ETH zürich

NO. 3/2016

GLOBE

FOCUS

GETTING PEOPLE MOVING

How machines are restoring quality of life

PAGE 14

Education: ETH launches medical programme

PAGE 34

The research station observing plant growth

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Valentina Kumpusch: a passion for tunnels

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IMPROVING DAILY LIFE

Lino Guzzella, President of ETH Zurich

The countdown has started: the world's first Cybathlon is taking place on Saturday, 8 October 2016 at the Swiss Arena in Kloten. This competition brings together 80 athletes from all around the world to perform everyday tasks. At this event, however, the participating athletes all have a physical disability and will be using the latest assistive technologies. These include arm prostheses and exoskeletons, whether prototypes fresh from the lab or devices already on the market. With each team comprising athletes and engineers of the assistance systems, the Cybathlon is designed to ensure that the needs of people with disabilities have a more direct influence on the development of novel technical solutions that will substantially improve their quality of life.

The teams compete in six different disciplines. More about this on page 14.

The creative force behind the Cybathlon is ETH Professor Robert Riener, who has drawn on his considerable experience in rehabilitation robotics and his international contacts to launch a major event with participants from around the world. We have been able to get this competition off the ground thanks to our partner institutions and companies, and thanks to the tremendous dedication of many ETH employees. I am extremely grateful to all the people involved in this adventure.

Recognising a problem, developing an idea to solve it, collaborating with internal and external partners to put a solution into practice, and thus helping to advance our society: this is what ETH Zurich stands for. And we also stand for cutting-edge research in the field of medical and rehabilitation engineering. In this issue of *Globe* you can find out how machines are making life easier for humans and what the individual Cybathlon disciplines entail.

I hope you enjoy reading the magazine –
and I would be delighted to see you in Kloten on 8 October 2016!

Lino Guzzella, President of ETH Zurich

Cover: Gerber Loesch Photography; Photocase; Editorial: Giulia Marthaler

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Image: Andrea Diglas; Alessandro Della Bella; Annick Ramp

NEW AND NOTED

Electric race car "grimsel" sets an acceleration record.

World record

FROM 0 TO 100 IN 1.513 SECONDS

Success for the Formula Student team at the Academic Motorsports Club Zurich (AMZ): their electric race car, "grimsel", accelerated from 0 to 100 km/h in just 1.513 seconds – a new world record. This was 0.266 seconds ahead of the previous record held by a team from the University of Stuttgart. The vehicle accelerated to 100 kilometres an hour in less than 30 metres at the military airfield in Dübendorf near Zurich. The record-breaking vehicle was developed and constructed by 30 students from ETH Zurich and the Lucerne University of Applied Sciences and Arts.

New materials

LATTICE STRUCTURE ABSORBS VIBRATIONS

A team of researchers headed by ETH Professor Chiara Daraio have developed a new, rigid lattice structure that can absorb vibrations. Until now, the established practice has been to dampen vibrations in vehicles, machines and household appliances using soft materials. The new structure can cope with a much larger range of vibrations than conventional absorption materials, particularly slow vibrations. It can also be used as a load-bearing component, for instance in propellers, rotors and rockets.

Marker substance

VISUALISING MUSCULAR DISEASE

Amyotrophic lateral sclerosis, commonly known as ALS, is an untreatable muscular disease in which the nerve cells responsible for controlling the muscles gradually break down. The result is muscular atrophy and paralysis that lead to difficulties walking, speaking and swallowing. Medication can do no more than slow the progression of the disease; often, life expectancy following diagnosis is just a few years. Little is known about the causes of the disease.

Now a new marker substance could make an important contribution to our knowledge of ALS. It was developed by a team of ETH researchers headed by Simon Ametamey, Professor at the Institute of Pharmaceutical Sciences, together with experts from the Cantonal Hospital in St. Gallen and University Hospital Zurich. The new substance could potentially follow the progression of disease in ALS patients using positron emission tomography (PET). PET is an imaging technique that can visualise specific molecules on cell surfaces within body tissue. It does this by attaching marker substances – what are known as PET ligands – to molecules. The marker substances are lightly radioactive (with a half-life of between a few minutes and a few hours). This radiation is then measured during the PET scan.

The new marker substance has already been successfully tested on rats and mice with inflamed nerve tissue, and the researchers have submitted the molecule for patent. Clinical trials on humans are yet to come.

Image: Alessandro Della Bella

NEW AND NOTED

Arch_Tec_Lab

BUILT BY ROBOTS

Organic curves and sustainable materials define the roof of ETH's new Arch_Tec_Lab. The building was constructed on the roof of the underground car park at the Hönggerberg campus and embodies the new facility's founding principle: to make construction of the future resource-efficient, zero-emissions and high-density. With its new Arch_Tec_Lab, ETH Zurich is demonstrating the key role that research and new technologies including digitalisation can play in this endeavour.

Six professors at the Institute of Technology in Architecture were involved in the development process, implementing their various ideas at actual scale. The new building features an array of innovations, from a completely digitised construction process to a robot-built wooden roof and an innovative new lab for digitised manufacturing. Equally impressive is the building's structure, which dispenses with the need for bracing cores and so allows for a variety of uses.

Researchers at the Institute of Technology in Architecture want to use the new building as a real-life experimental lab where they can work with their students to tackle new issues and test solutions on site.

Image: Andrea Diglas

ETH GLOBE 3/2016

Structural damage

Using sensors and algorithms to make infrastructure smarter

In the future, data-driven models will be used to constantly monitor infrastructure. From bridges and wind turbines to elephant enclosures, scientists hope that integrated sensors will provide real-time data on the current state of the structure.

The post-World War II period witnessed the construction of many key elements of infrastructure, ranging from roads and bridges to dams and nuclear power stations. Much of this infrastructure is now reaching the end of its lifespan; concrete foundations are developing cracks and steel girders are becoming increasingly deteriorated. In a report published in 2013, the American Society of Civil Engineers estimated that the United States needs to invest some 3.6 billion dollars in roads, bridges, aqueducts and airports to avoid serious losses caused by decaying infrastructure. Against this backdrop, it is hardly surprising that there is currently a great deal of interest in advanced technology for infrastructure monitoring.

The concrete ring beam surrounding the elephant house at Zurich Zoo is monitored by strain sensors.

With sensors and algorithms

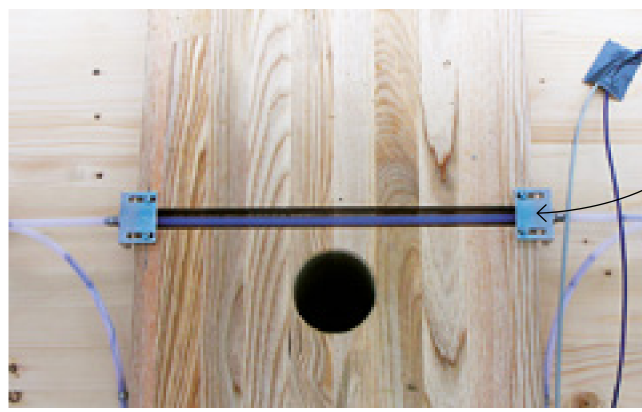
The Greek researcher Eleni Chatzi is one of the leading figures in efforts to assess the condition of infrastructure using sensors and sophisticated algorithms. "What we're developing here are essentially neuronal systems for infrastructure," says Chatzi, who has been working as an Assistant Professor in the Department of Civil, Environmental and Geomatic Engineering at ETH Zurich since 2010. Chatzi, who specialises in structural health monitoring, sums up one of their key goals: "We're investigating how we can obtain the maximum amount of information regarding the state of the structure, or need for repair, using a minimal amount of low-cost sensors."

Her work on bridges provides perhaps the best illustration of her area of research. In collaboration with the Swiss Federal Roads Office, her team of researchers fitted 20 sensors to the underside of a 25-metre motorway bridge near Affoltern. They linked these up into a measurement network that continually transmitted data on deformation, vibrations and signs of structural fatigue to a central on-site computer. "These kinds of structures are like living organisms," says Chatzi: "They're constantly changing in response to factors such as internal and external temperatures, humidity and wind strength." Real-time observations can provide an early warning of dangerous levels of deterioration and extreme stresses caused by events such as storms. Yet the researchers are even more excited by the potential this approach has for predicting future signs of structural fatigue and long-term deterioration. To this end, Chatzi is developing algorithms that can be used in combination with computer simulations to project data into the future. The engineer is hoping this will enable her to model the bridge's future behaviour.

Making the most informed decisions

Chatzi and her team draw inspiration for their methods from various fields, including electrical engineering, mechanical engineering and aviation technology. Sensors have long been used to monitor whether machines are functioning properly and to check their level of wear. But in the world of infrastructure, most status checks of this kind are still performed manually. In the course of regular inspections, experts appraise the condition of bridges and dams. In case of doubt, they use ultrasound, or other non-destructive testing means, to explore the inner structure of the concrete. The quality of these inspections depends heavily on the experience of the experts performing them. For example, potential points of failure are not always visible from the outside. Meanwhile, the consequences of an incorrect assessment could be catastrophic. On 1 August 2007, the 581-metre-long I-35W highway bridge over the Mississippi River collapsed in Minnesota, killing 13 people and injuring 145. Chatzi is convinced that these kinds of accidents could be prevented by networks of sensors and the real-time monitoring they enable.

Ideally, these kinds of sensor networks would be incorporated into the construction of new infrastructure right from the planning stage. And that's exactly what happened at Zurich Zoo's new elephant house. To protect the elephants, the architects designed an ornamental wooden roof with a span of 80 meters, which is supported solely by a concrete ring beam that runs around the enclosure. The ring beam is stabilised by concrete piles that are steel-reinforced and buried in the ground. Before the concrete was cast, Chatzi's team installed 40 rod-shaped fibre-optic strain sensors (20 cm long / 1.5 cm in diameter) on the ring reinforcement. Since then the embedded sensors have been providing real-time data on deformation and stress in the concrete ring beam. In the event of extreme stress caused by wind, snow or an earthquake, the engineers would now be in a better position to assess any damage to the structure and determine whether there was a need for further evaluation of the ring beam or even restoration work. The researchers are also collecting a constant stream of data on the concrete ring beam's ageing process, which Chatzi intends to use to calibrate and improve her monitoring system.



A fibre-optic strain sensor for monitoring the load-bearing capacity

Making wind turbines last longer

Smart monitoring systems like these have the potential to be used in a range of different areas. Last year Chatzi's research team embarked on a joint project with the Swiss energy company Repower. Wind turbines are already equipped with sensors that capture data on wind speed and direction, temperature and humidity. But now Chatzi is working on a system that could also be used to record data on oscillations and signs of structural fatigue in the tower and rotor blades. "Extending the lifespan of wind turbines improves the return on investment and thus boosts the appeal of wind power," says Chatzi. Last year her team fitted six sensors to a Repower wind turbine in Lübbenau and collected their first vibration response data. The EU found the concept so promising that it awarded a European Research Council (ERC) grant to Chatzi's basic research in the field of wind turbines.

The young engineer has ambitious goals: "Our vision for the future is that every major construction project will include a sensor system for monitoring from cradle to grave. But we'll need a shift in thinking among civil engineers if we're going to make that standard practice." There's no doubt that using these kinds of sensors involves some major changes. It essentially turns civil engineering into a big data science – and it converts infrastructure into yet another component of the all-encompassing "internet of things".
— Samuel Schlaefli

Chair of Structural Mechanics:
→ www.chatzi.ibk.ethz.ch

Image: Zurich Zoo, Jean-Luc Grossmann

Image: Chair of Structural Mechanics

NEW AND NOTED

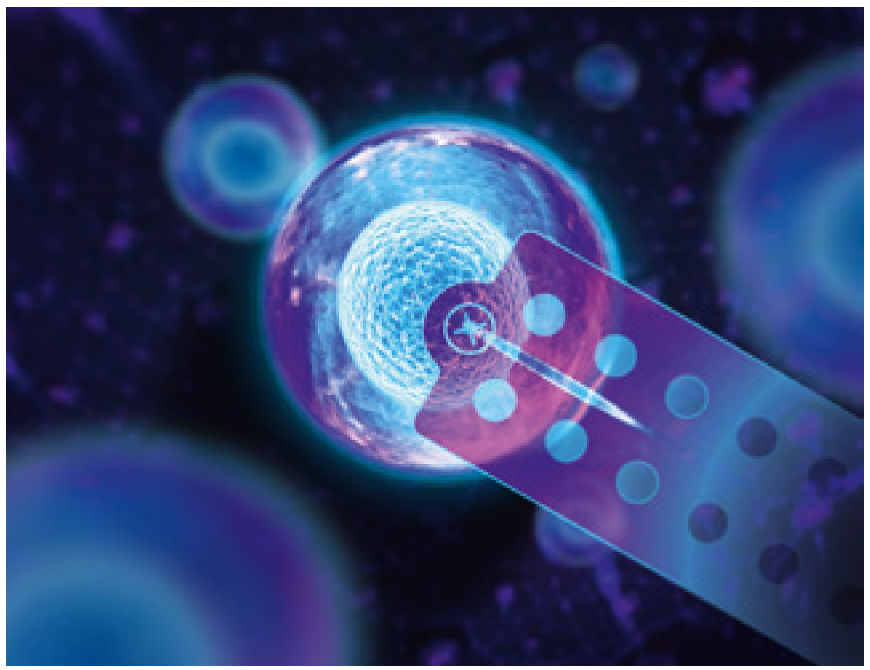
Revolutionary technique

EXTRACTING INDIVIDUAL LIVING CELLS

Biologists are increasingly interested in the behaviour of individual cells as opposed to whole groups of cells. Researchers at ETH Zurich have developed a new technique that could revolutionise this sort of single-cell analysis. Using the technique, scientists can prick individual living cells with a tiny syringe and extract their contents. "Our technique is a huge boost to biology research – a new chapter, if you will," says Julia Vorholt, Professor in the Department of Biology.

