A MAGAZINE

Czech Academy of Sciences

LIGHT

Microscopes, endoscopes, and lasers at the service of science

2024

No man's lands as part of Holocaust history

A new era of quantum computing is here

Facts and myths from the world of parasites

A / Magazine 2024


Top research
in the public interest
Czech Academy
of Sciences

Dear readers,

You are holding a special English edition of *A / Magazine*, the official periodical of the Czech Academy of Sciences. Published in Czech for its second year now, it is a direct continuation of *A / Science and Research*, which was first launched in 2017.

The magazine, which is available free of charge and also online, aims to present the remarkable scientific achievements and notable figures of the Czech Academy of Sciences to the general public. It has consistently achieved recognition in competitions for communication and marketing projects in the Czech Republic. This year, *A / Magazine* won first place in the Fenix Awards for printed magazines in the B2C category and took silver in the Zlatý středník competition. Last year, it won the company magazines for customers category in the Czech Top 100 competition. We believe the time has come to introduce our quarterly to an English-speaking audience as well.

The main topic of this issue is light – a brilliant and powerful tool for illuminating the world around us, not only at a macro level, but also on the micro- and nanoscale. On the following pages, you will learn about a unique holographic endoscope capable of deep-brain observations as well as a special nanofluidic scattering microscope which uses light to render individual biomolecules visible. We will also explore laser micro-machining, used to create superfunctional materials such as antimicrobial or water-resistant surfaces.

I trust you will enjoy this English edition of *A / Magazine*.

Wishing you a pleasant and inspiring read,

Eva Zažímalová
President
of the Czech Academy of Sciences

Cover image: Midjourney

IN FOCUS

ACADEMY HIGHLIGHTS

GLOBAL SCIENCE HIGHLIGHTS

FEATURE

Light is a precondition for life, but also a unique tool that has proven to be useful in microscopy and laser micromachining.

MEDICINE

In the Czech Republic alone, up to 300 people suffer spinal cord injuries every year. The aftermath of damaging this delicate bundle of nerve fibers is generally irreversible. Or is it?

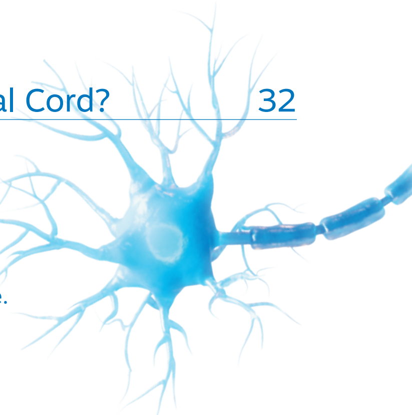


Photo: Shutterstock (4), Midjourney, Jana Plavec (2)

Text: Leona Matušková \ Photo: Shutterstock

THE LITTLE OWL IN DANGER

Monitoring and communication with locals are key to little owl conservation

The little owl (*Athene noctua*) is one of the most endangered bird species in the Czech Republic. At the beginning of the 20th century, the owl was a common sight in rural areas, but a mere 70 to 100 pairs remain in the wild today. Most of its population is concentrated in northern Bohemia, leading to inbreeding and a decrease in genetic diversity. “In some individuals, we’ve found abnormalities such as fused toes, reduced fertility, or egg abandonment,” says Martin Šálek from the Institute of Vertebrate Biology of the Czech Academy of Sciences (CAS). Annual monitoring of little owl populations is part of a conservation project. “Sadly, we know that nine out of ten chicks don’t survive the winter, and even adult little owls face many dangers, some of them dying needlessly in swimming pools, wells, or molasses tanks,” the biologist adds. That is why communication between experts, local residents, and farmers is crucial for the future of the little owl.

Save the Little Owl Project:

Text: Markéta Wernerová, drawing on press releases of the CAS
Photo: ISI CAS, Jana Plavec (2), Shutterstock

The first humans arrived in Europe 1.4 million years ago

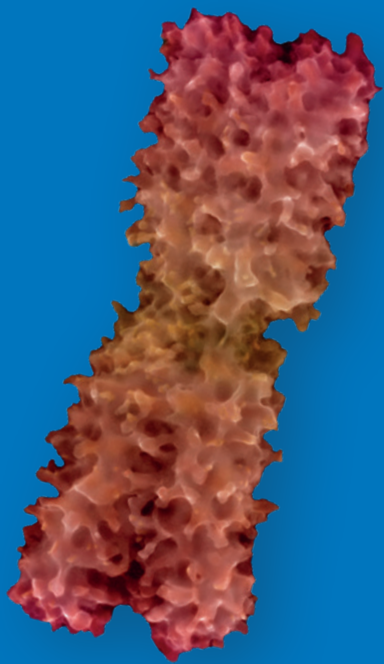
Nuclear Physics Institute of the CAS
Institute of Archaeology of the CAS, Prague
Institute of Geophysics of the CAS

When did members of the genus *Homo* first appear on the European continent after leaving Africa? Until 2024, the caves in Atapuerca, Spain, and Vallonnet, France, were regarded as the first inhabited locations in Europe (1.2–1.1 million years ago). However, new findings date the first human presence to 200–300 thousand years earlier in present-day western Ukraine. A recent advance in mathematical modeling combined with applied nuclear physics enabled the precise dating of the earliest hominin occupation of Korolevo in the form of stone tools found at this archaeological site. The groundbreaking results of the discovery, worked on by an international team led by Roman Garba from the Nuclear Physics Institute of the CAS and the Institute of Archaeology of the CAS in Prague, were published in *Nature*.

Parasitic fish embryos have learned a front-flip that helps them survive

Institute of Vertebrate Biology of the CAS

Bitterling fish are abundant in East Asia, especially in China and Japan. These brood parasites practice an exceptional form of parenting. Much like the cuckoo bird, which lays its eggs in the nests of other birds, bitterlings parasitize another species – freshwater mussels. The embryos hatch inside the mussel after one or two days, do a "front-flip" on the yolk sac, break through the egg membrane, and use a specialized anchor to attach themselves to the gill chamber of their host. The unique development process of bitterling embryos was described by an international team led by Martin Reichard from the Institute of Vertebrate Biology of the CAS in a study published in *PNAS*.



