cantonal school in Lucerne – and, as she laughingly admits, she’s an absolute computer game fanatic. But it’s not only her enjoyment of gaming that has led Giuliana to take part in this taster course. “Somehow, being involved with computer science means participating in the future of the world,” she says.

A committed teacher: Yeara Kozlov, a doctoral student in computer science

left: Flurina and Eva search for bugs

right: Giuliana and Fabia concentrate as they develop their quiz

Commands and bugs

First, though, it’s back to basics – which means unplugged, without using any computer at all. Wednesday morning brings an introduction to the world of binary numbers and all the things you can do with just the two commands 0 and 1. It starts with a card trick, and finishes with the girls trying in small groups to encode whole phrases. That’s quite a challenge for their concentration if you bear in mind that the number series 00001 01100 00101 11000 only spells out the name ALEX. After this, the girls move on to the third session of their Introduction to Java class. Here, they learn about if-then-else constructions, Boolean operators, and arrays. Yeara demonstrates Java commands on the board and gets the girls to formulate some themselves. “You’ll learn all this in your first week of study,” she says encouragingly.

Then, at last, the girls are allowed to use the computer again. Eva and Flurina are in their element today. These two young women create Java commands effortlessly, and they have completed the morning exercises without any bugs in next to no time. However, they are coming to this course from very different backgrounds. Eva is in the classical languages stream at the cantonal school in Winterthur, whereas Flurina has opted to focus on physics and maths at her school in Wohlen. Flurina is already quite sure that she would like to study computational science. “I find the combination of computer science and natural sciences really cool,” she says. Eva, on the other hand, is still in the process of deciding what to do; she wants to give herself some time to look around as widely as possible before she makes her decision. So far, she’s really enjoyed the computer science taster course. “It’s really exciting, and I can understand it all very well,” she says. Both girls can barely wait for the afternoon, when the introduction to app programming will finally begin.

Above: The young women are fascinated by objects from the 3D printer

Writing their own app

On Friday morning, everyone gathers punctually in the seminar room. The girls seem remarkably cheerful, even though yesterday had been a packed day for them. In addition to designing their own app project they had been given an insight into game development and taken on a visit to Disney Research. “That was right up my street,” says computer game enthusiast Giuliana. Today, the day begins with a round-table discussion, in which computer science students talk about their study experiences. The girls’ faces are filled with astonishment when someone openly admits, “The first time round, I failed my first-year exams; I then passed them on my second attempt.” So, it is possible for people to fail but still get through. “Hands-on” computer science is the next lesson, in which ETH Professor of Computer Science Stelian Coros demonstrates how 3D printing translates computer graphics into real objects. The girls crowd enthusiastically around the things he has brought along, amongst which is a robot with crab’s legs.

However, the highlight of the day is yet to come: in the afternoon, each pair of girls is due to present the app that they have created. There is still some time now to make the final improvements, and the tension in the computer room increases palpably. More and more arms shoot up into the air to ask Yeara or Zaheer for help. Fabia and Giuliana are the only ones who are really relaxed, because their quiz app is working. Eva and Flurina are still looking for a bug in the psychological test that they have devised. Eva groans, “I don’t want to do this all day – we solve one problem and create another!” Flurina counters: “Actually, I think it’s exciting; like detective work.”

When the apps are presented at the final plenary session, the tension disappears. All the girls are amazed at what they have achieved in such a short time. There’s an app to help children learn to read, a slimming app, and many others. When selecting their top app, the taster course students don’t end up going for the “Who Wants to be a Millionaire” quiz or the “Which Canteen for You” psychological test; instead, they choose a simple noughts and crosses game. However, that really isn’t very important. “What matters is the experience of the whole week,” says Eva, as she reflects back. ○

More information on the taster course (in German only):
→ www.csnow.inf.ethz.ch/fuer-schuelerinnen/schnupperstudium.html

CONNECTED

1 *Scientifica 2017*

FASCINATING WORLD OF DATA

Big data, digitalisation, artificial intelligence, the internet of things – over 30,000 visitors attended the fifth Scientifica organised by the University of Zurich and ETH Zurich, eager to find out exactly what data reveal. Around 300 researchers from the two universities were on hand to answer questions.