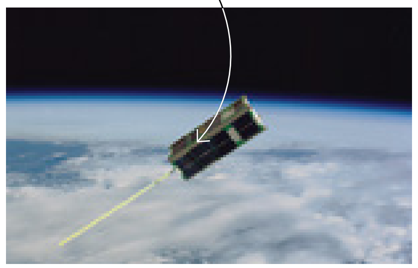
Thanks to the new technique, researchers can sample individual cells of a tissue culture directly in the Petri dish, allowing them to study questions such as how a cell affects its neighbouring cells in a cell group. In addition, the microsyringe is so precise that the researchers can specifically target either the contents of the cell nucleus or the fluid surrounding it, cytosol. The researchers can also pinpoint the quantity they extract with extreme precision – accurate to a tenth of a picolitre, which is one ten billionth of a millilitre. To put it into perspective, the volume of a cell is ten to a hundred times larger than that.

The new cell extraction method is based on the FluidFM microinjection system developed at ETH Zurich over the last few years – the smallest syringe in the world. Vorholt and her team then developed the system further to be able to extract cell contents.



The researchers can precisely determine the quantity to be extracted from the cell.

Attractive solution for small satellites



Power electronics

HIGH-SPEED

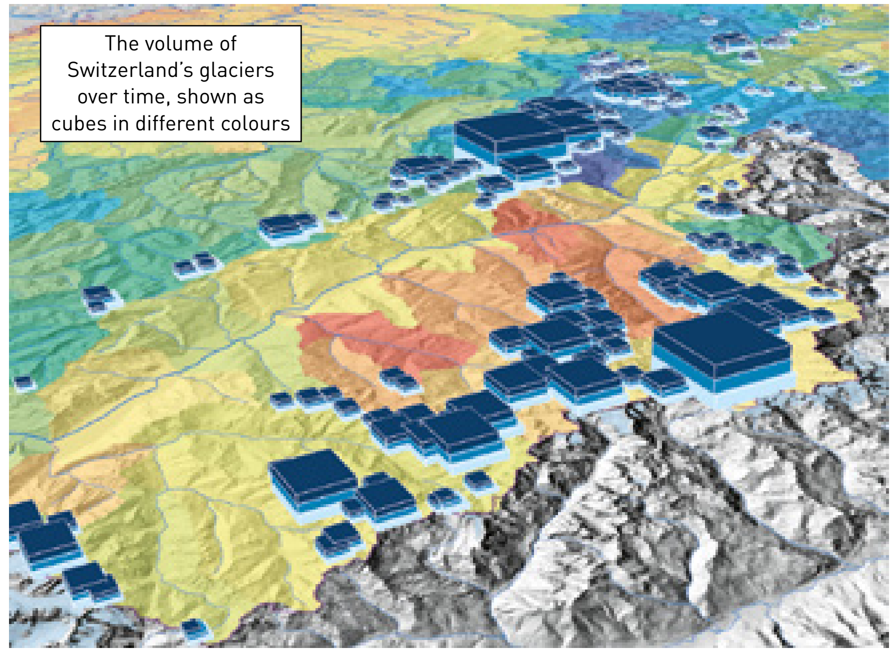
Reaching a dizzying 150,000 revolutions a minute: researchers at ETH Zurich's Power Electronic Systems Laboratory (PES) headed by Professor Johann Kolar have teamed up with colleagues from ETH spin-off Celeroton to develop an ultrafast, magnetically levitated electric motor for reaction wheels. Because the rotor is magnetically levitated – instead of using conventional ball bearings – the drive system can be significantly reduced in size, making it attractive for use in small satellites.

Epigenetics

OVERCOMING THE SYMPTOMS OF TRAUMA

Traumatic childhood experiences can lead to later behavioural disorders. These symptoms can be reversed in mice, provided that they live in a positive environment in adulthood, as a team of researchers headed by Isabelle Mansuy, Professor for Neuroepigenetics at the University of Zurich and ETH Zurich, has successfully shown. This allowed them to conclude that environmental factors can correct irregularities in behaviour that would otherwise be passed on to the next generation.

Image: ETH Zurich; Rick Kohnert



New Atlas of Switzerland

ONLINE ACCESS TO 3D MAPS

For the first time, ETH Zurich's Institute of Cartography and Geoinformation is making its multi-award-winning *Atlas of Switzerland* available online free of charge. The previous CD version has been overhauled with a new design for the user interface and menu structure in accordance with the principles of user-centred design. This allows users to call up maps quickly and intuitively, and now in 3D too. Users can download the Windows app for free, and a Mac version is in development. *www.atlasderschweiz.ch*

Mountain regions

FLOODS VS. DROUGHT

The Himalayas and Andes feature mountains over 6,000 metres high, plus glaciers, and climate models for the remainder of the century indicate that both regions will experience similar increases in annual mean temperatures. Despite these similarities, the water balance in the two regions is likely to develop differently. People in Nepal can expect to be faced with high water levels, while Chile should be prepared for long periods of drought. These are the findings of researchers from ETH Zurich and the University of Utrecht, who have thoroughly examined the water balance of both mountain regions using measurement data and climate models.

Electrochemical materials

SOLID BATTERIES IMPROVE SAFETY

Lithium-ion batteries can store a lot of energy in an extremely small space, making them the power source of choice for mobile electronics such as mobile phones and laptops, and even e-bikes and electric cars. However, lithium-ion batteries are not without their dangers, and there have been multiple instances of mobile phone batteries exploding, injuring their owners. Now, researchers from ETH Zurich have developed a type of battery that, unlike conventional lithium-ion batteries, relies solely on solid chemical bonds and is non-flammable.

In traditional lithium-ion batteries, the positive and negative terminals – the two electrodes – are made from solid conductive material; the charge then moves between them in a liquid or gel electrolyte. If these batteries are charged incorrectly or left out in the sun, their liquid can ignite. This is in contrast to the solid-state batteries currently being developed in laboratories around the world. In this case, the electrolyte is also made of solid material and cannot catch fire.

Led by Jennifer Rupp, Professor for Electrochemical Materials, ETH researchers have developed just such a battery, using a layer of a compound containing lithium (lithium garnet) as the solid electrolyte. "Thanks to the solid electrolyte, we can operate batteries at a higher temperature and build thin-film batteries," says Rupp. "These batteries could revolutionise the energy supply of portable electronic devices."

Image: Atlas of Switzerland

FOCUS

A MOVING COMPETITION

The exoskeleton developed by the ETH team "Varileg" helps people with paraplegia to walk independently over uneven terrain in everyday life.

The design of the "Scewo" wheelchair developed by ETH students features caterpillar tracks, which means it can tackle flights of stairs.

Machines that help people with physical disabilities are constantly being improved. Whether tackling flights of stairs in a wheelchair, regaining the ability to walk with the help of an exoskeleton, or mastering tricky tasks with an arm prosthesis – at the Cybathlon, disabled people will demonstrate how much they can achieve with assistive technology. This ETH Zurich competition is the first of its kind, and a spur to innovation.

TEXT Martina Märki IMAGE Alessandro Della Bella

Professor Riener, the Cybathlon is starting in just a few weeks. Some 80 athletes and their teams from 24 nations have registered for this major event.
What are you busy working on at the moment?
Right now we're checking all the team registrations again to see that they meet the specifications – fulfilling the safety requirements is particularly important. We take this seriously as, unlike in a sports competition, the participants here are using highly innovative technologies that have not yet been tried out extensively. Also, our competitors are not professionals, but people with disabilities who have offered to be "pilots" for the first time.

Robert Riener
Head of the Department of Health Sciences and Technology, Cybathlon organiser

Robert Riener, who came up with the idea for the Cybathlon, is Full Professor for Sensory-Motor Systems at the Department of Health Sciences and Technology (D-HEST) and a member of the Faculty of Medicine at the University of Zurich. He was appointed Assistant Professor for Rehabilitation Engineering at ETH Zurich in May 2003, becoming Associate Professor in 2006 and Full Professor in 2010.

How is the Cybathlon different from the Paralympics?
The Cybathlon is not about top physical performance. Instead, the pilots have to master challenging tasks taken from everyday life. We are also promoting the use of technologies that are not permitted at the Paralympics, such as motors, sensors and displays. This allows us to address people with the types of disabilities that prevent them from participating in the Paralympics. In our competition, participants even include individuals with severe paralysis resulting from high spinal cord injury – for instance, in the powered wheelchair race or the brain-computer interface race.

The Cybathlon aims to be an exciting experience, not just for those directly involved but also for the wider public. What's the idea behind this?
We want to draw attention to the opportunities that new technologies offer people with disabilities, and at the same time demonstrate the limitations of current assistive technology. And we want to inspire researchers to develop novel devices that are useful, practical and acceptable for those living with a disability. We hope to reach as many people as possible – we'll be streaming the event live online, while national and international media outlets plan to broadcast news segments and documentaries. Swiss Television will also broadcast the entire event live.

How have you made sure that your plans address the needs of people with disabilities?
This was a learning process. We started by thinking about technical problems, but we soon realised that this approach only covers a part of the real needs of people with disabilities. It's not enough for assistive technologies to function well – individual users also have to find them user-friendly enough to accept them. And they have to be affordable. We also learned about some people's fear that promoting high-tech assistance could shift attention away from the public sector's responsibility to ensure barrier-free environments. This type of question came up often during the project. That's why alongside the competition, we are running a comprehensive series of talks and events where such aspects can be discussed. We also have people with disabilities serving as experts on the advisory committee, and disabled organisations both large and small on board as either donors or sponsors. In this way, we've been able to include their opinions and experiences too.

Some people fear that high-tech assistance systems may turn a human into a cybernetic organism – a cyborg. What's your response to this?
You mean that there's a temptation to use machines to improve function in non-disabled people, too? This problem hasn't really come up yet, as current technology can't match the functionality, or above all the versatility, of the human body. At the Paralympics you sometimes see high-tech leg prostheses, for example, that allow disabled athletes to jump even further than non-disabled people. But these prostheses are totally unsuitable for everyday activities like walking, climbing stairs or driving a car. The real problem is just that: many of the new technologies only work in specific circumstances or in the lab, and can't be used in everyday life. That's what we want to change.

Who will be taking part in the Cybathlon?
About a quarter of the teams participating are from industry, and three quarters are teams from university >

Powered Wheelchair Race

Sleepers, curb stones and stairs are obstacles that wheelchair users encounter every day. A range of different solutions to these problems are being presented at the Cybathlon. In the line-up are powered wheelchairs steered with a joystick, tongue control, touchpad or other technical means. Four pilots at a time will race against each other in parallel lanes to navigate the six obstacles swiftly and precisely.
The pilot who completes the most assignments in the shortest time is the winner.

labs. We wanted to keep the competition open, to pit the strengths of products already on the market against brand new ideas from the lab, or prototypes put together in a garage by an inventor. We hope this will provide the most inspiration for further innovations.

Can you already spot some trends among the participating teams?
It's fair to say that the equipment from industry is mostly more robust, whereas the lab prototypes are more innovative, but not so fully developed and more prone to malfunction. To a certain extent, there are also differences in the complexity of the technology, depending on the country in which it has been developed. Which isn't to say that a piece of highly complex technology is automatically a better solution. Sometimes there are advantages to simple equipment. I'm expecting some surprises!

What's especially interesting about the development of assistive devices at present?
At the moment there are interesting developments in many areas of technology. Smaller batteries make equipment lighter; longer running time makes it more mobile. Advances in computer technology and robotics mean there are things we can do today that we simply couldn't ten years ago. And new materials are being developed all the time; these are perhaps better suited to the body, say, or they are lighter while also more stable.

> *Switzerland is strong in robotics and rehabilitation robotics*

Is Switzerland a good environment for developing such technologies?
Absolutely. Research and technology here are top-level, and we have an outsize share of the medical engineering industry, especially small and medium-sized companies. We're also strong in robotics – particularly neurorehabilitation robotics – both in research and in industry. That's why a lot of companies are supporting the Cybathlon, which we're very thankful for. Without this support from firms and associations, it wouldn't be possible to run an event like this – and we're always on the lookout for more partners and sponsors who would like to help us to stage this event by supporting the ETH Zurich Foundation.