Revolutionary method reveals chromosome structure

Institute of Scientific Instruments of the CAS
Institute of Experimental Botany of the CAS

Researchers from two CAS institutes have achieved a significant breakthrough in the fields of genetics and imaging methods. Thanks to a new method called A-ESEM (Advanced Environmental Scanning Electron Microscopy), they succeeded in visualizing the chromosome in its native state. Revealing its surface structure, consisting of tiny protrusions and chromatin fibers spatially organized in loops, could potentially impact fields such as medicine and agriculture. The A-ESEM imaging method enables researchers to examine practically all types of living samples: plant cells and, to some extent, animal cells in their native state, small living animals, fungi, molds, mites, protein and bacteria molecules. The results were published in *Scientific Reports*.

New type of contrast agent will help with early detection of covert diseases

Institute of Organic Chemistry and Biochemistry of the CAS

While magnetic resonance imaging (MRI) is mainly suitable for detailed examinations of internal organs and the brain, positron emission tomography (PET) is ideal for detecting malignant diseases, such as tumors. There was no doubt that combining these two imaging methods would improve diagnostics. However, the strong magnetic field in MRI obstructs the functioning of the electronics required for PET. Once the researchers solved this problem, they still needed to develop a dual-purpose contrast agent that would work with both methods. This breakthrough, contributed to significantly by researchers from IOCB Prague, promises a substantial improvement in diagnostics and subsequent treatment, particularly for kidney diseases and tumors. The research was published in *Angewandte Chemie*.

How an exoplanet became a brown dwarf

Astronomical Institute of the CAS

Using data from NASA's TESS mission and ground-based telescopes in Arizona and Chile, scientists have discovered a brown dwarf that had recently been an exoplanet. These substellar objects are born very hot and shrink as they gradually cool. Unlike stars, however, they do not burn hydrogen through thermonuclear fusion, but instead fuse deuterium, a process that transforms giant planets into brown dwarfs. Researchers were surprised to find that the object, designated BD-14 3065b, has an unexpectedly large radius for its age. "It likely burned deuterium very slowly for most of its life, this hydrogen isotope remaining an untapped energy source," explains Ján Šubjak from the Astronomical Institute of the CAS, lead author of the study published in *Astronomy & Astrophysics*. The star around which BD-14 3065b orbits recently evolved into a red subgiant, doubling in size, which intensified the interaction between the two bodies and increased the energy stored in BD-14 3065b. According to the researchers, the rapid deuterium burning process only began recently.

A groundbreaking method reveals the composition of cosmic rays

Institute of Physics of the CAS

Cosmic rays from outer space constantly bombard Planet Earth. It is likely that the highest-energy cosmic ray particles penetrate our atmosphere much deeper than previously thought. At the same time, it appears that the composition of cosmic rays, which is currently most commonly determined by particle shower penetration, may also be significantly heavier. These new insights stem from a method that generalizes the approach to predicting models of cosmic particle collisions and the Earth's atmosphere. The method was developed by astroparticle physicist Jakub Vícha from the Institute of Physics of the CAS, who studies ultra-high energy particles arriving from outer space using data from currently the world's largest experiment – the Pierre Auger Observatory in Argentina. The study was published in *Physical Review D.*

How are autoimmune disorders and tooth enamel related?

Institute of Molecular Genetics of the CAS

An international research team has uncovered new insights into amelogenesis imperfecta, a tooth development disorder which affects dental health in patients with autoimmune diseases. The study, published in *Nature*, focused on weakened, discolored, and easily damaged teeth in patients with autoimmune polyendocrine syndrome type 1 (APS-1) and celiac disease. The research demonstrated that most of these patients develop autoantibodies, particularly the IgA isotype, against proteins specific to ameloblasts – the cells responsible for enamel formation. As a result, the body's tolerance to these proteins is disrupted, leading to defective tooth enamel production. Jan Procházka from the Czech Center for Phenogenomics at the Institute of Molecular Genetics of the CAS was part of the research team.

Unique reproductive strategy of edible frogs confirmed in another species

Institute of Animal Physiology and Genetics of the CAS

Only male edible frogs live in the Poodří region, Czech Republic, with no females present. Edible frogs are a hybrid species that evolved from the hybridization of the pool frog and the marsh frog and are something like half-clones. Even so, these frogs still reproduce, all with the help of partners from another frog species. They always carry one set of chromosomes of the parental species and need to acquire the second set during mating. The scientific term for this type of reproduction is hybridogenesis. This remarkable reproductive strategy that avoids mixing genetic information from both parents has now been confirmed by scientists from the Institute of Animal Physiology and Genetics of the CAS in another species of frog found in France and Spain – Graf's hybrid frog. The findings were published in *Genome Biology and Evolution*.

Text: Leona Matušková, Radka Římanová \ Photo: KM3Net, Shutterstock (3)

UNDERWATER OBSERVATORY DETECTS ULTRA-HIGH-ENERGY NEUTRINO

Sometimes called mysterious, elusive, or even poetic, the neutrino – an elementary particle invisible to the naked eye and difficult to detect with instruments – has captivated scientists all over the world. As a result, new observatories are being constructed at various locations with the aim to capture neutrinos. One such project is KM3Net/ARCA, which has been operating for about a decade at the bottom of the Mediterranean Sea, southeast of Sicily. The research facility, which is still expanding, currently consists of 28 vertical detector arrays, anchored at depths between 2,700 and 3,500 meters below sea level. The observatory has already produced intriguing results. The latest breakthrough came on 18 June 2024, at the Neutrino 2024 conference in Milan, where physicist João Coelho announced that the Mediterranean observatory has likely detected the highest-energy neutrino ever recorded.

COMMENTARY: ASEN CHRISTOV

Institute of Physics of the CAS

For now, the KM3Net scientists, represented by João Coelho, who announced the findings, are keeping a tight lid on the details, particularly the direction from which the neutrino originated – for a good reason. Preliminary analysis indicates that this particle's energy is in the range of several tens of peta-electron volts. While fascinating in itself, equally significant is the high probability that this neutrino is of astrophysical origin. In other words, it's a neutrino that didn't originate from cosmic ray interactions in Earth's atmosphere but is instead a messenger from the distant universe. Neutrinos are extremely difficult to detect due to their unique properties, yet they serve as a valuable source of information about the most energetic phenomena in the universe. This is primarily because they have an extremely low probability of interacting with matter – they don't interact with interstellar dust or radiation, allowing them to travel to us from the farthest reaches of the cosmos. Furthermore, they are produced exclusively in high-energy hadron interactions, the existence of which is known, but their origins remain one of the most intriguing unsolved mysteries in the field. There's also speculation that neutrinos may be produced during the annihilation of dark matter particles. Additionally, the paths of astrophysical neutrinos aren't bent by galactic (or intergalactic) magnetic fields, meaning the direction they arrive from directly indicates their source. This is why the KM3Net scientists are withholding the detected direction for now – they hold a rare and valuable clue about where to look for the exotic cosmic event that produced this neutrino. And given its immense energy, it is bound to be something extraordinary!