2 *ETH Day*

TWO NOBEL PRIZE WINNERS HONOURED

At this year's ETH Day, five researchers were awarded honorary doctorates: Nobel laureate Kip Thorne (left) received this distinction for his outstanding scientific achievements, in particular his decisive contributions to the discovery of gravitational waves, as well as for his extraordinary efforts to bring the basic sciences closer to a broader public, and Nobel laureate Richard Henderson (third from left) in recognition of his ground-breaking work in the development of electro-microscopy for high-resolution structure determination of biological macromolecules. Françoise Brochard-Wyart (second from left) received it for her fundamental insights into the phenomena of capillarity and their application in living systems. Fabio Reinhart (second from right) and Bruno Reichlin (right) were awarded horory doctorates for their exceptional services to architecture.

1 *Scientifica 2017*

Children are especially fascinated by the digital possibilities showcased at Scientifica

2 *ETH Day*

Images: Frank Brüderli (3); Oliver Bartenschlager

3 *Cybersecurity*

4 *think talk tibits*

5 *AgroVet-Strickhof*

Images: Nick Soland (2); ETH Zurich Foundation; Alessandro Della Bella

3 *Cybersecurity*

SWISS FEDERAL COUNCILLOR IS COUNTING ON ETH

Swiss defence minister Guy Parmelin paid a visit to ETH Zurich. In his public address, he highlighted among other things the importance of establishing a unit against attacks from cyberspace. In this, the federal councillor is counting on the support of ETH – and above all of the university's graduates. ETH President Lino Guzzella (left) also stressed the close relations between the federal defence sector and the university.

4 *think talk tibits*

FASCINATING INSIGHTS

At the third "think talk tibits" event, ETH alumnus and spin-off founder Pascal von Rickenbach (2nd from right) presented ETH spin-off GetYourGuide and his ETH biography to an interested audience. The event is an after-work meet-up that tibits and the ETH Zurich Foundation organise specifically for donors under the age of 40.

5 *AgroVet-Strickhof*

NEW CENTRE OFFICIALLY OPENED

ETH Zurich President Lino Guzzella (left) and the Rector of the University of Zurich, Michael Hengartner, officially opened the AgroVet-Strickhof farm, the universities' joint livestock project with the canton of Zurich. The modern centre enables participating ETH professors to conduct interdisciplinary research with direct practical relevance.

Agenda

EVENTS

12 December 2017 / 8.30 a.m. – 6 p.m.

Safeguarding the energy future

At the Energy Day organised by the Energy Science Centre, guests can engage researchers and students in discussion about the challenges and opportunities of a sustainable energy system – in Switzerland and worldwide. The morning will feature discussions of energy visions. In the afternoon there will be a symposium followed by a panel discussion. Registration required (this event will be held in German and English).

ETH Main Building
→ www.esc.ethz.ch

28 January 2018 / 2 – 3 p.m.

Magical geology: The equator

In conjunction with the Swiss Fairy Tale Society, *focus*Terra invites you to an exciting afternoon of discovery. Wilbert Junior Gill accompanies the fascinating tales of storyteller Marianne Wenner with his steelpan music. Afterwards activities for children will enable them to discover phenomena from the equator. The programme is suitable for families with children aged 6 and up.

ETH Zentrum campus, *focus*Terra
Sonneggstrasse 5
→ www.focusterra.ethz.ch/en

Emergency landing of the Super Constellation in the Mexican desert. Image from Volker Schlöndorff's filming of Max Frisch's "Homo Faber"

Max Frisch Archive

60 YEARS OF HOMO FABER

Until 20 April 2018 The original German edition of Max Frisch's *Homo Faber* was first published in October 1957. The story of Walter Faber – the rational engineer devoted to technology, haunted by fate although he doesn't believe in destiny – still captivates us today. Homo Faber has been translated into around 40 languages, filmed twice and performed countless times on stage. The exhibition organised by ETH Zurich's Max Frisch Archive traces the intricate genesis and impact of this classic work of literature: from the ruins of Greece to the publishing house in Frankfurt and into today's classrooms. On 28 February 2018 at 6 p.m. there will be a film showing and discussion with director Volker Schlöndorff.