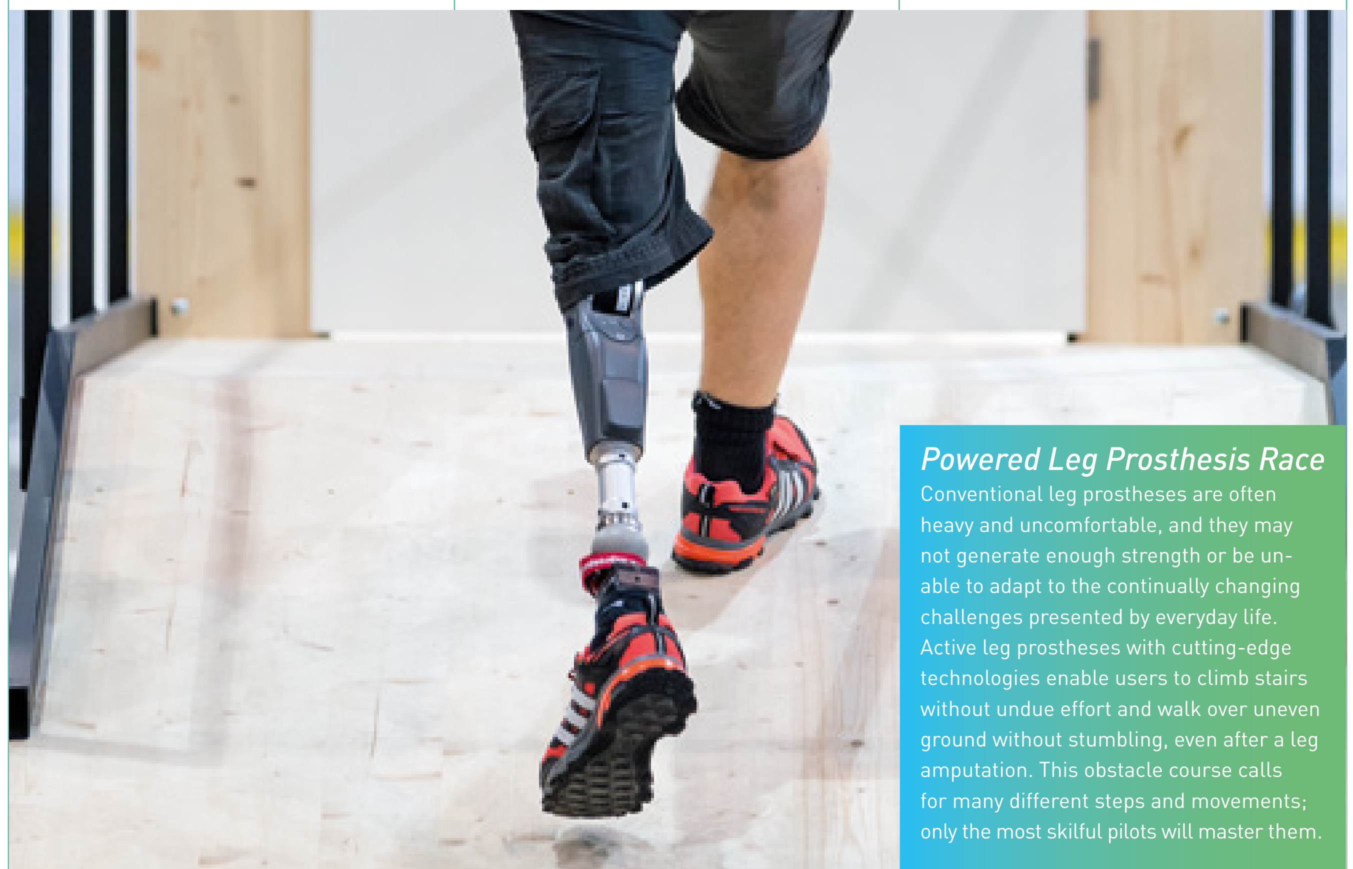
How do you rate the chances of the ETH projects at the Cybathlon?
There are two ETH projects in the competition: team "Scewo" is pre- >

Brain-Computer Interface Race

Brain-computer interfaces enable even completely paralysed people to control devices, such as a computer or a robotic arm, with signals from the brain. In this virtual race, the pilots use the interfaces to guide on-screen figures (avatars) in a specially developed computer game. The pilots must send the right commands at the right moment for their avatars to jump over obstacles or accelerate.

Powered Arm Prosthesis Race

Arms and hands are almost indispensable for tackling the challenges of everyday life. Fortunately, there have been major advances in prosthetics. At the Cybathlon, individuals who have had an arm amputated either above or below the elbow will show us just what the latest arm prostheses can do. Whether pegging out clothes, preparing a meal, carrying heavy things up stairs or getting a grip on tiny objects, the tasks in this competition are all taken from real life.



Powered Leg Prosthesis Race

Conventional leg prostheses are often heavy and uncomfortable, and they may not generate enough strength or be unable to adapt to the continually changing challenges presented by everyday life. Active leg prostheses with cutting-edge technologies enable users to climb stairs without undue effort and walk over uneven ground without stumbling, even after a leg amputation. This obstacle course calls for many different steps and movements; only the most skilful pilots will master them.

Functional Electrical Stimulation Bike Race

Electrical muscle stimulation enables paralysed muscles to move again. An electrical impulse is transmitted to the muscles through electrodes on the skin or using an implanted pulse generator, causing the muscles to contract. In this way, a pilot with a spinal cord injury, whose nerve pathways between the brain and leg muscles have been disrupted, can initiate a movement such as pedalling, with the help of an intelligent control unit. Only pilots with a severe spinal injury are competing in this race, and only bicycles without a motor are allowed. All the energy required must be generated by muscle power alone.

senting one of the few wheelchairs that can tackle stairs, while team “Varileg” is showcasing an exoskeleton. I think both are in with a good chance, although they’re still very young. The products have been developed by student project groups that started just two years ago. When you consider this, they’ve come a long way.

Do any other projects particularly impress you?
Yes, I’m fascinated by the project from a Swedish team – an arm prosthesis with a robotic hand. Here the prosthesis is directly integrated into the arm bone, and a 12-channel electromyograph is implanted in the arm muscle to detect the intended movement via muscle activity in the arm stump. This enables the pilot to move his hand with the help of impulses from the arm muscles. We’ll have to see just how robust this type of connection is.

What’s going to happen once the Cybathlon is over?
ETH Zurich wants to continue with further Cybathlon events. As an incentive for innovation, we’ve already planned similar national and international competitions in various countries and for individual disciplines. We’re also looking to give demonstrations at schools to get young people interested in this subject area, and to motivate them to make contact with people with disabilities. We’ve got big plans. ○

CYBATHLON

8.10.2016, Swiss Arena Kloten
Come and experience the Cybathlon, the competition where people with disabilities test the latest technical assistance systems. Some 80 athletes from 24 countries are taking part. A scientific symposium and a programme for schools linked to the event serve to strengthen contacts between people with disabilities, experts and researchers.

Order your tickets
www.ticketcorner.ch/cybathlon

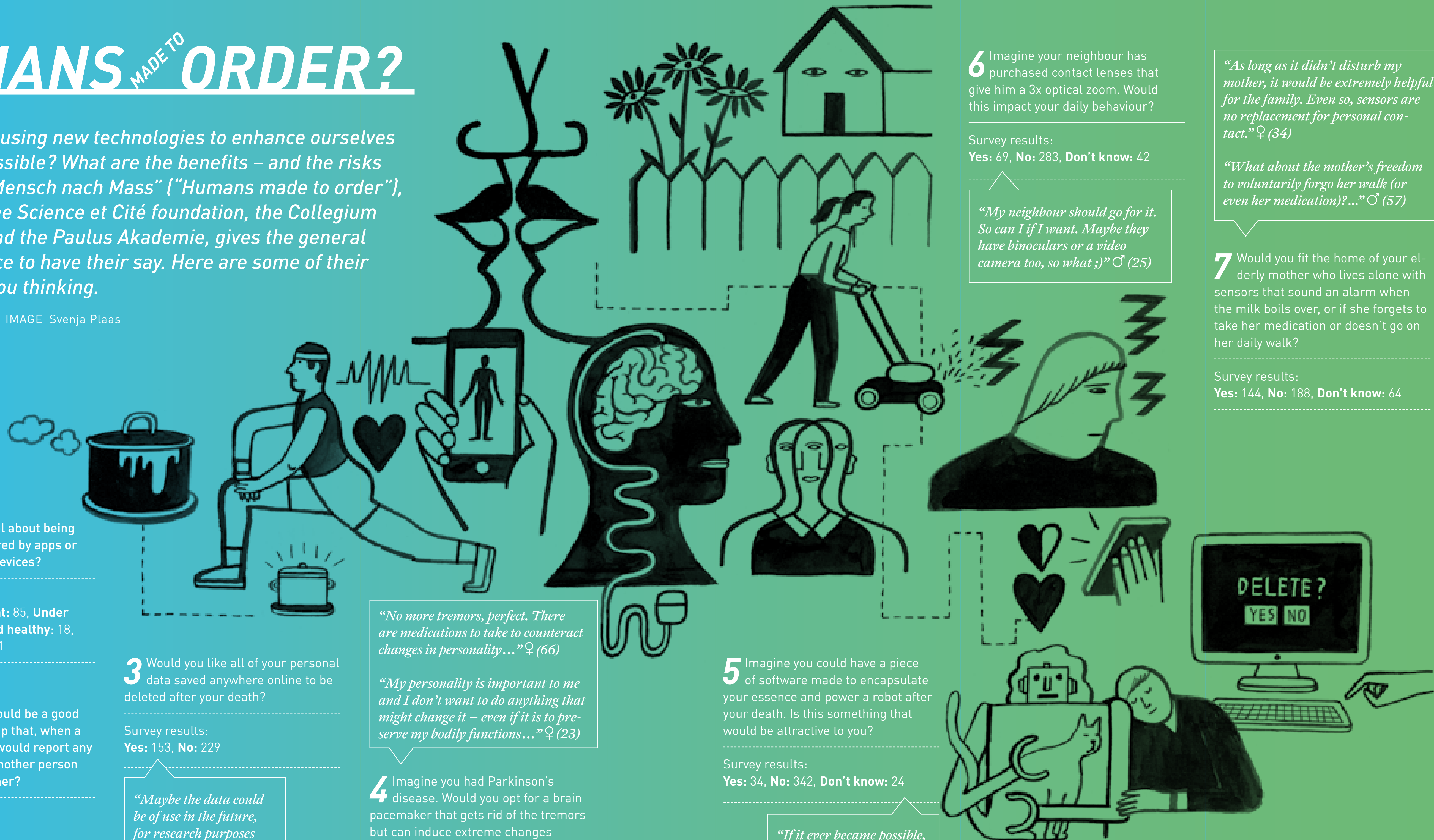
Powered Exoskeleton Race

Once the stuff of science fiction films, today robotic exoskeletons are being used in hospitals in therapy for patients who can no longer move around without help. It’s thanks to exoskeletons that people with paraplegia can walk again. The Cybathlon is seeking out the most comfortable and flexible exoskeletons, ones that enable their pilots to reliably carry out a range of everyday tasks, such as walking over uneven terrain.

HUMANS MADE TO ORDER?

Should we be using new technologies to enhance ourselves in any way possible? What are the benefits – and the risks and limits? "Mensch nach Mass" ("Humans made to order"), a project by the Science et Cité foundation, the Collegium Helveticum and the Paulus Akademie, gives the general public a chance to have their say. Here are some of their views to get you thinking.

TEXT Martina Märki IMAGE Svenja Plaas



1 How would you feel about being constantly monitored by apps or other technological devices?

Survey results:
Safer: 29, **No different:** 85, **Under pressure**: 220, **Fit and healthy**: 18, **A bit sick:** 41, **Crazy:** 1

2 Do you think it would be a good idea to offer a chip that, when a person got married, would report any sexual activity with another person to that person's partner?

Survey results:
Yes:10, **No:** 384

"The return of the chastity belt??!" ♂ (65)

3 Would you like all of your personal data saved anywhere online to be deleted after your death?

Survey results:
Yes: 153, **No:** 229

"Maybe the data could be of use in the future, for research purposes perhaps." ♀ (33)

"No more tremors, perfect. There are medications to take to counteract changes in personality…" ♀ (66)

"My personality is important to me and I don't want to do anything that might change it – even if it is to preserve my bodily functions…" ♀ (23)

4 Imagine you had Parkinson's disease. Would you opt for a brain pacemaker that gets rid of the tremors but can induce extreme changes in personality such as depression?

Survey results:
Yes: 57, **No:** 243, **Don't know:** 106

5 Imagine you could have a piece of software made to encapsulate your essence and power a robot after your death. Is this something that would be attractive to you?

Survey results:
Yes: 34, **No:** 342, **Don't know:** 24

"If it ever became possible, definitely!" ♂ (40)

"Everyone is unique and should stay that way!" ♀ (30)

6 Imagine your neighbour has purchased contact lenses that give him a 3x optical zoom. Would this impact your daily behaviour?