DOI: 10.1038/d41586-024-02074-5

ANT PHEROMONES COULD HELP PROTECT AGAINST TICKS

Due to climate change, ticks are finding increasingly favorable conditions for reproduction, and each year, there are more cases of diseases from tick-borne pathogens. Scientists all over the world are working hard to find ways to protect people from tick-borne pathogens. Researchers from Simon Fraser in Vancouver, Canada, are now on a promising path. Their research focuses on the natural enemy of the tick – the ant. They have discovered that ant pheromones could serve as an effective tick repellent. According to their findings, published in the *Royal Society Open Science* journal, ticks tend to avoid surfaces where ants have been present.

COMMENTARY: RYAN O. M. REGO

Biology Center of the CAS

Pheromones, which are chemical substances secreted by organisms across a wide range of biological species, help facilitate communication between members of the same species, altering their behavior or physiology. Ants, for instance, use pheromones to signal danger or mark food sources. The Vancouver researchers have now found that ant pheromones deter ticks from entering areas where ants are or have passed through. More importantly, this effect appears to last long after the ants have left the area. The scientists were able to identify the specific chemicals and the ant glands that secrete them, synthesize these organic compounds, and demonstrate that they work as an effective repellent, as ticks avoided areas treated with the synthetic pheromones. In the future, it may be possible to develop a spray utilizing ant pheromones as a protective repellent, or to treat wood chips that could form barriers against ticks. This could lead to fewer tick bites and a reduction in the spread of pathogens these parasites transmit, causing diseases such as Lyme disease and tick-borne encephalitis. If successful, these substances would offer an advantage over current repellents, which, while somewhat effective, often contain environmentally harmful chemicals.

DOI: 10.1098/rsos.231355

NURSERY RHYMES REVEAL LANGUAGE DEVELOPMENT PROCESSES

Due to their regular, easily imitable rhythms and the repetition of words and verses, children's songs and nursery rhymes play a key role in language acquisition. A new study by British and Irish researchers, published in *Nature Communications*, used nursery rhymes to track how infants perceive speech. Previous research on this topic mainly focused on how children process individual words or sounds. In this study, however, researchers concentrated on continuous speech, recording the brain activity of 50 infants at four, seven, and eleven months old while watching videos of a woman reciting nursery rhymes. Using specialized algorithms, they then analyzed how the infants encoded different types of information.

COMMENTARY: KATEŘINA CHLÁDKOVÁ

Institute of Psychology of the CAS

The experiment led by Giovanni Di Liberto, Adam Attaheri, and their team is among the first few to reveal how infants' brains perceive continuous natural speech. While the neuroscientific study of infant speech perception has a 25-year history, it has largely focused on isolated sounds and words. To capture a more realistic picture of how early language skills develop, it is essential to examine the perception of continuous, naturally spoken language. In this study, the researchers examined how infants perceive nursery rhymes, a type of speech to which young children are regularly exposed, its rhythm, melody, and repetition supporting language development. The study, conducted on a sample of 50 infants at the ages of four, seven, and eleven months, investigates at which point the brain begins to track spoken language through mental linguistic patterns. The findings show that while four-month-old infants process the acoustic properties of speech (i.e., how it sounds), older infants at seven and eleven months perceive speech on a more abstract level. Their brains, much like those of adults, track distinctive speech features (for instance, differentiating between the syllables "pa" and "ta"). The study helps define the direction of contemporary neuroscience research on language development. It illustrates the necessity of studying the perception of continuous natural speech, highlights how to utilize new methods for analyzing neural activity, and serves as an example of best practices for data sharing, procedures, and source materials. Research focusing on neural and bodily activity during natural speech communication and development, conducted at the Institute of Psychology of the CAS as part of the "Rhythms of the Brain and Body in Language Interaction" project (2024–2028), was recently awarded the Lumina Quaeruntur fellowship bonus by the CAS.

DOI: 10.1038/s41467-023-43490-x

ELEPHANTS "ADDRESS" EACH OTHER BY NAMES

Researchers from Colorado State University analyzed over 400 elephant vocalizations recorded in Kenya using a machine learning model. Among these vocalizations, analytical software identified sounds that might play a similar role in elephant communication as names do in human interaction. When these sounds were played back to the elephants, the researchers found that the animals responded to calls directed at them, while ignoring those meant for others. The findings were published in *Nature Ecology & Evolution*.