→ www.mfa.ethz.ch/en

Collection of prints and drawings

HISTORY OF DRAWING

Until 21 January 2018 Antiquity, nudes, landscapes: In the final exhibition in the 150-year anniversary series, the Graphische Sammlung der ETH Zürich takes visitors back in time through the history of draughtsmanship. Prints spanning 4 centuries illustrate the development of aesthetic perceptions from the Renaissance to the 19th century. The exhibition has been curated under the guidance of Dr Michael Matile, together with students from the University of Zurich's Institute of Art History, in collaboration with Zurich-based artist Zilla Leutenegger.

→ www.gs.ethz.ch/current

Images: Marion Deichmann; Ascot Elite Entertainment Group

EXHIBITIONS

8 December 2017 until 16 January 2018

Drafts in the limelight

Master's students from the Department of Architecture present their final projects to the public.

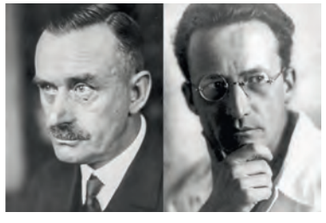
ETH Hönggerberg, HIL Building
→ www.arch.ethz.ch/en

Extended until 13 April 2018

"Lebenswende in Arosa" (Turning point in Arosa): Thomas Mann and Erwin Schrödinger

Physicist Erwin Schrödinger developed his wave equations while living in Arosa. Writer Thomas Mann chose it as a place of exile. The local history museum Arosa-Schanfigg tells the stories behind these days in the lives of the two Nobel Prize winners based on facsimiles from the Thomas Mann Archives collection.

Local History Museum Arosa-Schanfigg
→ www.tma.ethz.ch/en



CONCERTS

19 December 2017 / 7.30 p.m.

Christmas concert

"Bei Menschen, welche Liebe fühlen" (In people, who feel love) – Ballads and aria duets by F. Schubert, R. Schumann, J. Brahms, F. Mendelssohn and W. A. Mozart. Bass-baritone: Reto Knöpfel, soprano: Leticia Kahraman, piano: Andrea Wiesli.

ETH Main Building, Semper Aula
→ www.musicaldiscovery.ch

30 January 2018 / 7.30 p.m.

Orchestra concert: Serenade

The concert evening with the classical music ensemble Giraud from Zurich promises high artistry as well as exceptional musical intensity and diversity.
Violin: Andreas Janke
Conductor: Sergey Simakov

ETH Main Building,
Auditorium Maximum
→ www.musicaldiscovery.ch

GUIDED TOURS

19 December 2017 / 6.15 – 7.15 p.m.

Campus in the countryside

Discover, explore and experience ETH Zurich: the Services Department invites interested visitors to take an evening tour of ETH's ever-changing Hönggerberg campus.

ETH Hönggerberg
→ www.tours.ethz.ch

Recommended reading

CLIMATE GARDEN 2085 – HANDBOOK FOR A PUBLIC EXPERIMENT

Although global climate change is real, it is still largely not a tangible phenomenon. Juanita Schläpfer-Miller and Manuela Dahinden from the Zurich-Basel Plant Science Center therefore came up with the idea of a public experiment initially created at the Old Botanical Gardens in Zurich over six months in 2016. The Climate Garden 2085 invites visitors to experience at first hand the effects of global climate change at the local level. It demonstrates what plants will grow where, what food we will be eating and how our gardens might look. In their handbook, Schläpfer-Miller and Dahinden illustrate how their public experiment can be implemented locally anywhere in the world.

Published by Park Books
ISBN 978-3-03860-060-2
96 pages, 73 illustrations
CHF 29.00

Images: Thomas Mann Archive ETH Zurich, UZH Archive; Mark Xiao; Manfred Richter; Park Books/Nina Mann

A latecomer to astronomical research

Even as a boy, Rudolf Bär was fascinated by astronomy. After graduating from ETH, however, he opted for a career in banking. Only after his retirement did he reach for the stars.