Survey results:
Yes: 69, **No:** 283, **Don't know:** 42

"My neighbour should go for it. So can I if I want. Maybe they have binoculars or a video camera too, so what ;)" ♂ (25)

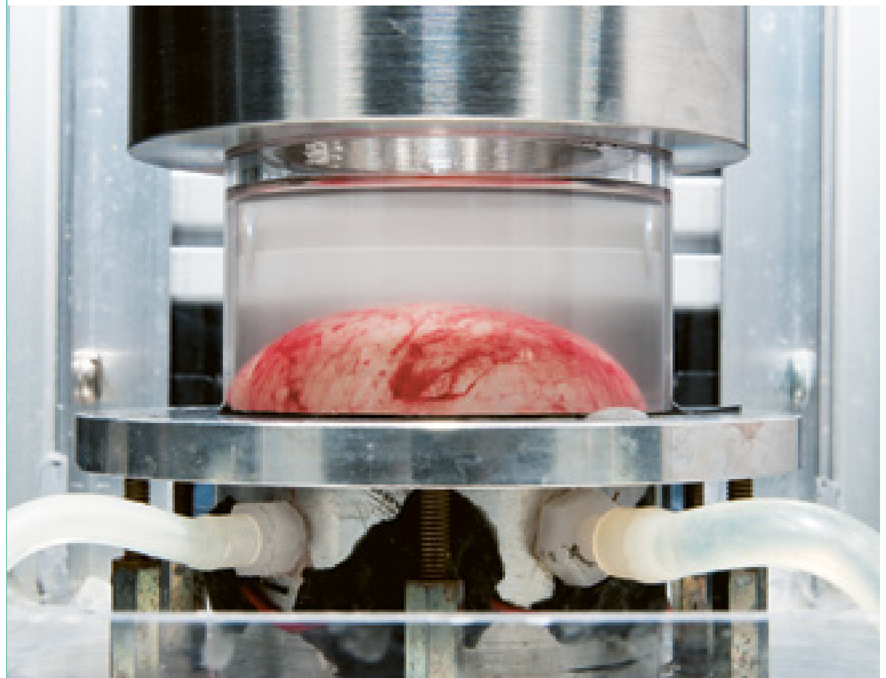
"As long as it didn't disturb my mother, it would be extremely helpful for the family. Even so, sensors are no replacement for personal contact." ♀ (34)

"What about the mother's freedom to voluntarily forgo her walk (or even her medication)?…" ♂ (57)

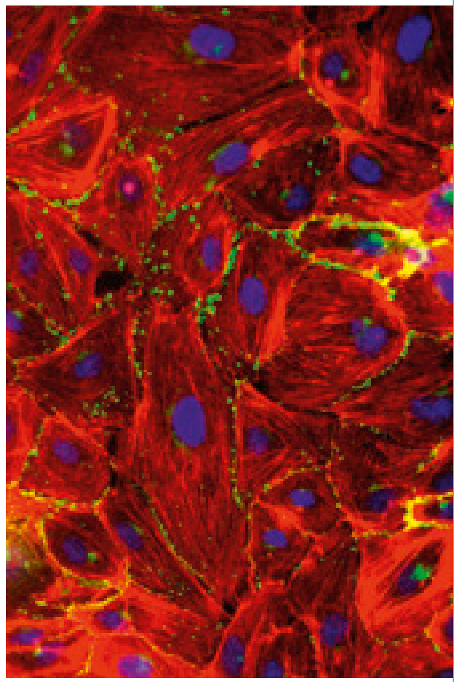
7 Would you fit the home of your elderly mother who lives alone with sensors that sound an alarm when the milk boils over, or if she forgets to take her medication or doesn't go on her daily walk?

Survey results:
Yes: 144, **No:** 188, **Don't know:** 64

For more information on the "Mensch nach Mass" project, please visit:
→ menschnachmass.ch



Researchers use this device to study the mechanical properties of different tissue types.



In laboratory tests, they have managed to cultivate a complete layer of endothelial cells on a substrate under extreme mechanical stress.

PROGRESS ON ALL LEVELS

More and more people are living with an artificial heart, but today's devices have serious drawbacks. ETH researchers are now working with doctors to develop alternatives.

TEXT Felix Würsten

Image: M. Maurer; L. Bernardi and B. Bachmann

Image: Giulia Marthaler (2); Volkmar Falk

In 1982 in Salt Lake City, American heart surgeon Robert Jarvik implanted the world's first permanent artificial heart into a patient. While it is true that Barney Clark, a retired dentist, survived for "just" 112 days, this operation nonetheless heralded a new era in heart surgery. Ever since, artificial hearts like the one given to Clark have been implanted not only as an interim measure, but increasingly as a longer-term solution for keeping patients alive.

Figures from the German Heart Institute Berlin, which runs the world's biggest mechanical circulatory support programme, indicate just how much demand there is for these life-saving devices: to date, the institute has implanted over 2,500 cardiac support systems. Demand is likely to grow even higher in coming years, since more and more patients are suffering from heart failure – not least because of increasing life expectancy – while the number of donor hearts is plateauing.

Close cooperation with doctors

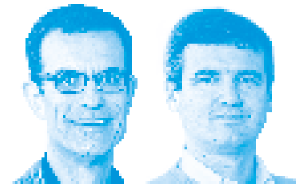
The problem with this development is that today's artificial hearts exhibit a number of major weaknesses. One of them is the frequency of severe complications, which arise from the blood clots that tend to form inside the artificial hearts and subsequently cause a stroke. Another is that, since these devices are electrically powered, they need a connection to a battery – and the entry site into the body through which the connector cable passes is a haven for dangerous infections.

Five years ago, this unsatisfactory state of affairs led ETH – together with the University Hospital Zurich and Zurich University, its partners in the Zurich University Medicine initiative – to launch the Zurich Heart project. The idea was to pool the broad medical and technical expertise at hand in Zurich and use it to refine the existing technologies. According to Edoardo Mazza, a Professor at the ETH Institute for Mechanical Systems and Co-Director of Zurich Heart, since then the people working on the project have developed a truly functional community. "Our work tackles a variety of problems," Mazza says, "and we can all benefit from each other's knowledge." Indeed, a whole series of chairs at both universities is now involved. Between them they have 28 doctoral students and a total of 75 scientists working on various sub-projects.

"Zurich offers an ideal environment for this sort of undertaking," explains Volkmar Falk, Medical Director of the German Heart Institute Berlin. It was Falk who initiated the project back when he was Director of Cardiovascular Surgery at University Hospital Zurich. When he took up his role at the institute in Germany, he managed to bring a major new partner on board: after all, the doctors at the Berlin institute have a long history of clinical experience in the field of mechanical circulatory support. For Dimos Poulikakos, ETH Professor for Thermodynamics and the project's other co-director, the opportunity to work closely with the Berlin-based specialists and learn from them is an exciting one: "Doctors think in terms of solutions, just like we engineers do, which explains why we get on so well. Their feedback helps us to set the right development priorities."

Better components, new ideas

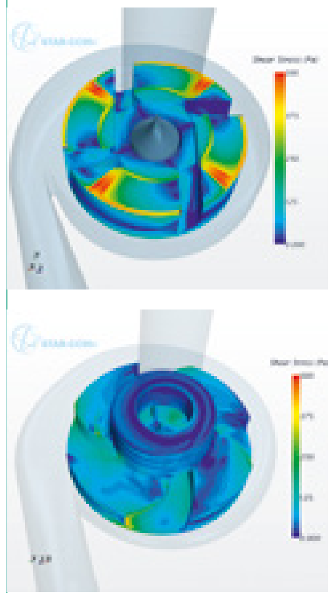
One major objective for Zurich Heart is to optimise individual components in a way that leads to fewer complications while improving system performance at the same time. For instance, ETH engineers are developing a ›



System modifications: Dimos Poulikakos
Professor of Thermodynamics at ETH's Department of Mechanical and Process Engineering. In the Zurich Heart project, he is in charge of system modifications, with a focus on improving the current support systems.

Alternative systems: Edoardo Mazza
Professor of Mechanics at ETH Zurich's Department of Mechanical and Process Engineering. He runs the alternative systems section of the Zurich Heart project, which includes work on how to employ new materials systems in artificial hearts.

Clinical integration: Volkmar Falk
Full Professor at the Department of Cardiothoracic and Vascular Surgery at Charité in Berlin and Medical Director of the German Heart Institute Berlin. As the former Director of Cardiovascular Surgery at University Hospital Zurich, in the Zurich Heart project he is responsible for clinical integration of the newly developed systems.



Lower stress thanks to new geometry: In today's pumps, the blood is exposed to high mechanical stresses (see the upper picture, which shows areas with high shearing forces in red). An improved design markedly reduces these stresses (lower picture).

new kind of control unit to improve today's passive control systems. If they are successful, the new control unit will ensure that artificial hearts no longer pump blood at a largely constant rate; instead, the volume pumped will be automatically adjusted to the body's needs, within certain limits. Initial short-term testing over several hours in an acute animal model showed that this approach holds much promise. The next step is to conduct long-term pre-clinical studies with the novel controllers for several weeks.

The engineers have also improved the heart pump's design. With the help of simulations, they were able to design a pump with a high degree of hydraulic efficiency that also causes less damage to red blood cells. This blood trauma is a grave problem for patients, as it impacts how effectively their blood transports oxygen around their bodies.

There is good news on the power supply front, too: ETH engineers are developing an efficient wireless system for supplying the artificial pump with electricity. Their system is built on the principle of electrical induction – similar to wireless mobile phone chargers. The challenge is to avoid excessive heating of body tissue. In an experiment, they were able to transmit 30 watts of power while keeping electrical losses so small that the tissue temperature rose no more than 1.5 degrees.

Improvements to existing technology are of course just one part of the project. Another part sees engineers and scientists pursuing wholly new approaches that might well lead to completely novel designs. For instance, they are experimenting with highly deformable materials that could be used to make a "soft" pump that more closely resembles the native organ. Of pivotal concern here is how such materials perform over the longer term if they are required to constantly change shape.

Endothelial cells are the key

Whether they are seeking to improve existing components or develop new concepts, researchers' work often throws up questions that touch on basic research. One central question is how to prevent blood from coming into contact with foreign materials, since this in particular gives rise to complications. The interior of natural blood vessels is lined with a layer of endothelial cells, which regulate the passage of materials in and out of the bloodstream. Now the researchers from ETH and UZH are working together with colleagues at EMPA (the Swiss Federal Laboratories for Materials Science and Technology) to cultivate autologous endothelial cells on a flexible substrate and bind this new tissue to the artificial materials.

Scientists are now in a position to generate an artificial layer of endothelial cells of this kind in a matter of hours. Moreover, they have developed a special bioreactor that they can use to emulate the conditions within the human body. The reactor enables them to realistically test cell adhesion on synthetic materials in the laboratory and determine whether the cell layer is capable of withstanding the high mechanical loads in new pump systems. Not least, this laboratory set-up gives the scientists hope that they will be able to reduce the amount of animal testing.

Comprehensive testing

Despite the excellent progress that so many Zurich Heart sub-projects have already made, it will still be some time before these new technologies can be employed in everyday medicine. For one thing, new materials must undergo thorough testing to prove their suitability for clinical use; for another, scientists need to conduct animal tests of longer duration in order to gather long-term data on how well the devices function over time within the circulation. What's more, the new sensors and algorithms used to control the pumps must pass innumerable tests, as do the components responsible for the wireless transmission of power and data. Like the pumps themselves, these components must demonstrate that they will operate with absolute reliability in practice and will never cause the cardiac support system to break down, since this would result in acute danger for the patient. "And then, of course, quite apart from meeting the onerous regulatory requirements for medical device approval for use in humans, it's essential we secure financing for the technology transfer," Falk adds, "because translation is expensive." ○

Image: Stefan Boës; Lena Wiegmann, UZH

BRAIN TO ROBOT: "MOVE, PLEASE"

Using the power of thought to control a robot that helps to move a paralysed hand: a project from the ETH Rehabilitation Engineering Laboratory could fundamentally change the therapy and daily lives of stroke patients.

TEXT Roland Baumann

One in six people will suffer a stroke in their lifetime. In Switzerland alone, stroke affects 16,000 people every year. Two thirds of those affected suffer from paralysis of the arm. Intensive training can – depending on the extent of damage to the brain – help patients regain a certain degree of control over their arms and hands. This may take the form of classic physio- and occupational therapy, or it may also involve robots.

Roger Gassert, Professor of Rehabilitation Engineering at ETH Zurich, has developed a number of robotic devices that train hand functions and sees this as a good way to support patient therapy. However, both physio- and robot-assisted therapy are usually limited to one or two training sessions a day; and for patients, travelling to and from therapy can also be time-consuming.

Roger Gassert has been Professor of Rehabilitation Engineering at ETH Zurich since 2008. He studied micro-engineering at EPFL, where he completed his doctorate in the field of neuroscience robotics. Following research placements in London, Vancouver and Kyoto, he became head of the joint robotics laboratory of EPFL and the University of Tokyo in 2007, before being appointed Assistant Professor at ETH Zurich. In 2014 he was promoted to Associate Professor; his Chair is supported by the ETH Zurich Foundation in collaboration with Hocoma AG.

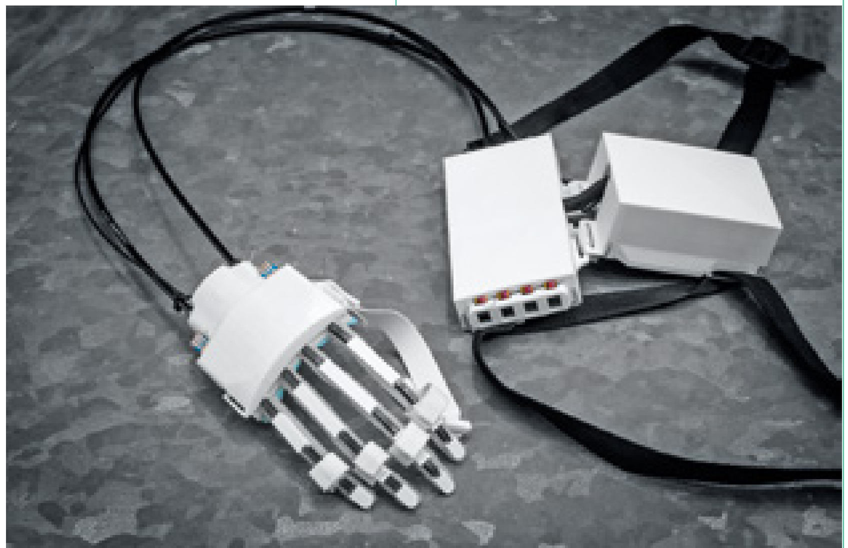
Exoskeletons as exercise robots

"My vision is that instead of performing exercises in an abstract situation at the clinic, patients will be able to integrate them into their daily life at home, supported – depending on the severity of their impairments – by a robot," Gassert says, presenting an exoskeleton for the hand. He developed the idea for this robotic device together with Professor Jumpei Arata from Kyushu University (Japan) while the latter was working in Gassert's laboratory during a sabbatical in 2010.