COMMENTARY: TOMÁŠ PETRÁSEK

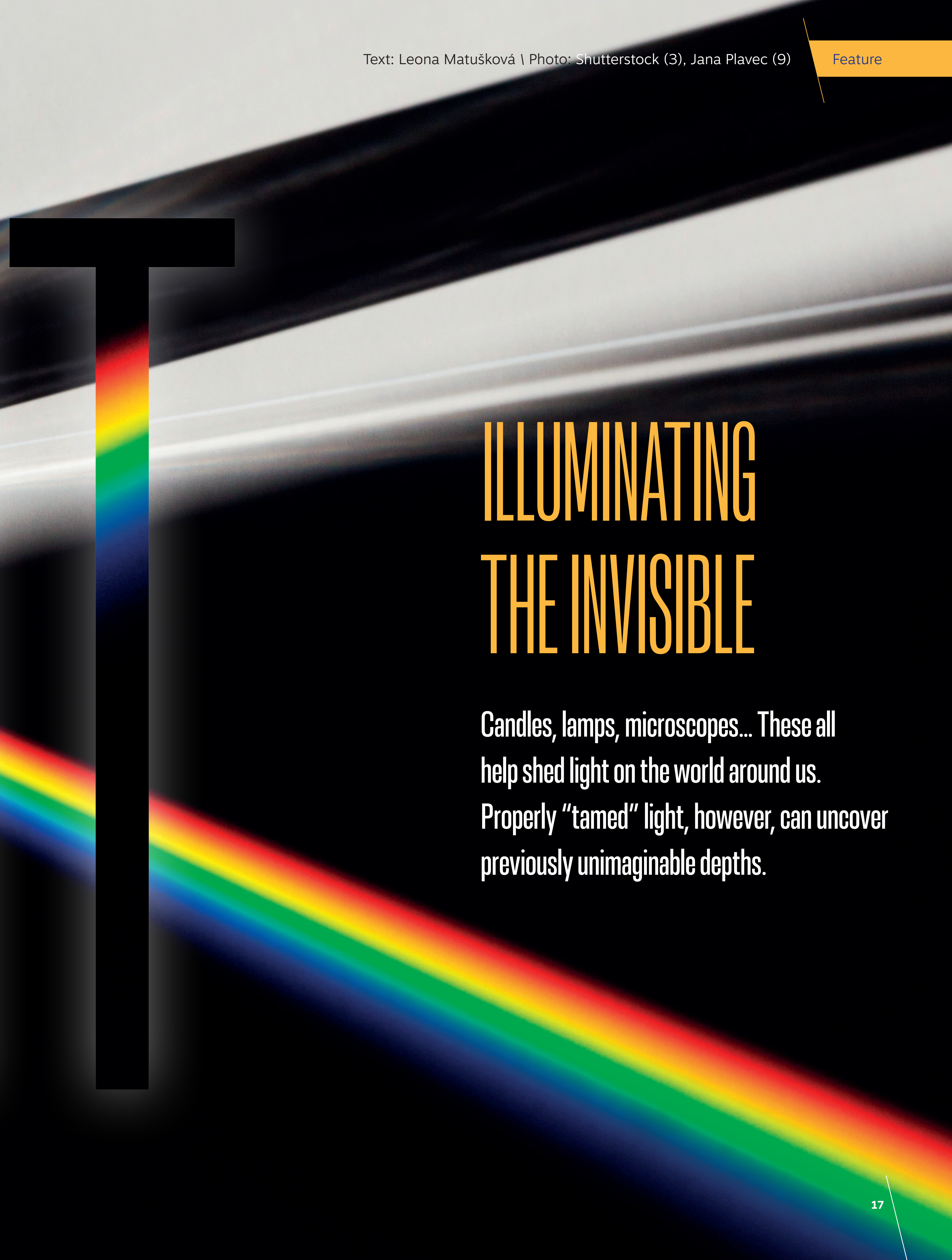
Institute of Physiology of the CAS

Few animal species are known to address each other by "names." Bottlenose dolphins, for example, use what is called a "signature whistle," which resembles their mother's. They recognize each other by it, use it to call out to one another, and can even recall it after many years of separation. A similar behavior has been observed in green-rumped parrotlets in communication between parents and offspring. However, according to this recent study, elephant communication is unique in that an individual is addressed by a sound they typically do not produce themselves (just as humans don't usually shout their own names). The discovery was aided by the increasingly popular machine learning method. Interpreting animal communication can be tricky, though, and artificial intelligence is no more infallible than humans. A key issue with elephants is that researchers haven't yet been able to clearly identify these "names," meaning we don't know if all members of a group address a specific individual with the same "name." What we do know is that both AI and the elephants themselves can distinguish between calls meant for them and those meant for others, though this doesn't necessarily prove the existence of "names." Given what we already know about these largest living land animals, the discovery isn't particularly shocking. Like cetaceans (and humans), elephants maintain long-term social relationships, possess a diverse communication repertoire, and likely possess a degree of self-awareness, as demonstrated by their ability to recognize themselves in mirrors (although obtaining a mirror large enough for an elephant is no simple feat). The existence of "names" could be a natural consequence of these traits. It will be fascinating to discover whether these "names" are also used during elephants' mourning rituals. In terms of understanding the significance of animal communication, we are only at the very beginning. It is likely that other species of cetaceans or birds will reveal similar surprises in the future.

DOI: 10.1038/s41559-024-02420-w


LIGH
A / Magazine 2024

Text: Leona Matušková \ Photo: Shutterstock (3), Jana Plavec (9)



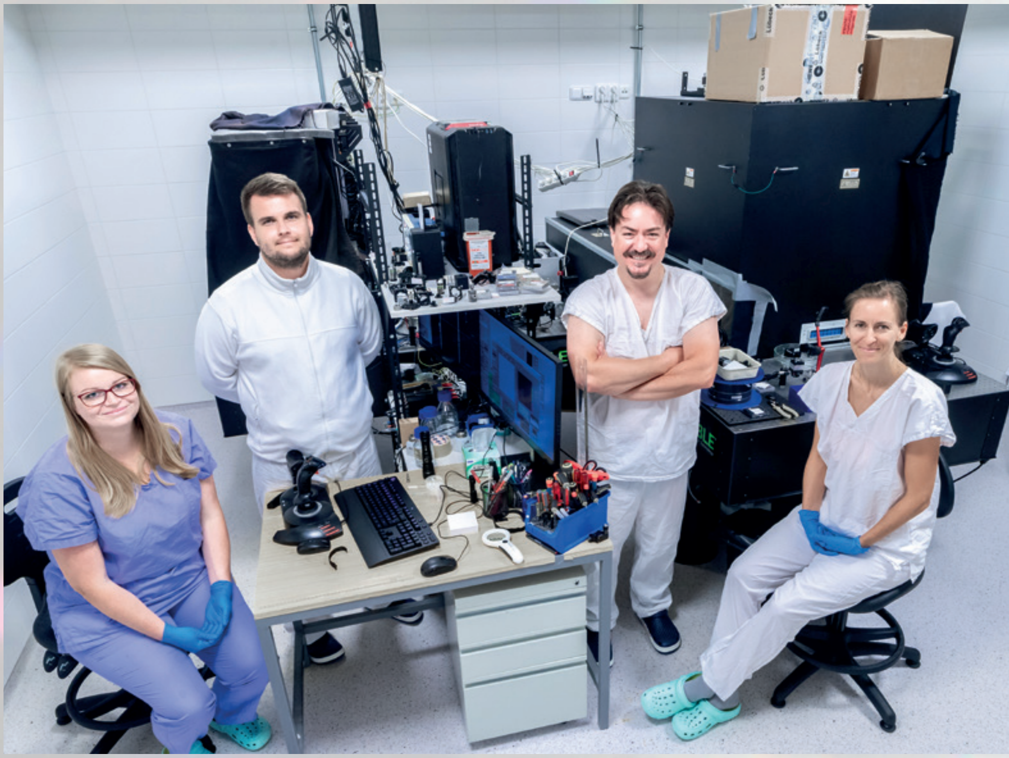
ILLUMINATING THE INVISIBLE

Candles, lamps, microscopes… These all help shed light on the world around us. Properly "tamed" light, however, can uncover previously unimaginable depths.