TEXT Claudia Hoffmann IMAGE Daniel Winkler

When you see Rudolf Bär with his white hair and black-rimmed glasses, carrying a laptop under his arm, you might think that he is an emeritus professor. In fact, the 79-year-old is a complete newcomer to research. He has been working for just three years as a volunteer in ETH's Galaxy and Black Hole Astrophysics Research Group – where he's had considerable success. With the support of his experienced research colleagues, Bär published his first scientific paper last December. In it, he was able to demonstrate that a new technique can identify around 20 percent more black holes than the previous method.

Bär is a lay researcher, not a trained scientist. "However, I've been fascinated by astronomy all my life," he says. After he retired, he attended various lectures given by astrophysicist Kevin Schawinski at ETH Zurich, eventually striking up a conversation with him. Schawinski is a great advocate of citizen science and believes that everyone who really wants to do research should have the opportunity to do so; he therefore invited Bär to attend his research group's weekly meeting.

Still, joining the group was not quite so straightforward: Bär first had to prove that he was a suitable candidate, and was asked to do so by reproducing some of Schawinski's own experimental results. That's a difficult job for a self-taught astronomer with no formal training in the subject. He even had to learn a new programming language, although he was helped by already having done some programming previously. "The challenge spurred me on," Bär says. He worked away at a solution for three months, until he was at least partially successful. Then he was allowed to embark on his own research project for the first time.