"Existing exoskeletons are heavy, and this is a problem for our patients because it renders them unable to lift their hands," Gassert says, explaining the concept. The patients also have difficulty feeling objects and exerting the right amount of force. "That's why we wanted to develop a model that leaves the palm of the hand more or less free, allowing patients to perform daily activities that support not only motor functions but somatosensory functions as well," he says. Arata developed a mechanism for the finger featuring three overlapping leaf springs. A motor moves the middle spring, which transmits the force to the different segments of the finger through the other two springs. The fingers thus automatically adapt to the shape of the object the patient wants to grasp. ›

Image: Giulia Marthaler

However, the integrated motors brought the weight of the exoskeleton to 250 grams, which in clinical tests proved too heavy for patients. The solution was to remove the motors from the hand and fix them to the patient's back. The force is transmitted to the exoskeleton using a bicycle brake cable. The hand module now weighs slightly less than 120 grams and is strong enough to lift a litre bottle of mineral water.



A hand exoskeleton with motors that can be fixed to the patient's back: A bicycle brake cable transmits enough force to lift a litre bottle of mineral water.

Researching brain processes
Gassert is currently driven by the question of what happens in the brain and how commands pass from the brain to reach the extremities after a stroke. "Especially with seriously affected patients, the connection between the brain and the hand is often severely or completely disrupted," Gassert explains, "so we are looking for a solution that will help patients pass on commands to the robotic device intuitively." The idea is to detect in the brain a patient's intention to move his or her hand and directly pass this information on to the exoskeleton. This may also produce a therapeutic benefit. According to Gassert, a number of studies show that it is possible to strengthen existing neural connections between the brain and the hand with regular exercise. An important component for this is that the brain receives somatosensory feedback from the hand when it produces a command to move.

In order to understand what goes on in the brain, Gassert is carrying out fundamental research with clinicians, neuroscientists and therapists. For their research, the scientists can draw on a number of imaging techniques, such as functional magnetic resonance imaging (fMRI), which allows them to map the activities of the whole brain. While this technology allows them to gain fundamental new insights, fMRI is both very expensive and highly complex and consequently not suitable for therapy. "And of course, it's not portable," Gassert adds with a mind to his project. He therefore focuses on simpler techniques such as electroencephalography (EEG) – and in particular functional near-infrared spectroscopy (fNIRS), the least expensive of these technologies. Gassert is currently engaged in the challenging task of figuring out whether and how fNIRS can be robustly employed. He is working on this together with a group from the University Hospital, who are contributing their experience in clinical application of the technology.

Fundamental insights
Another question that is still not fully understood is how the brain controls limbs that interact with the environment. "Here, robotics is making a valuable contribution to basic research because it is ideally suited for capturing a movement, perturbing it and measuring the reaction," Gassert explains. For example, the robotics experts have developed an exoskeleton that makes it possible to block the knee for 200 milliseconds while walking and extend it by 5 degrees. With the help of sensors, the scientists measure the forces that are involved and use this data to infer how the brain modulates the stiffness of the knee. These findings then flow into applications such as the control of new, active prostheses.

If the researchers succeed in establishing an interaction between the brain and the exoskeleton, the result will be a device that is ideally suited for therapy. If, on the other hand, the deficits are permanent, a robotic device could offer long-term support – as an alternative to invasive methods, which are also being researched. These for instance envisage implanting electrodes in the brain and triggering stimulators in the muscles. However, as long as stroke patients can expect to experience a reasonable degree of recovery, the robot-assisted therapy will be the obvious choice. ○

Rehabilitation Engineering Laboratory:
→ www.relab.ethz.ch

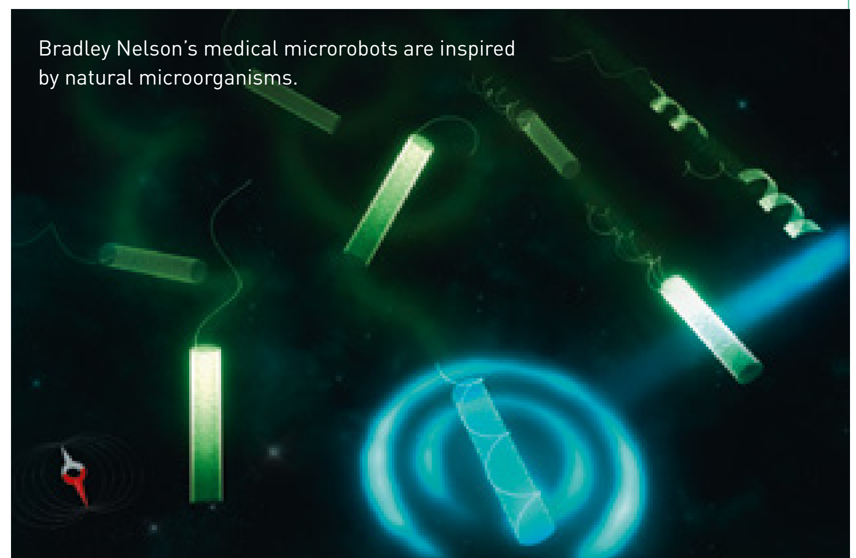
Image: Stefan Schneller

THE MICRODOCTORS IN OUR BODIES

ETH researchers are developing tiny, sophisticated technological and biological machines enabling non-invasive, selective therapies. Their creations include genetically modified cells that can be activated via brain waves, and swarms of microrobots that facilitate highly precise application of drugs.

TEXT Samuel Schlaefli

Richard Fleischner, who directed the 1966 cult film *Fantastic Voyage*, would have been delighted with Bradley Nelson's research: similar to the story in Fleischner's film, Nelson wants to load tiny robots with drugs and manoeuvre them to the precise location in the human body where treatment is needed, for instance to the site of a cancer tumour. Alternatively, the tiny creatures could also be fitted with instruments, allowing operations to be performed without surgical intervention. The advantages compared with conventional treatments with drugs are clear: far more targeted therapy, and as a result, fewer side effects.



Bradley Nelson's medical microrobots are inspired by natural microorganisms.

Fine-tuning materials and designs
Nelson isn't a dreamer or a storyteller – he is Professor of Robotics and Intelligent Systems at ETH Zurich, and he has an international reputation for his micro- and nanorobots. He still holds the Guinness World Record for the "most advanced mini robot for medical use". His robots are typically just a few micrometres in size and are inspired by nature. He derives models for his own micrometre-scale mechanical propulsion systems by observing microorganisms and seeing, for example, how the flagellum – a sort of curly tail that aids in movement – works in bacteria. The robots get the energy to move from an external impulse, such as an electromagnetic field.

Although this vision seems to be science fiction, Nelson's group is gradually making it a reality: in an in vivo experiment, they were able to accurately guide a swarm of 80,000 microrobots within a mouse to demonstrate the delivery of a model drug to targeted locations. Nevertheless, the researchers still have to resolve a number of questions before they can address the first set of applications in humans. The ques- ›

Image: Multi-Scale Robotics Lab

Bradley Nelson
has been Professor of Robotics and Intelligent Systems at ETH Zurich since 2002. His primary field of research is micro- and nanorobots for medical applications. He has more than 30 years' experience in robotics and has received numerous awards for his research.

Martin Fussenegger
has been Professor of Biotechnology and Bioengineering in the Department of Biosystems Science and Engineering (D-BSSE) at ETH Zurich in Basel since 2002. He is developing new therapies through biotechnological reprogramming of cells. He has published more than 270 articles in scientific magazines and is a co-inventor of several patents.

tions focus on materials and design: "When designing robots like this, we can't rely on our intuition because, on this small a scale, materials often behave differently than we are used to," explains Nelson. Special 3D printers have expanded the range of materials used in microrobot design, going beyond semiconductor metals to include polymers. As a result, last year Nelson's team in collaboration with Professor Christofer Hierold's team was able to create a robot from a biocompatible biopolymer that dissolves in the body after completing its task.

In his latest publication, Nelson goes one step further. The microrobots presented there can transform their shape depending on the environmental conditions, which is why Nelson calls them "origami robots". The change in shape can be stimulated by a change in the pH of body fluids, a temperature difference or a light pulse. The robots' plasticity is based on a multilayer structure with different hydrogels. Since the biopolymers expand or contract differently under external stimuli, the robot is able to change shape.

Again, nature provided the model for the design: the *Trypanosoma brucei* bacterium, the pathogen responsible for sleeping sickness, has a narrow, elongated shape to help it move efficiently in body fluids. However, as soon as the bacterium is in the bloodstream and no longer has to propel itself, it transitions to a stubby, compact shape – a further design option for a maximum-efficiency medical microrobot.

"Fifteen years ago we were just getting started, but today we are already able to control many different mechanisms very precisely," says Nelson. The next big challenge is autonomy: "We're examining how we can make the microrobots intelligent," he says. Specifically, once they have been released in the body, the researchers want the tiny devices to find the targets on their own – just as natural single-celled organisms have been doing for millions of years.

Cells as biological surveillance systems

Nelson isn't the only ETH researcher who is fundamentally rethinking medicine: Martin Fussenegger, Professor of Biotechnology and Bioengineering, is planning a minor revolution in medical therapy. He thinks it's "outrageous" that we simply pump drugs into our bodies, usually relatively late in the course of the illness, and then hope for the desired effect.

That's why his team in the Department of Biosystems Science and Engineering (D-BSSE) in Basel is pursuing a different route, intended to get the treatment to the core of the illness. "We reprogram the body's cells to be biological surveillance systems. In the body, they respond quickly to illnesses," says Fussenegger. These "molecular prosthetics" will be aimed at compensating metabolic defects that are responsible for such illnesses as diabetes, cancer and obesity.

Using standard molecular methods, Fussenegger can reprogram cells in such a way that an external impulse causes them to produce and excrete a desired active substance – usually certain proteins. His team uses light as the impulse; although the field of optogenetics is still quite young, it has made great progress in recent years in systematically controlling genetically modified cells using light. Two years ago Fussenegger succeeded for the first time, in the mouse model, in stimulating modified human cells to release a model human protein through irradiation with light in the near-infrared range.

Using implants to produce drugs

To allow the most precise control possible, Fussenegger's group developed a synthetic implant that combines the light source (a tiny infrared LED) and a semipermeable culture chamber with the genetically modified cells. The lamp is then powered inductively by an external electromagnetic field. This sophisticated system paves the way for mind-directed therapies, for instance by means of an electroencephalogram recorded on the patient's forehead (see graphic on p. 31). Fussenegger is certain that "such optogenetic therapy systems will be an important component of personalised medicine." The implant tested in the mouse model was the size of a 2-Swiss-franc coin. The next generation will be more along the lines of a matchstick and will require significantly less energy.

"In future, the electricity for activating the lamp – and thus the protein production – could also come from a smartphone or a watch," predicts Fussenegger. This would open up completely new possibilities for the doctor patient relationship: a doctor in the US could control the insulin level of a diabetes patient who is currently traveling in Europe by activating the production of the designer cells over the internet. At least, that's one vision of medicine in the coming age of the internet of things. ○

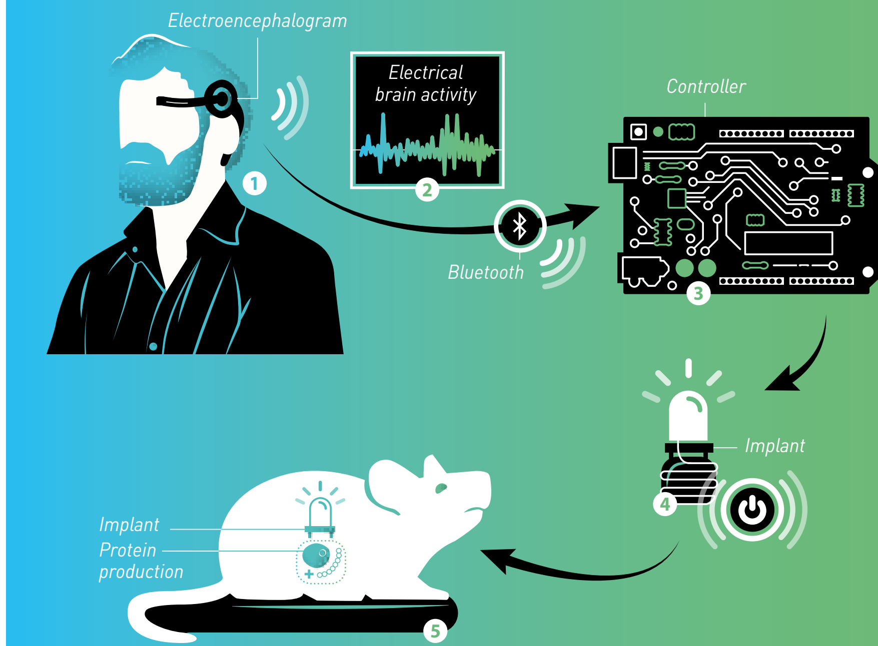
More information:
→ www.silva.bsse.ethz.ch/groups/group_fussenegger
→ www.msrl.ethz.ch/research

Image: Giulia Marthaler (2)

Image: Pia Bublies

HEALING THOUGHTS

It sounds fanciful, but a sophisticated implant could make it easier to do: activating healing substances in the body through thought.