Sometimes, the lives of ordinary people change history, but sometimes, it is their deaths, too. On 25 November 1901, 51-year-old Auguste Deter was brought in for an examination to the Institution for the Mentally Ill in Frankfurt. She was confused, forgetful, experienced severe mood swings, and didn't recognize her surroundings. She couldn't remember where she lived or that she was married. The doctor in charge of her case was Alois Alzheimer.

Alzheimer was familiar with similar symptoms in much older patients, so Deter's case captured his attention. He recorded her fragmented and confused responses in their conversations, carefully documenting the manifestations of her disease. When she died, he was given the unique opportunity to study her brain. Examining samples of it under a microscope, the doctor noticed significant changes – severe neuron loss and "tangles" formed by neurofibrils (filaments).

More than a century has passed since Alois Alzheimer's time, and the field of microscopy has seen astonishing advancement. In addition to optical microscopes, the range now includes X-ray, electron, and atomic force microscopes, with scientists continuing to develop new types.



Tomáš Čižmár's team in the Complex Photonics Lab. From left: Petra Kolbábková, Miroslav Stibůrek, Tomáš Čižmár, and Hana Uhlířová. Other group members include Tomáš Tyc, Tomáš Pikálek, and Bára Krbková.

Although microscopy today can reveal previously unthinkable details, it comes with the disadvantage of having to treat samples – such as freezing or placing them in a vacuum, essentially "killing" them. This can cause issues when trying to study living matter – for instance, when observing in real time what is happening deep in a diseased brain or how DNA molecules behave.

Two unique discoveries made by Czech scientists aim to bridge these limitations of modern microscopy. The first is holographic endoscopy designed for deep-brain in vivo observations of nerve cell activity. The second is the nanofluidic scattering microscopy method, which uses light to observe individual biomolecules in their native state.

> "An eye-opening experience for me was a visit to the Institute of Scientific Instruments of the CAS, where they were researching and developing optical trapping (optical tweezers). When I saw what light could do, I knew then and there this was what I wanted to do."
>
> *Tomáš Čižmár*

FROM OPTICAL TWEEZERS TO THE BRAIN

Imaging the brain remains a significant challenge even today. Creating a probe that can penetrate deep enough to visualize the synapses between individual neurons is extremely difficult. Current imaging methods risk damaging delicate brain tissue.

A special holographic endoscope, utilizing the unique properties of light transmitted via hair-thin optical fibers, could offer a potential breakthrough. The development is led by Tomáš Čižmár, who works at the Institute of Scientific Instruments of the Czech Academy of Sciences (CAS) and also heads the Fiber Research and Technology Department at the Leibniz Institute of Photonic Technology.

"I actually stumbled upon brain research by accident. I'd never set out to study it specifically," Čižmár recalls. He also came across the entire field of optics and photonics by chance, as he initially studied plasma physics at Masaryk

University in Brno. However, a fateful excursion to the Institute of Scientific Instruments, specifically the Microphotonics Research Department led by Pavel Zemánek, changed his course.

"They were researching and developing optical trapping (optical tweezers). When I saw what light could do, my jaw dropped. I knew then and there this was what I wanted to do," Čižmár says, joining Zemánek's team as a Ph.D. student soon after.

Optical trapping is a technique that uses light to capture and manipulate microscopic objects, often micrometers in size. Optical tweezers are one of the most widely used types of optical trapping. Zemánek's microphotonics research team has succeeded in commercializing some of these devices in cooperation with the company Meopta.

Čižmár also focused on optical trapping during his postdoc at the University of St. Andrews in Scotland. His task there was to create spatially structured optical fields that could be used for manipulating microobjects.

At the time, he was frustrated by how often he encountered aberrations when working with optical beams. Optical aberration causes a point not to appear in focus, but as a blurry spot with uneven intensity distribution. People with an eye condition called astigmatism experience a similar issue, which is corrected with glasses that have cylindrical lenses.

Čižmár spent a long time experimenting with different solutions, often in increasingly aberrated optical systems. "Eventually I realized that the solution is applicable to media that is completely optically random, such as optical fibers," he recalls.

THE TAMING OF THE LIGHT

Optical fibers are commonly used for high-speed internet transmission. They are immune to electromagnetic interference and transmit signals over longer distances with higher speed. Increasingly replacing the once-dominant metal wires, optical fibers are made from glass or, in some cases, plastic. ›

Prof. Mgr. TOMÁŠ ČIŽMÁR, Ph.D.
INSTITUTE OF SCIENTIFIC INSTRUMENTS OF THE CAS

Tomáš Čižmár studied physics at Masaryk University in Brno, focusing on optics in his doctoral studies. Even as a Ph.D. student, he worked at the Institute of Scientific Instruments of the CAS in Pavel Zemánek's team, focusing on the development of optical tweezers. He completed his postdoc research in Scotland at the University of St. Andrews. From 2013 to 2017, Čižmár taught at the University of Dundee in Scotland, and since 2017, he has led the Fiber Research and Technology Department at the Leibniz Institute of Photonic Technology. He also teaches at the Friedrich Schiller University and heads the Complex Photonics Lab at the Institute of Scientific Instruments of the CAS..

However, the focus of Čižmár's research at St. Andrews wasn't on speeding up the internet; it was on effectively "taming" light to create beautiful, aberration-free optical fields. One of the potential applications of this technology is imaging biological tissues – particularly brain matter. "Neuroscience seemed like a natural fit, as it was clear this was exactly what it lacked – the ability to peer deeper into the brain and reveal the fascinating things happening within," Čižmár explains.