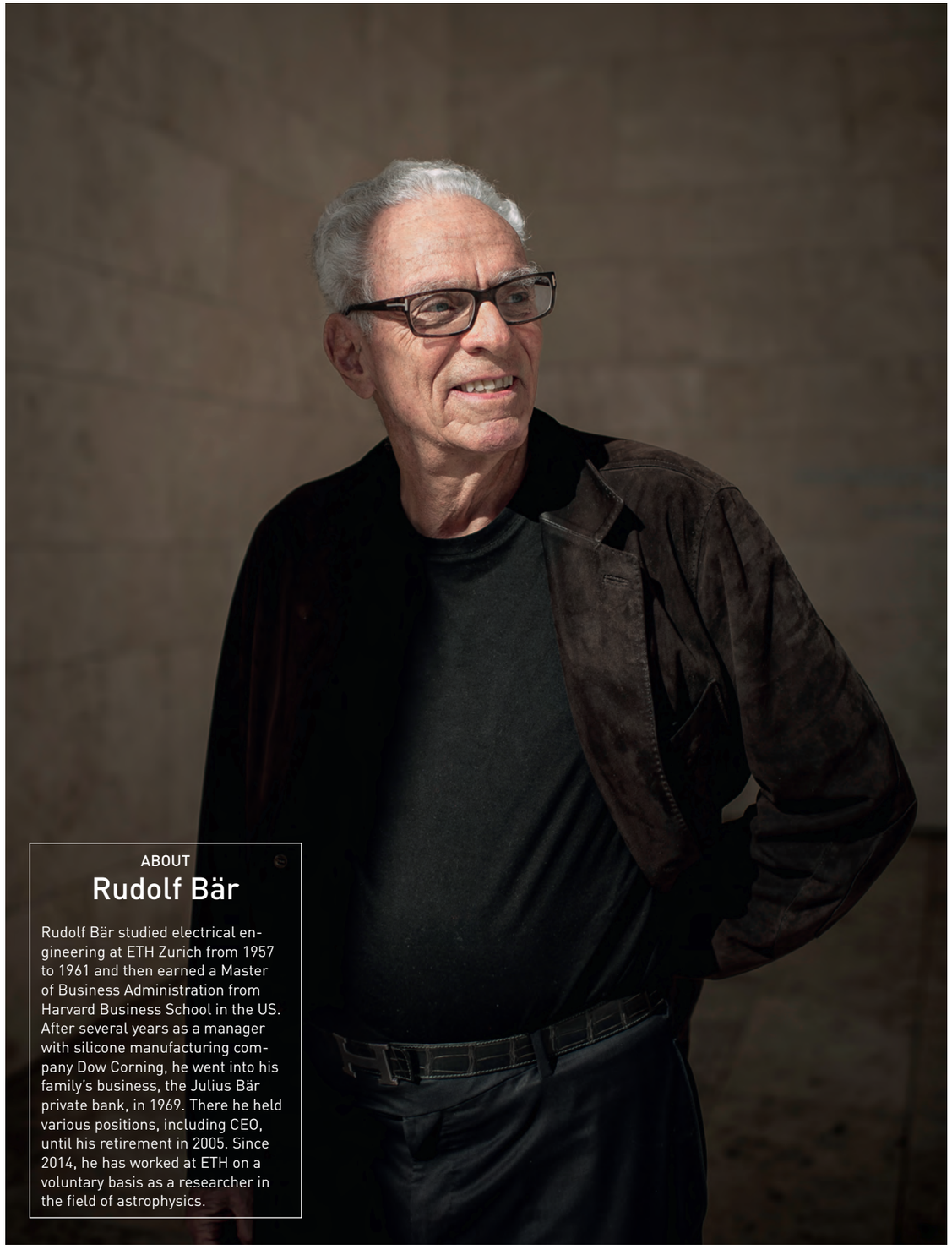
A schoolboy who watched the stars

Rudolf Bär actually comes from the world of finance. He is a grandson of Julius Bär, who founded the private bank of the same name, and he himself spent most of his working life in the family business. Yet even as a child, he came into contact with science in his family home in Zurich. His aunt was married to the mathematician Hermann Weyl, whilst the quantum physicist Wolfgang Pauli was a friend of his parents and sometimes came to dinner. "These encounters had a great influence on me," Bär recalls, and he developed an early interest in astronomy. As a schoolboy, he joined an amateur group that met twice a week in the basement of what is today the Urania car park. Together, they built a telescope and watched the stars.

Bär was so fascinated by astronomy that he considered studying it at university. However, when he asked a professor for advice, he was advised against it; the professor told him that astronomy focused on a very narrow field, which could make it difficult if he wanted to do something different later. Bär therefore opted for something more concrete and began to study electrical engineering at ETH in 1957.

Yet even as he was studying electrical engineering, he increasingly began to focus on business issues. "Hardly surprising, given ›

"The bank didn't have the same relaxed atmosphere I had been used to with the Americans."



ABOUT

Rudolf Bär

Rudolf Bär studied electrical engineering at ETH Zurich from 1957 to 1961 and then earned a Master of Business Administration from Harvard Business School in the US. After several years as a manager with silicone manufacturing company Dow Corning, he went into his family's business, the Julius Bär private bank, in 1969. There he held various positions, including CEO, until his retirement in 2005. Since 2014, he has worked at ETH on a voluntary basis as a researcher in the field of astrophysics.

my family background," he says. This led him to register for additional courses in economics at the University of Zurich.

After completing his studies at ETH, Bär went to the US in 1962, where he completed a Master of Business Administration at the prestigious Harvard Business School in Cambridge. Immediately afterwards, he was approached by Dow Corning, a silicone products manufacturer. They offered him a position as a finance expert to help in establishing a branch office in Europe. At the age of 26 and without any professional experience, Bär was thus appointed Chief Financial Officer – serving first in Zurich, and then in Brussels. "I was just told 'Do it!'" Bär remembers. Within a few years, the number of company employees in Europe grew to over a hundred. There was a lot of responsibility, but also a great deal of freedom.

"The expedition leader said: if you don't die within the next hour, there is a chance you will survive."

A career in the bank

This did not change until five years later, when Bär returned to Zurich to go into the family business, Bank Julius Bär. "Their way of doing things wasn't quite as relaxed as what I was used to with the Americans," says Bär. When he pressed ahead too far with a number of decisions as a newcomer, he was pulled back. He was told that he first had to submit a request to his superior, and then wait for the decision. "That took some getting used to at the beginning," Bär recalls. However, he obviously did so successfully, since he stayed in the family business until his retirement and held a variety of different roles. From 1993 to 2000, he was CEO of the Julius Bär Group, which had by now become a listed company. Nevertheless, he never made decisions on his own. Once a week, those members of the Bär family who took an active part in the bank met for lunch to discuss problems and take decisions. "It didn't much matter whether one of us was the CEO," says Bär. He thoroughly enjoyed his time at the bank, but it involved a great deal of work, too.