The electrical activity of the brain can be recorded in a simple electroencephalogram (EEG) 1 by means of electrodes attached to a patient's forehead. Via Bluetooth 2 the brain activity is transmitted to a controller 3 that activates the implant lamp 4 by means of an electromagnetic signal. This self-directed method could help particularly patients who suffer from chronic head and back pain and those with epilepsy. Since pain episodes are often heralded by changes in brain activity, these changes can be viewed much like seismic waves are for earthquakes. Through early expression of an appropriate protein, the patient would receive therapy before the first pain emerges.

In initial studies, participants hooked up to an EEG were able, depending on their thought mode (concentrated or relaxed), to control the protein production of modified cells in an implant in mice 5. Fussenegger expects to see the first clinical trials in five to ten years. He assumes that the necessary implants would have to be replaced every six months on an outpatient basis, through a small incision in the upper arm or thigh.

View of the courtyard of the new HWO building

Student housing

PLENTY OF ROOM TO MEET

The ETH Zurich Hönggerberg Campus is set to become a place where people not only do research and teach, but also live. In September, around 900 students will move into their new accommodation in the immediate vicinity of lecture halls and laboratories. The two new buildings, HWW and HWO, have been built on leasehold land in the southwest of the campus by Luzerner Pensionskasse (Lucerne Pension Fund) and Swiss Life. To ensure the campus is a vibrant place to live and not just reside, the new halls of residence also have shop space that is leased out to retailers, alongside numerous common rooms.

Venture 2016

BUSINESS IDEAS HONOURED

The Venture start-up competition has its roots in a joint ETH Zurich, McKinsey and Knecht Holding initiative. The winner in the 11th year in the Business Idea category was theMOFcompany, a start-up founded by researchers from ETH Zurich, the Paul Scherrer Institute (PSI) and the Zurich University of Applied Sciences (ZHAW). TheMOFcompany's goal is to offer a unique production service for what are known as metal-organic frameworks (MOFs). With its product, the start-up wants to revolutionise the industrial process. Second place in the Business Idea category also went to an ETH start-up: hemoTUNE is developing a new therapeutic platform for blood purification. Functionalised, magnetic nanoparticles are applied in a dialysis-like circuit to remove specific disease-related compounds from the blood.

The top spot in the Business Plan category went to T3 Pharmaceuticals, a University of Basel spin-off, for a novel method of fighting cancer with bacteria. Two ETH representatives, ComfyLight and Peripal, also made it into the top five in the Business Plan category. ComfyLight manufactures an intelligent light bulb and Peripal has developed a device for home dialysis. Interest in the Venture business plan and business ideas competition remained strong: 230 teams took part in this year's competition, with 114 submitting their ideas and 116 their business plans.

Society in Science

THREE NEW ETH FELLOWS

Nine new fellows have been accepted for the "Society in Science" development programme. Three of the future Fellows, Matthieu Emmanuel Galvez, Vanessa Rampton and Takuya Segawa, come from ETH. Society in Science is based at ETH Zurich and was endowed with several donations from the entrepreneur and ETH alumnus Branco Weiss, who passed away in 2010. It gives young, highly talented post-doc scientists from all over the world the opportunity to explore research fields of their own choosing for a period of up to five years.

Image: Alessandro Della Bella

New Bachelor's degree

Studying medicine at ETH

Beginning in autumn 2017, ETH Zurich will be offering 100 places on its Bachelor's degree course in medicine, an innovative course that combines medicine with natural sciences.

Personalised medicine is one of the new course's five areas of focus

Last year, the Swiss Federal Council made a request to the universities and federal institutes of technology, asking whether they might be able to help to ease the shortage of doctors in Switzerland. ETH Zurich's resounding answer was: "Sì, possiamo. Yes, we can."

Outside observers may have been surprised that ETH will be offering 100 places on a Bachelor's degree course in medicine from autumn 2017. But when you consider how new findings in technology and the natural sciences are revolutionising medicine, it is not such a surprising step. "Medical diagnostics, prognoses and treatment are all undergoing rapid change thanks to new developments in bioinformatics, molecular biology and imaging techniques – all disciplines in which ETH is at the forefront both in teaching and research," explains ETH President Lino Guzzella. Seen in this light, ETH's involvement in medical education is a logical, even necessary, step.

"To implement the new technologies promised by disciplines such as personalised medicine as quickly as possible, we will need doctors that have in-depth knowledge of technology and natural sciences, as well as medical training," says ETH Rector Sarah Springman, who is responsible for education at ETH. The University wants to add to the diversity of educational offers in medicine. As we speak, a project team is working flat out to develop a new and complementary course. The team includes representatives of the rector as well as members of the ETH Department of Health Sciences and Technology (D-HEST), which will host the new programme. They are being assisted by colleagues from the University of Zurich (UZH), the University of Basel (UniBas) and the Università della Svizzera italiana (USI). These are the three partner universities that joined ETH in replying to the Swiss Federal Council with a "Sì, possiamo. Yes, we can": they are providing the necessary Master's degree places. The project team is also advised by a committee that includes international experts.

Innovative curriculum

The curriculum for the ETH Bachelor's degree includes medical, clinical and natural sciences modules, as Professor Christian Wolfrum, who heads up the new programme, explains: "We begin by teaching the basics of the various organs and organ systems in collaboration with the University of Zurich." There are also natural sciences modules encompassing biology, chemistry, physics, and maths and statistics. "Once they have this foundation, the students can then immerse themselves in the five medical modules that define the course," says Wolfrum. These modules cover drug discovery and personalised medicine, medical technology, medical imaging, medical computing, and public health. The programme is rounded off with a research internship at the interface of basic research and clinical application.

Once they have completed their Bachelor's degrees after three years at ETH, the students will then continue on to a Master's degree at one of the three partner universities. These institutions have guaranteed that every graduate of the ETH Bachelor's programme will be offered a Master's place in medicine. And because UZH, UniBas and USI have helped to design the ETH Bachelor's curriculum, graduates of the programme will be able to move on to their Master's degrees without undertaking any additional work.

Students will find out at the end of their second year of study which of the universities they will be assigned to for their Master's degree. This process takes into account their individual wishes depending on academic performance and social factors. A similar model at the University of Fribourg has proved very successful.

Enhanced career prospects

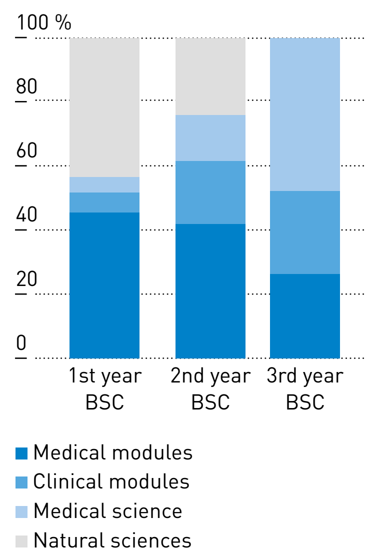
Once students have completed their Master's degree after a total of six years, they are eligible to take the Swiss federal examination in medicine, which is what allows them to practise as doctors. Graduates can also pursue careers in industry, healthcare policy, insurance or research alongside the options of working in a hospital or later setting up their own practices.

ETH will welcome its first medicine students in a year's time. There is one last hurdle to overcome before they start: in order that ETH can scale the number of graduates in line with the number of Master's places at Swiss medical faculties, it must have the power to limit the number of students admitted to the new Bachelor's programme. This requires a revision of the ETH law, a matter which is currently being discussed in the Swiss Federal Parliament. If everything goes to plan, the amendment should enter force at the beginning of 2017.

— Roland Baumann

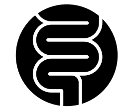
Structure of the ETH Bachelor's course in medicine

The Bachelor's degree carries 180 ECTS points and lasts three years. In the first two years, students acquire a foundation in natural sciences alongside medical and clinical knowledge, and this forms the basis of the later medical modules.



Spin-offs

INTESTINAL INFECTIONS



With the increase in antibiotic resistance, intestinal infections such as *Clostridium difficile* are becoming life-threatening. Instances of this dangerous infection are constantly on the rise, and in Western countries the costs run into billions. ETH spin-off PharmaBiome is developing a revolutionary treatment that introduces healthy bacteria into the intestine and can drastically reduce complications. The young entrepreneurs successfully presented their proposal at the Venture Kick Finale in June and received start-up funding of 130,000 francs.

→ www.pharmabiome.com

SEARCHING FOR MARKERS

Haelixa is a new ETH spin-off that wants to bring DNA-based marker substances to market. Substances that mark products or liquids are used in many sectors, including on oil fields. However, these substances are often toxic or radioactive. Haelixa's new DNA-based marker substances, on the other hand, are environmentally friendly and also extremely versatile. The young start-up, whose cofounder Michela Puddu holds an ETH Pioneer Fellowship, is now looking for partners with which to enter the petroleum and geothermal sector.

→ www.haelixa.com

Image: Shutterstock

Rössler Prize

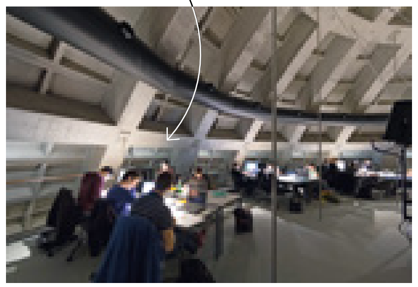
AN OBSESSION WITH SURFACES

Christophe Copéret was presented with the Rössler Prize on 15 June. As far as the jury was concerned, he stood out as a highly creative and versatile researcher in the field of inorganic chemistry. The chemist focuses on the design of functional materials, such as solid catalysts and microelectronic applications, taking a molecular approach. He is also developing new imaging techniques to visualise individual particles and track metabolites in the human body.

Copéret has won around a dozen academic prizes over the course of his career – but none worth quite as much as the Rössler Prize, which brought the 46-year-old Frenchman 200,000 Swiss francs in prize money. After finishing his PhD with Nobel chemistry laureate Professor Ei-ichi Negishi at Purdue University in West Lafayette, Indiana, he embarked on a postdoc at the Scripps Research Institute in La Jolla, California in 1996 under the guidance of another Nobel laureate, Professor Karl Barry Sharpless. In 2010, Copéret was appointed Professor of Surface and Interfacial Chemistry at ETH Zurich. Since then his research has focused on how chemical reactions behave on the surface of solid catalysts, and how these surfaces can be designed to improve the energy efficiency and sustainability of chemical reactions. To this end, Copéret has worked together with international research groups to develop methods for dramatically increasing the sensitivity of nuclear magnetic resonance spectroscopy (NMR) for surface sites.

Christophe Copéret (left) explaining the principle of his new NMR method to prize sponsor Max Rössler.

Revising for exams in blocks in the future



Studies

FLEXIBLE FIRST-YEAR EXAMS

The first-year exams are the first extensive performance assessment on the Bachelor's course. From the 2016/17 academic year, the Departments of Computer Science, Information Technology and Electrical Engineering, Mathematics and Physics will for the first time offer the first-year exams in two independent examination blocks as part of a pilot project. Students can sit the exams after their first semester and find out sooner whether they are suited for the course.

ETH Alumni

NEW HONORARY MEMBERS

At the Assembly of Delegates on 9 May 2016, Swiss President Johann Schneider-Ammann, donor Hansjörg Wyss, IAETH (association of computer science alumni of ETH) honorary member Robert Weiss, as well as donor and board member Jörg Sennheiser were appointed honorary members. Hanspeter Fässler was appointed Jörg Sennheiser's successor on the board. Additional items on the agenda were the annual report, the 2015 accounts and an outlook on the issues to be addressed in 2016.

Image: Peter Rüegg; Alessandro Della Bella

Column

Building bridges

For many years now, building bridges has been a guiding concept in my work. And whether as CEO and chairman of the board at an international company, or as ETH Professor for Entrepreneurship, I'm convinced that these bridges are essential to forging successful connections between science and business, engineering and management. Close and open collaboration enables us to harness synergies and take full advantage of the possibilities that are open to us. But the only way this will work is if both sides understand each other and actively build these bridges together.

It was this mutual understanding that I wanted to promote when I joined ETH in 2007 after many years in business. I was very fortunate in my professional life and learnt a great deal; I often wondered how I could give something back to society. The ETH chair gave me the chance to introduce students to a management style based on principles, and to pass on to them the appropriate business tools and skills. I have been able to play a part in training students to be researchers and business leaders who in future can establish bridges that not only span disciplines, but also link academia with practice.

Ultimately, the key to success is not the bridges themselves, but rather those people who build them and then use them – researchers with fire in their bellies as they work on new solutions, courageous young business people who dare to act on their convictions, students who are full of promise. These are the people who together take our university to the very top level.

As the new President of the Board of Trustees at the ETH Zurich Foundation, I shall continue building bridges. It's fantastic to see how the Anglo-American tradition of "giving back" is increasingly taking a hold here and that the number of donors is rising. These are people who feel a deep connection to ETH: some may have studied here and now want to give back a part of their business success; others choose to leave a legacy to ETH, showing commitment even beyond their lifetimes. Our partners also include companies and foundations who realise how important it is to invest in young people and science, in order to address global challenges and to strengthen Switzerland as a centre of industry. Thanks to their active support, we can press ahead on important topics and launch them swiftly, and we can deliver the kind of teaching and science that gives our researchers the creative space they require to achieve great things.

I'm delighted that at the ETH Zurich Foundation I can count on stable, reliable pillars of support – a motivated and committed team. And together we will be building many bridges.

Pius Baschera was for many years CEO and is currently Chairman of the Board of Directors at the Hilti Corporation. He has been President of the Board of Trustees at the ETH Zurich Foundation since the beginning of 2016.