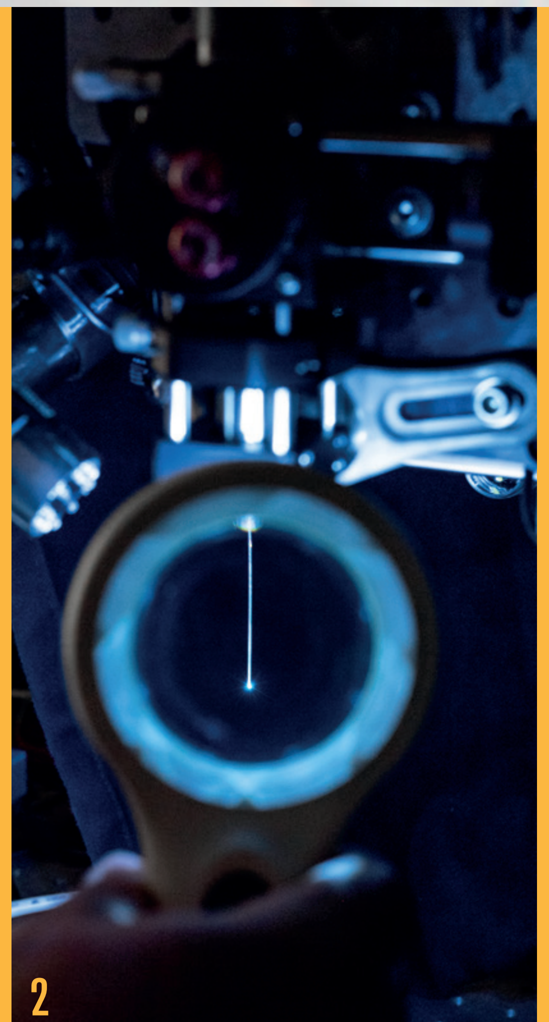
Soon after, Čižmár received an important job offer from the University of Dundee (2013–2017), followed by an ERC Consolidator Grant for a project titled LIFEGATE, amounting to two million euros. Simultaneously, he was awarded a grant from the European Regional Development Fund totaling seven million euros, with both grants running from 2017 to 2022.

"That was a rather hectic period, because I relocated from Scotland to Germany with my family, while one of the projects was conducted in Brno at my original home institute. I was working with and coordinating two teams at the same time, which was no easy feat," Čižmár recalls. During this time, he was fully focusing on developing the holographic endoscope – a device that utilizes optical fibers to direct light beams.

At the starting point of the system is a laser roughly the size of a shoebox. It sends light through an optical cable to a set of lenses and mirrors. Here, the light refracts and is redirected to a computer-controlled holographic modulator about the size of a matchbox, which imparts the properties to the light that are needed for the intended use.

The modified light is then sent into a special multimode optical fiber (ap-

We have learned to use light to manipulate (and even sort) microobjects, transmit data, change the structure of materials with laser-bound light, and use it in machining and cutting. But we still haven't tapped into all the possibilities light has to offer.



proximately one tenth of a millimeter wide) which is ready to penetrate animal tissue – in this case, the brain. Specifically, it targets the brain of a model organism for human disease, often a lab mouse. Animal models enable neuroscientists to better understand brain function, and the findings can be applied in further medical and pharmaceutical research.

THE UNIVERSE OF A MOUSE'S BRAIN

Working with mouse models is subject to strict ethical controls aimed at eliminating unnecessary suffering of the animals. The procedure for inserting the fiber, i.e., craniotomy (drilling a small hole into the skull), is done under anesthesia. The mouse does not feel the fiber insertion into its brain, and it can be conducted while the animal is active. Compared to previous endoscopic techniques, a major advantage of this method is the miniature size of the probe, which is far less invasive.

Researchers use fluorescent tags to visualize neurons and other parts of the brain they need to observe. In simplified terms, cells and their surroundings are "stained" (this can ❯

OPTICAL TWEEZERS AND ATOMIC CLOCKS

Light serves as both a tool and a subject of research for many scientific teams at the Czech Academy of Sciences, the scope of which could fill a book. "In our Microphotonics Research Department, for instance, we use optical traps to capture, manipulate, cool, or characterize both non-living and living microorganisms with light," says Pavel Zemánek from the Institute of Scientific Instruments of the CAS. "Our work closely aligns with that of Ondřej Číp's Coherence Optics Research Department, which uses light for highly precise measurements, cooling ions in atomic clocks, distributing stable optical frequencies across European communication networks, and even welding and micromachining."
More info:

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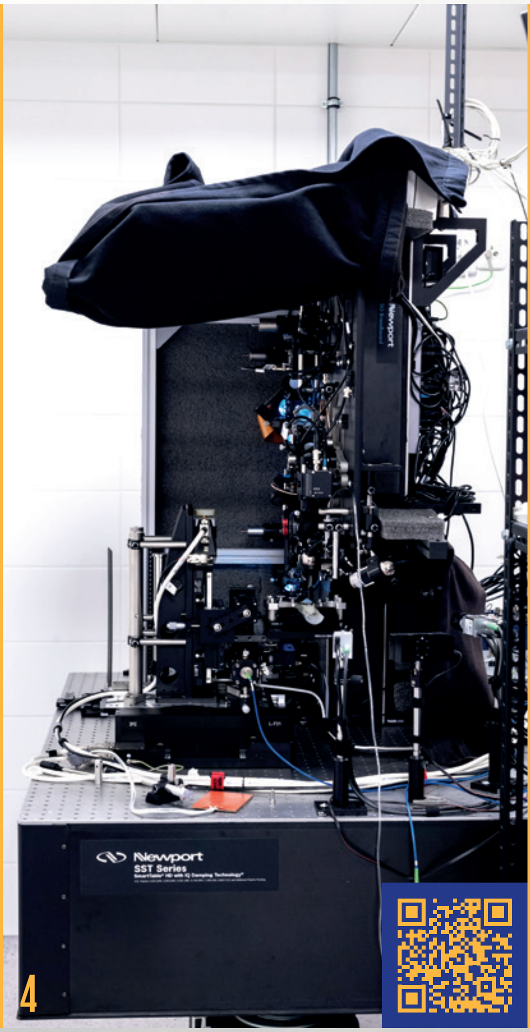


4

DEEP INTO THE BRAIN
The holographic endoscope, developed by Tomáš Čižmár's team, enables deep penetration into the brain to visualize individual neurons and their communication. A laser sends light via an optical cable to a device consisting of lenses and mirrors (1). Here, the light is split and directed toward a computer-controlled holographic modulator that imprints specific properties onto the light for the given application. The modified light is then fed into a multimode optical fiber about a tenth of a millimeter wide (2), which penetrates biological tissue – in this case, the brain of a mouse (3), a model organism for human diseases. Photo 4 shows the holographic endoscope device that is used in the lab. The commercial version of the endoscope, intended for neuroscientific or pharmaceutical research, is more compact and practical. You can see examples of it on the website of the spin-off company DeepEn.