Despite his workload, Bär spent as much time as possible with his wife and two daughters. His wife, whom he had met during his days as an ETH student, was interested in art and other cultures, and together they explored far flung parts of the world. "We travelled to the most remote places," says Bär. In 1974, they went on their first journey to the Colombian jungle, where they stayed with the Embera indigenous tribe in stilt houses several metres high. "It was fantastic," Bär says. He was thrilled to see how the Embera live and was inspired by the magnificent orchids and colourful birds he saw in the jungle.

No fear in the jungle

However, the trips they went on were not always safe. Two years later, as they were canoeing to Angel Falls in Venezuela, he was bitten by a poisonous snake. "Our guide said to me: if you don't die within the next hour, there is a chance you will survive," Bär remembers. They canoed for six hours back to the nearest settlement. On the following day, a small plane airlifted him to the hospital, where he remained for another two weeks.

Further travel adventures included visits to the Yanomami people in the Amazon basin and the indigenous tribes of Papua New Guinea. Bär never had any fear that he might someday not return from one of these expeditions. As he puts it: "You can't foresee everything; you have to take things as they come."

Bär still travels today. He was in the US only recently, albeit this time for scientific reasons: he had the privilege of taking part in astronomical observations at the great mountaintop Palomar Observatory in California. He very much appreciates this opportunity, as well as that, as a newcomer, he has been allowed to take part in research at all. "Without Kevin Schawinski and the support of the other team members, none of this would be possible," says Bär. He also tells how much they helped him last year when he was writing his first published paper, on which he worked almost every day until midnight for several weeks. Even though he found this a real challenge, his curiosity is driving him on to do further research. He is already working on his second project, and he hopes to publish his next paper soon. ○

5 QUESTIONS

Come rain or shine, Ulrike Lohmann is always doing something outdoors – whether she's working as a cloud specialist or rowing a boat: *"Nothing energises me more than fresh air."*

Ulrike Lohmann is Professor of Atmospheric Physics at the Department of Environmental Systems Science.
→ www.iac.ethz.ch/group/atmospheric-physics

1 *What do you find particularly fascinating about your area of research?*

The variety. Clouds differ not only in their appearance, but also in their influence on weather and climate. We have been studying clouds for a long time now, but we still don't understand them in any detail. That's because the way they form and dissipate depends both on large-scale weather conditions and on processes that occur on a micrometre scale.

2 *Your work involves studying the climate. How "eco-friendly" are you in your daily life?*

That's a good question! The most eco-friendly things I do as a matter of routine are to ride my bicycle whatever the weather and to travel by train wherever possible, and I often take my holidays in Switzerland. We also live in an energy-efficient "Minergie" apartment, and I buy organic, local and seasonal products whenever I can. Unfortunately, the fact that conferences are an important part of my work means that I have to fly more than I would like. However, direct personal contact is simply crucial and can't always be replaced by video conferences.

3 *What are your leisure interests?*

Definitely sport. I am a passionate rower and cross-country skier. Sport helps me to clear my head as well as to enjoy nature and the fresh air. I have been in the ETH professors' rowing eight for ten years, where I'm fascinated by the interplay of physical effort, technique and team spirit. I also love competitions: I've taken part in the Engadin ski marathon in Switzerland and won medals at quite a few rowing regattas.

4 *What would you change about academic life today, if you could?*

I'd like to fundamentally rethink the practice of "publish or perish". The trend towards more and more publications leads to us having increasingly less time and leisure to read academic papers. I would therefore change the criteria by which we evaluate success. If the number of publications and citations carried less weight, it would be easier to have a part-time career in academia – and that could increase the number of women in management positions.

5 *With whom would you like to swap jobs?*

I'd like to spend a week as a journalist, with unlimited access to famous people. If I could have a week in the past, the person I'd most like to interview would be Nelson Mandela. I always found him a fascinating character, and I would like to see how South Africa's new beginnings looked through his eyes. If my week began today, I'd like to be stationed at the Swiss Federal Council so as to get a better insight into its work and into Swiss politics. — Interview conducted by Isabelle Herold

Image: Courtesy of Ulrike Lohmann

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