Image: Tomas Fryscak; F. Hoffmann-La Roche

A watchful eye on crops

A task for an experienced crew: Lukas Kronenberg (r.) and Kang Yu prepare the sensor head for start-up.

The Lindau-Eschikon research station is home to the world's largest permanently installed field phenotyping platform – a trailblazer for digital precision agriculture.

TEXT Peter Rüegg IMAGE Daniel Winkler

The command centre offers a view over the entire test field. The latest data is continuously received here.

Not a sound penetrates the command centre. Glass panes shield it from the outside world, which in this case is a wheat field and four lattice-tower corner structures with double cords almost as thin as string running from their summits to the middle of the field. There, two men are working on a frame – the details are imperceptible from a distance. Then the wireless telephone crackles and indistinct words can be heard. Norbert Kirchgessner, a physicist at the Institute of Agricultural Sciences, looks over at the two men, enthralled, and acknowledges the message: "Now I'll raise it up a little." With his left thumb and forefinger, he nudges a joystick on a console gently upward. The frame is now half in view.

"Powering up the sensor head requires a watchful eye and complete concentration," he says. The load on the rope has to be as uniform as possible to ensure that the sensor head rises straight upward. He then returns his focus to what is happening in the test field. "Did you perform checks on Dolly? Winding termination fine?" asks Kirchgessner – the voice says: "Good!" – "Clamping screws?" – "Fine!" – "Bolt screws? Nuts?" – "Checked!"

Sophisticated technology

Everything is in place. Then the sensor head rises over the heads of the two assistants in the field, Lukas Kronenberg and Kang Yu, and comes to a stop a few metres above them. The digital camera attached to the sensor head provides a bird's-eye view: an asphalt lane, grass and running shoes from above. Then the sensor head begins traversing a programmed route over the soy field. This sensor head, which the researchers call Dolly, is the core component of the field phenotyping platform (FIP), a new large-scale facility for researching crop plants that is operated by ETH Zurich's agricultural sciences research station in Lindau-Eschikon. The platform is helping ETH researchers working with Achim Walter, Professor of Crop Science, to take a major step toward "agriculture 4.0", in which computers and sensor-based data become indispensable tools for farmers, breeders and agricultural researchers. Phenotyping – the large-scale collection of data on the external appearance and metabolic functions of plants with the aid of digital technologies – will be one of the pillars of this digital agriculture.

> "We can see tiny changes on a leaf."

The four 24-metre-high corner structures that stake out the 100-by-130-metre test field are already visible on the approach to the ETH research station. Each one comprises three lattice towers, with a double cord running from the tip of each one to the sensor head, which is brimming with the latest technology: sensors, a variety of cameras and a laser scanner. The sensor head sits at the intersection of the cords, which are made of aramid, an extremely tough synthetic fibre sold under the trade name Kevlar. Fibre-optic cables run through the aramid cords and continuously transmit control signals between the command centre and the sensor head. The sensor head can be precisely positioned at any desired location over the test field by selectively winding the cords.

On the sensor head sit conventional digital cameras that capture the red, green and blue (RGB) colour spaces that humans can see. The researchers additionally use a brand new hyperspectral camera and two spectrometers, which capture more than 100 different colour channels, far exceeding the capability of the human eye. Thermal and near-infrared cameras provide yet further data, allowing the researchers to measure how densely the soil is covered by plants – important information for the early detection of weed growth.

Last but not least, the researchers have installed a modern laser scanner in the sensor head. This allows them to measure plants with millimetre precision in a matter of seconds, and to produce three-dimensional views from this data. The researchers can then rotate these views in any direction on their monitors. ›

Comparing crops
The phenotyping of crop plants emerged around ten years ago and rapidly gained in significance. In the early days, plant researchers worked mainly in laboratories. Then researchers increasingly developed tools for performing phenotyping in the field, such as sensor systems for hydraulic lifts, moving tractors and stationary frames. But there has never before been a facility like the one the ETH researchers designed and built at the Lindau-Eschikon research station.

In the coming ten years – the duration of the operating permit for this provisional setup – the plant researchers aim to obtain new findings on crop plants. They want to discover, for instance, how individual varieties differ from one another, how long they take to blossom, or how their development depends on temperature or soil moisture. To this end, the ETH researchers are currently analysing hundreds of small plots of different varieties of wheat, soy, maize, buckwheat and forage grasses. With their system, the researchers can analyse crop plants in great detail nearly all year round. "Over the long term, this system will help with plant breeding and precision agriculture," is how Walter sums up the benefit of the large-scale facility.

He came up with the idea for the installation while watching football. Spidercams were providing spectacular images of the game and the stadium from a bird's-eye perspective. Walter, who at that time still worked in Jülich, quickly sketched a first draft of how he envisaged a Spidercam system for phenotyping. In 2010, he was appointed as a professor at ETH Zurich – and felt the time had come to realise the idea of his field phenotyping platform (FIP).

Patience and skill
In May 2011, Walter presented a FIP model, and in April 2012, he and his colleagues submitted the planning application for the facility to the municipality of Lindau-Eschikon. Since the researchers had previously provided the municipality with detailed information about their project, emphasising that they would not be cultivating any genetically modified plants, no objections were lodged. In March 2014, the lattice towers were erected on concrete foundations that extend three and a half metres into the ground. They used lattice towers because solid poles


Inspired by football: The ETH researchers' phenotyping platform is based on the principle behind the Spidercam.

would have cast too much shade on portions of the test field, strongly influencing plant growth and thus the phenotypes of the shaded plants. Winch housings were built under each tower. Spidercam installed the winch drums, provided the control electronics for them, and supplied Dolly, the sensor head. The researchers shot their first images from above in August 2014, but they weren't able to officially inaugurate the facility and begin to systematically collect data until June 2016.

"It's been a long journey," says Walter. And it was a journey that he could not have undertaken without his image-processing specialist, Norbert Kirchgessner. In Walter's words: "He was the engine that drove this project." A physicist, Kirchgessner is the project's technical director; he designed the system, wrote many of the control programs and the analysis software himself, and programmed interfaces. He was also responsible for connecting the sensors and cameras. "Linking these things together is no easy task," he says.

Kirchgessner looks over to the sensor head. It travels as planned from one plot of the soy field to the next, stops briefly, captures some images, then moves to the next position. Data acquisition is in progress. The laser scanner collects 100,000 points per second. The researcher points out that "everyone needs to leave the field when the scanner begins its measurements. Otherwise, they'll show up in the point cloud and botch the measurement."

Agriculture drones are coming
High above the test field whirrs a drone. Frank Liebisch, the coordinator of the ETH Lindau-Eschikon research station, watches it, his hands resting on his hips. Although the FIP was just recently officially inaugurated, Liebisch currently works mainly with drones,


Satisfied with the work they've done: Physicist Norbert Kirchgessner is the engine driving this unique project.

which will be the next step in digital agriculture. They have one key advantage over static FIPs: they are mobile and can be used anytime on any field. Even farmers themselves could soon be working with drones. "Drones are quite clearly the future of digital agriculture," he says.

Nevertheless, the FIP is vital for research because the data acquired with this system is used to calibrate the drones. Furthermore: "The resolution of the FIP is so high that we can detect colour changes measuring less than a millimetre on a wheat leaf from a height of five metres. A drone can't achieve that resolution – one of its pixels is as wide as a single leaf," Liebisch says, plucking one from a wheat plant. He points to a couple of light brown spots that can hardly be larger than a pinhead: the feeding tunnels of the larvae of the cereal leaf beetle. The FIP's eye in the sky can easily spot this sort of tiny blemish, and fungal infections too, while a drone would miss them. So both devices are needed.

Work on the FIP is not yet done. The system is a prototype, and above all, it is one of a kind – which means the ETH researchers are only able to benefit from others' experience to a limited extent. Kirchgessner openly admits that "the system is still having some teething troubles." And it isn't easy to incorporate new sensors into the system, either. So for the time being, he won't – even if researchers approach him with such requests.

But the FIP has also attracted attention abroad. Scientists in the US and Australia would like to build similar systems, and they hope their colleagues at ETH will provide their support and experience. Kirchgessner is pleased, and is in open discussion with his colleagues, but he also waves dismissively: "It'll be a while yet before we achieve smooth, routine operation." ○

Field phenotyping platform (FIP):
→ www.kp.ethz.ch/infrastructure/FIP.html

1 *Gotthard*

CONSTRUCTION OF THE CENTURY OPENS

ETH was represented in many ways at the opening of the Gotthard base tunnel. At the ETH Zurich exhibition to mark the completion of what could be called the construction of the century, ETH President Lino Guzzella spoke with pride and enthusiasm about the University's contributions to the base tunnel project. Working alongside engineers were geologists, geomatics engineers, spatial planners and computer scientists – many of them ETH alumni. With the help of the experiments and exhibits on show, visitors to the exhibition were able to discover how ETH researchers and students are working on "the mobility of the future". Among the star attractions were the Formula Student electric race cars.

2 *Venice Biennale*

STRONG PRESENCE

This year's Venice Architecture Biennale will feature a number of ETH Zurich projects. Curator Alejandro Aravena has invited several project groups with ETH members to showcase their work as part of the main exhibition. They will also be appearing at national pavilions and participate in other parts of the event. ETH President Lino Guzzella and Swiss Federal Councillor Alain Berset attended the official opening of the Swiss pavilion, which was designed by Christian Kerez, who holds a Chair of Architecture and Design at ETH Zurich.

3 *Gift from ABB*

A ROBOT FOR ETH

This year, ABB is celebrating 125 years since its founding in Switzerland. To mark this anniversary and to acknowledge the many years of collaboration with Swiss researchers, ABB presented ETH Zurich with a YuMi. YuMi (shown below alongside Remo Lütolf, Country Managing Director at ABB Switzerland, and ETH Professor Roland Siegwart) is the first collaborative two-arm robot designed for small-parts assembly. This gift gives doctoral candidates and students the chance to incorporate this ultramodern industrial robot into their research and develop new concepts. These may include research into new control concepts or the automated production of 3D models.

Lino Guzzella recognises the achievements of ETH engineers.

1 *Gotthard*

4 *Chemical Engineering Medal*

5 *ETH Alumni Singapore*

2 *Biennale*

3 *ABB*

4 *Chemical Engineering Medal*

EXCEPTIONAL CONTRIBUTION

Every year, the Institute for Chemical and Bioengineering (ICB) awards the ETH Zurich Chemical Engineering Medal to an outstanding individual for his or her exceptional contributions to the field of chemical engineering. On behalf of ETH and the ICB, ETH Rector Sarah M. Springman presented the Medal to Suzanne Thoma, CEO of the BKW Group.

5 *ETH Alumni Singapore*

VISIT FROM THE PRESIDENT

The ETH Alumni Chapter in Singapore received a distinguished guest: during his state visit to Singapore, Swiss President Johann Schneider-Ammann (left) made sure to pay a visit to the Singapore ETH alumni. He has been an honorary member of the Chapter since 2012. Together with the teaching staff of the ETH-Singapore Centre and members of the Swiss community in Singapore, the Chapter welcomed its guest with a dinner at the Swiss Club Singapore.

Image: Giulia Marthaler (3); Pro Helvetia, ABB (2)

Image: Sandro Hutter; ETH Alumni Singapore

ETH GLOBE 3/2016

Agenda

EVENTS

28 September 2016 / 6.30 p.m.
Big Data
At a Focus Event sponsored by ETH Alumni, ETH Professor Dirk Helbing will be speaking about the social, economic, ethical and legal challenges of the digital revolution. His talk will be followed by a panel discussion with Victor Schlegel, Senior Manager Big Data Solutions at Swisscom AG. Talks will be given in German.
ETH Zurich, Main Building, Dozentenfoyer
→ www.ethz.ch/alumni-bigdata

10 November 2016 / 6.00 p.m.
Long Night of the Careers
The Long Night of the Careers is aimed at students, doctoral candidates and alumni. It is an excellent opportunity to meet and mingle with former ETH students plus people from the corporate world and other spheres of interest.
ETH Zurich, Main Building
→ www.ethz.ch/alumni-langenacht

CONCERTS

11/21 November 2016 / 7.30 p.m.
Autumn Concert 2016
The Alumni Symphony Orchestra, conducted by Johannes Schlaefli, will perform Gustav Mahler's Symphony No. 3 in D minor.
Kirche St. Johann, Schaffhausen (11 Nov.); **Tonhalle Zürich** (21 Nov.)
→ www.alumniorchester.ch

World 4.0: What is visionary, what is reality?

Treffpunkt Science City

LIFE IN THE WORLD 4.0

Will we soon be living in a world where cars drive around on their own and talking robots cook, shop and water the flowers? Will my smartphone be able to detect illness and disease, replacing my doctor? Who owns all the data we produce? How can I protect myself from hackers when banking online? Our autumn programme "Life in the World 4.0" seeks to answer these questions. Drones and walking robots will show what they can do. Teenagers are invited to visit the Game Lab Lounge and there is also much to discover in our children's programme.

The science Sundays, part of ETH Zurich's free education programme, cater to all ages and will take place on 30 October, 6 November, 20 November and 27 November 2016. There will also be plenty of other opportunities to delve into the world of science.