> As the optical fiber moves through the mouse's brain, an entire universe of interconnected neurons appears on the screen.

be done via genetic manipulation of the sample or viral transfection – what then fluoresces is the protein, produced by the cell in response).

As the fiber moves through the mouse's brain, an entire universe of interconnected neurons appears on the screen. "We can see various details, such as the dendrites extending from the neuron. Dendrites have spines – structures where neurons exchange information through synapses. It's a dynamic structure, so many scientists are interested in how the cells activate, how individual parts of neurons are formed, how they establish connections, and how active they are," Čižmár explains.

The holographic endoscope developed by Čižmár and his team is now ready for use. DeepEn, a spin-off company founded by the Czech scientist and his colleagues in Germany, is managing the transition to practical applications. They are now presenting the device at neuroscience conferences and hosting workshops aimed at explaining how it works. Various research institutions, particularly those focusing on brain research, neuron activity, and neural degeneration, have already expressed interest.

Though the project may appear to be completed, it is far from over. Čižmár and his colleagues are continuing to refine the instrument. The next milestone is to adapt the equipment to allow the mouse models free movement. Currently, the endoscope works reliably when the mouse has a holder with the probe attached to its head and it only runs on a pad under the holder. However, the flexibility and plasticity of the fiber theoretically allow for monitoring the brain's activity in the animal's natural environment – something that isn't yet possible. When the animal moves at will, the light in the fiber clashes, distorting the transmitted information.

Ing. BARBORA ŠPAČKOVÁ, Ph.D.
INSTITUTE OF PHYSICS OF THE CAS

Barbora Špačková studied physical engineering at the Czech Technical University in Prague. As a PhD student, she worked at the Institute of Photonics and Electronics of the CAS on the development of optical biosensors (2005–2017). From 2017 to 2021, she was a research fellow at Chalmers University of Technology in Sweden, working in Christoph Langhammer's group. She co-founded the Swedish spin-off company Envue Technologies, which focuses on the commercialization of nanofluidic scattering microscopy. Currently, she leads the Dioscuri Center for Single-Molecule Optics, initiated by the Max Planck Society, which started its operations on 1 July 2024.

And what about using the holographic endoscope on a human brain? It would certainly be fascinating to observe the brain of a patient, like Auguste Deter mentioned before, in real-time. Technically, it is possible – with several obstacles at play. For instance, using fluorescent labeling in the human body (which involves manipulating a living organism) is complicated. "The benefit for humans, however, is evident. It lies primarily in imaging and studying a given disease in animal models," Čižmár concludes.

TAMED LIGHT?

Light possesses unique physical properties, and the more we learn about it, the better we get at utilizing it. We've learned to use light to manipulate (and even sort) microobjects, transmit data, change the structure of materials with laser-bound light, and we're even capable of using light in machining and cutting. But we still haven't tapped into all the possibilities light has to offer.

"There are still plenty of gaps to fill. We've only tamed light to a certain extent. We still face the challenge of how to shape light effectively in both space and time. Achieving that would result in remarkable applications, particularly in medicine," Čižmár adds.

Many scientists are trying to harness light and utilize its properties, particularly for medical research. Barbora Špačková from the Institute of Physics of the CAS approaches light from a slightly different angle. Yet in the long run, her research too could help patients like Auguste Deter.

THE RAW POWER OF LIGHT

"For most of us, light is a tool that allows us to see. What's surprising, though, is that in the nanoscale world where my research takes place, light is an incredibly crude and imprecise tool," Špačková explains. That's because the wavelength of light is about one hundred times larger than the objects she focuses on in her work. "It's fascinating that we can trick light and use it not only for observing but also measuring and weighing nanoscale objects," she adds.

Her primary interest is in biomolecules – the fundamental building blocks of all life. These molecules are up to one hundred thousand times smaller than dust particles and invisible to conventional optical microscopy. They are also incredibly fast. In their natural aqueous environment, they can move hundreds of nanometers within a single millisecond.

Just how can such a super-fast and invisible entity be observed and recorded? "It's extremely difficult, like looking for a black cat in a dark room. And often, you're not even sure if it's there," Špačková notes. This issue is often circumvented by fluorescent microscopy, which attaches a fluorescent marker to the observed molecule that then acts as a beacon in the dark. However, the marker can significantly influence the behavior of the studied molecule. Observing biomolecules without markers is difficult – but not impossible. Špačková has managed to overcome this hurdle.

Originally, Špačková's research focus lay elsewhere. Like Tomáš Čižmár, a pivotal shift in her career took place abroad – at Chalmers University of Technology in Sweden, where she went as a postdoctoral researcher in 2017. She wanted to develop biosensors suitable for detecting chemical and biological substances, such as air pollutants or biomarkers in blood – a topic she had explored at her previous workplace, the Institute of Photonics and Electronics of the CAS.

One day, her colleagues in the Swedish lab showed her an optical phenomenon interfering with their project they wanted to eliminate. They didn't know why it worked the way it did or what it might be good for. Špačková found the issue intriguing and decided to investigate it further. She delved into the relevant theory, analyzed various possibilities, and explored how light should behave in certain situations – such as when encountering a biomolecule. The theory suggested that in this case, ›

"We are embarking on a journey through the biological nanoverse, like nanoscale explorers discovering the fundamental building blocks of life."

Barbora Špačková

WHEN LIGHT MEETS MATTER

"We study what happens when light – or more specifically, a photon – interacts with a molecule or atom. Most of the time, nothing happens; they pass each other by. But in one out of a million tests, something does occur, and we explore all possible interactions," explains Marek Piliarik, head of the Nano Optics group at the Institute of Photonics and Electronics of the CAS. His team is developing new microscopic methods. "Current microscopes can observe molecules and distinguish individual atoms, but the issue is that the examined sample has to be frozen and placed in a vacuum, essentially killing it before we can look at its structure," Piliarik adds.