Programme:
→ www.ethz.ch/treffpunkt-en

ETH Alumni Ball 2016

SWING WITH ME – SWAY WITH ME

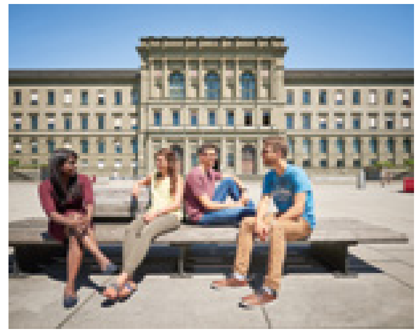
1 October 2016 from 6.00 p.m.: A festive ball for dance-loving ETH alumni calls for a special venue: the Dolder Grand in Zurich. In addition to an exquisite dinner, guests can look forward to dance music played by This Masquerade and the thrill of roulette and blackjack. The highlight of the show will be an appearance by Swiss pop and soul artist Marc Sway. His deft mix of Brazilian rhythms, soul, R&B and pop guarantees first-class entertainment.

Information and registration:
→ http://ethz-alumniball.ch

Image: Alumni Symphony Orchestra; Fotalia

GUIDED TOURS

27 September 2016 / 6.15 p.m.
Save the books!
Guest speaker Martin Strebel explains why and how old books have to go to the "book doctor".



ETH Zurich, Zentrum, Bibliothek
→ www.ethz.ch/eveningtours

11 October 2016 / 6.15 p.m.
The Main Building of ETH Zurich
Discover the architectural beauty and historic achievement of the ETH Main Building, built by famed architect Gottfried Semper.
ETH Zurich, Zentrum
→ www.ethz.ch/eveningtours

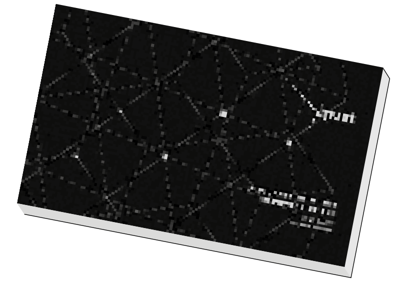
15 November 2016 / 6.15 p.m.
In the Steps of Albert Einstein
Take our guided tour to experience the University District and the places where Albert Einstein worked in Zurich.
ETH Zurich, Zentrum
→ www.ethz.ch/eveningtours

* All tours are given in German.

EXHIBITIONS

Until 31 January 2017
Tambora and the Year Without a Summer
The eruption of the Indonesian volcano Tambora led to 1816 being christened the "Year Without a Summer" in Europe and North America; it also caused a famine in Switzerland. Visitors to the exhibit will learn about Tambora's eruption in 1815, the subsequent effects on the climate, and current volcano and climate research at ETH Zurich.
ETH Zurich, NO building, Sonneggstrasse 5
→ www.focusterra.ethz.ch

Until 16 October 2016
Architecture as image
The Collection of Prints and Drawings is showcasing architectural designs by the prominent Prussian painter and builder Karl Friedrich Schinkel (1781–1841). Many of his buildings shaped the cityscape of central Berlin, and a whole generation of architects belonged to the school that bears his name.
To contrast with Schinkel's neoclassical architecture of the 19th century, the exhibit also displays works by British architect Bryan Cyril Thurston (born 1933), who has been working in Switzerland since 1955.
Collection of Prints and Drawings, ETH Zurich, Main Building
→ www.gs.ethz.ch



Book tip

A JOURNEY INTO TIME IN POWERS OF TEN

Some things in our universe took incredibly long to form, such as planets or galaxies. In contrast, some processes happen unbelievably quickly. The book, authored by researchers at the MUST (Molecular Ultrafast Science and Technology) Swiss National Center of Competence in Research, depicts the range of timescales that play a role in the lives of all living beings. These timescales are organised into powers of ten. Open the book in the middle, and you will find familiar timescales such as running 100 meters in 10 seconds. The farther you leaf forward or back through the pages, the farther you move along the timescales of our everyday existence. These range from electron motion in molecules, measured in trillionths of a second – more precisely, 100 attoseconds (10^{-16} sec) – to the formation of the Milky Way, which took 30 billion years (10^{18} sec). Each of these processes is explained in a two-page spread and illustrated with ten images.

ISBN 978-3-033-05191-1
NCCR MUST, Anna Garry, Thomas Feurer
Price: CHF 38

Image: ETH Zurich; Rob Wood – Wood Ronsaville Harlin; NCCR MUST

A bedrock of confidence for the head of the Gotthard project

Valentina Kumpusch originally wanted to be an archaeologist, yet a desire to create something tangible through her work proved stronger. She became a structural engineer and currently manages the massive project to build the second Gotthard road tunnel.

TEXT Samuel Schlaefli **IMAGE** Annick Ramp

Valentina Kumpusch is small and petite; she is wearing floral print jeans, purple ballerina flats and pearl earrings. The mother of an eight-year-old son, she laughs easily and has a friendly, engaging manner. Hardly anyone would guess that the 42-year-old ETH alumna, after years of struggling to establish herself in a male-dominated field, is currently in charge of a 2 billion Swiss franc project. Kumpusch has always forged her own path. For three years after her son was born, she reduced her hours as an engineer at a large Austrian construction company by 50 percent. Later, in an interview for a new full-time position, she was asked with an undertone of reproach why it was that she had not recently completed any advanced training courses. “I had a son and raised him – that was my advanced training” was her quick retort. Today, she is tackling the Herculean task of managing the huge project for building the second Gotthard road tunnel, but in a position that is just 90 percent of a full-time job: she spends Wednesday afternoons with her son, whose school is closed at that time.

“Being a woman is something that makes me good at my job,” says Kumpusch, without false modesty. “If two men at the same level of seniority work together, it can quickly turn into a power struggle.” In contrast, colleagues do not usually view her as direct competition, she says. She is convinced that this is a key factor in her being able to focus on solutions and bring projects to a successful conclusion as efficiently as possible.

For Kumpusch, 28 February 2016 was a decisive day. With a majority of 57 percent, Swiss voters approved the construction of a second tunnel to maintain the Gotthard road link while the existing tunnel was being renovated.

Post-vote relief

That day, Kumpusch was skiing with her family and parents in Klosters. During the trip back to Bellinzona, where she lives with her husband (also a structural engineer), she heard the final results of the vote. “It was a huge relief! I was walking on air,” she recalls. A week after the vote, Kumpusch and her team sent two boxes filled with plans, technical documentation and environmental impact assessments to the affected cantons of Uri and Ticino for review. She had invested three years of her working life in this project. “If the result on that Sunday had been ‘no’, the plans would simply have vanished into a drawer somewhere,” she says.

Managing large-scale projects is nothing new for Kumpusch, who had already been in charge of equipping the Lötschberg Tunnel with rail technology during her time as a project manager at Implenia. But the Gotthard tunnel project was different because of how politicised it had become. In the run-up to the vote, the second tunnel was hotly debated in the media and in panel discussions. Environmental associations, Switzerland’s Green Party, Green Liberal Party, and Social Democratic Party were joined by parts of the country’s more conservative political parties opposing the “pro” campaign run by the Swiss Federal Department of the Environment, Transport, Energy and Communications (DETEC) >

> “Being a woman is something that makes me good at my job.”

ABOUT

Valentina Kumpusch

After graduating from ETH Zurich with a degree in civil engineering, Valentina Kumpusch went to work in project management for Ernst Basler + Partner. In 2001, she took a position with Implenia, where she was in charge of overall project management for the rail technology team for the Lötschberg Tunnel, an assignment that lasted seven years. Kumpusch held similar positions for the Brenner Base Tunnel and the Zurich Cross-City Link – both times on behalf of the Austria-based Rhomberg Bahntechnik Group. Since 2013, Kumpusch has served as project manager for the second Gotthard road tunnel as well as for the renovation of the Gotthard Pass road with the Swiss Federal Roads Office (FEDRO). She has an eight-year-old son and lives with her family in Bellinzona, Switzerland.

and its head, Federal Councillor Doris Leuthard. Their opposition was rooted in concerns over further increasing the capacity for road usage. Employees in the Swiss Federal Roads Office (FEDRO) did no more than provide technical information, yet as Kumpusch says, “Suddenly even technical information became a political issue.” Ticino’s politicians accused Kumpusch and her team of doing Leuthard’s bidding. This was a new and painful experience – but she didn’t lose any sleep over it. “I had plenty of sleepless nights when I was working on the Lötschberg project. The client didn’t want to take delivery of the construction, which cost 800 million Swiss francs, while the subcontractors were threatening to file claims against us to the tune of 80 million francs,” remembers Kumpusch. When the pressure is on, she goes jogging or hops on her exercise machine at home in front of the television. The best weapon against sleepless nights, Kumpusch believes, is fatigue.

“I’ve always been interested in the bigger picture.”

A project for the next decade

If everything goes according to plan, construction work on the second Gotthard road tunnel will begin in 2020, but it’s a date that Kumpusch still names with caution. She expects that a range of organisations will lodge objections to the tunnel. “For me, the most important fixed date is not the start of construction, but when the project will be completed,” says the ambitious engineer. And that won’t be before 2027. At present, when Kumpusch is not working on project coordination at the FEDRO branch office in Bellinzona, she is often travelling to the affected communities in Uri and Ticino. Following our meeting in Flüelen, she will head to Altdorf to meet with the staff of the power stations there to clarify the power demand during construction and for the subsequent operation of the tunnel. Together with the communities, Kumpusch is looking for locations to deposit the material excavated from the tunnel and installation sites for the tunnel boring machines. She is also seeking ways to organise the construction work so that the noise, traffic and dust do not unduly disturb residents. This won’t be easy, as the valley floor of both tunnel portals is relatively narrow.

As the head of this large-scale project, Kumpusch devotes most of her time to management tasks. Does she ever yearn to solve a tricky structural problem, or to someday build a viaduct from the ground up? “No. I’ve always been more interested in the bigger picture and in pooling different kinds of expertise than I have in detail work. I also knew, even as a student, that the construction site wasn’t going to be my workplace,” she says. It’s no coincidence that today she is calling the shots for Switzerland’s most important tunnel construction project. Kumpusch has always viewed tunnel construction as the pinnacle of civil engineering.

From Latin to engineering

Kumpusch’s original decision to become a structural engineer was not a complete surprise: in doing so she was following in her father’s footsteps. A civil engineer himself, he occasionally took her with him to construction sites. Her mother, by contrast, wanted her to study archaeology; Kumpusch complied with her mother’s wishes until she finished secondary school (where she focused on Latin and Greek). “But at some point I knew that I wanted to learn a proper profession in a field in which I could find work and really make an impact,” she recalls. The fact that only one in ten civil engineering students at ETH was a woman never deterred her.

Kumpusch has fond memories of her student days: “When it comes to infrastructure and professors, ETH offers a marvellous learning environment.” She also greatly valued the broad range of courses, which included technical disciplines, contract management and economics. “These are essential when you’re starting out professionally,” she says. “You can specialise later on the job.” The strict organisation of the course of study was a good fit for her own way of working. For her preliminary exams, she drew up detailed lists of what she needed to cram for when – so she could be sure her revising didn’t clash with parties given by the group of students from Ticino that she spent most of her time with at university. “I didn’t really learn German until I first started working,” explains Kumpusch. “In this respect, I could have certainly got more out of my studies back then.”

When asked what advice she would give ETH for the future, Kumpusch replies, “In my day, studying civil engineering was very complex and challenging. Don’t ever change that!” ○

THE PROJECT
The Gotthard Road Tunnel requires thorough renovation and restoration work to guarantee that it will remain functional and safe in the coming decades. On 28 February 2016, Swiss voters decided in favour of building a second road tunnel and renovating the existing one. The project is currently undergoing several rounds of review. Construction work will begin in 2020 at the earliest and theoretically could be concluded in 2027.

5 QUESTIONS

Elgar Fleisch takes a critical view of measuring researchers' performance based purely on their number of publications. *"Goals determine development – in sport and in research."*

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1 *What was your first encounter with ETH Zurich?*

When I was studying in Vienna, we used Pascal and Modula-2 to learn how to work with procedural programming languages. I have held the names Niklaus Wirth [the developer of the two programming languages mentioned above] and ETH Zurich in high regard ever since.

2 *Who have been your most influential teachers?*

In primary school I had a teacher who impressed me because he could transform the atmosphere in the room simply by bringing out his guitar. From university, there are two professors I'll never forget: One had the ability to explain the intricacies of algorithms and data structures with the greatest of ease and make them simple and easy to understand. The other taught us the key points and interconnections of economics with the required objectivity and with natural wit.

3 *Does the current system of publishing harm academic research?*

If you were to judge the performance of downhill skiers not on their time, but on the number of jumps they manage, then ski circuits would look completely different. It's the goals set for skiers that determine how their discipline develops. This also holds true for goals that make no sense in the longer term. To measure performance in academic research purely in terms of the number of publications in renowned journals is simply misleading. This approach is also especially dangerous because it steers the research system off course.

4 *What's your take on critical thinking, and how do you apply it in your day-to-day life?*

It's about questioning established ideas, developing alternatives to widely accepted ways of thinking, being sceptical of statistics, gathering raw and original data for your own investigations, challenging assumptions, questioning generalities, and working outside and across disciplines. In everyday terms, this means for instance not blindly accepting other people's conclusions and opinions, but instead objectively examining their reasoning and using solid data to see whether it holds up.

5 *Are there any areas in which your work hasn't been a success?*

I've definitely failed, sometimes massively, more times than I have succeeded in my life – whether personally, culturally, academically or economically. That's just a fact of life and failure is such a great educator. Of course, looking back we see only those trees that have weathered all the storms and forget the many saplings that didn't make it. Winners are not those who never fall, but rather those who keep getting right back up again.

— Recorded by Felix Würsten

Image: Giulia Marthaler