Light is a form of electromagnetic radiation within the visible spectrum, with wavelengths ranging from 380 to 750 nanometers. Shorter wavelengths correspond to UV, X-ray, and gamma radiation. On the opposite side of the spectrum are infrared, microwave, and radio waves.

light could be capable of detecting the biomolecule. This led to the idea of creating a unique microscope that could visualize biomolecules in their natural aqueous environment. “I received incredible support from my supervisor at the time. He too thought that if it worked, it would be groundbreaking. He asked me what I needed – a lab? Time? Equipment? The idea was so appealing that he provided all the resources I needed to realize it,” Špačková says.

LIGHT TRAPPED IN A PIPE

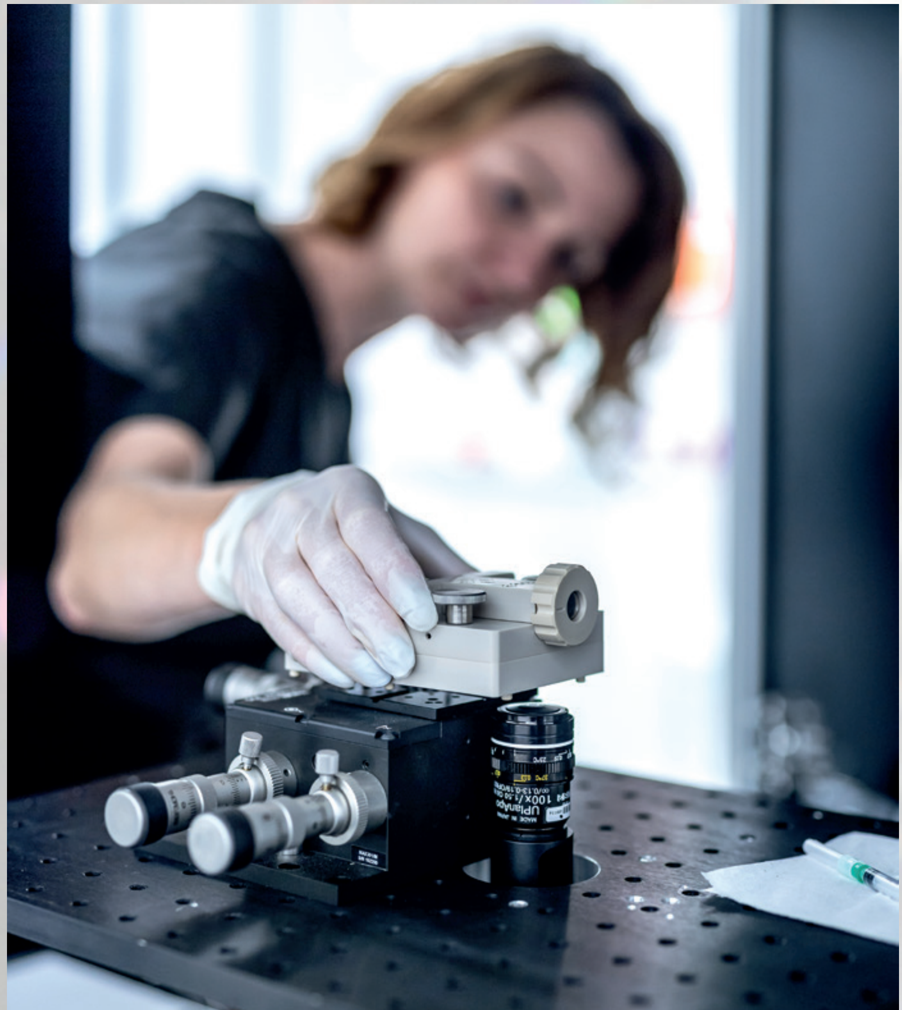
Several months of intensive work gave rise to the prototype microscope. “The moment I first saw a DNA molecule in our microscope is something I’ll never forget. It happened to coincide with the same day the media released the very first photo of a black hole,” the researcher recalls, referring to 10 April 2019.

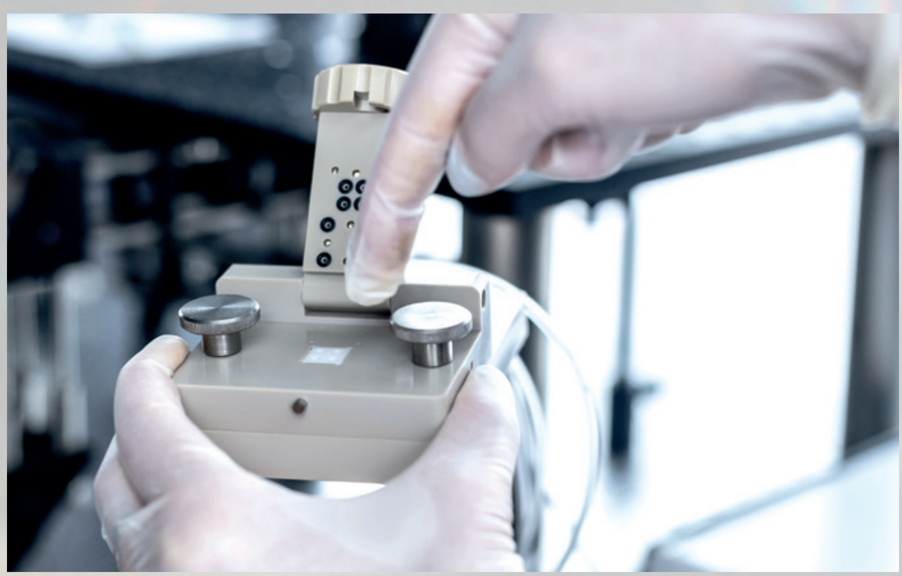
The scientists named it the Nanofluidic Scattering Microscopy method. Nanofluidics is the study of fluid flow at the nanoscale, and it’s a field that Christoph Langhammer’s team, which Špačková was part of in Sweden, specializes in.

A nanofluidic device can be likened to a miniature pipeline through which fluid flows. The “pipe” is made of glass and is constructed using electron-beam lithography (instead of the stylus used in traditional lithography, the structure is drawn with an electron beam).

To visualize the observed biomolecule in the “pipe,” Špačková employed the principle of light interference. When light waves interact, they influence each other, amplifying their effects. “The intensity of the two interacting light waves doesn’t simply add up – one and one can equal two, but just as well zero or four, in this case,” Špačková explains.

In size, the nanofluidic microscope is comparable to Čižmár’s holographic endoscope. Both fit within a space roughly the size of a smaller bathroom. The device developed by Špačková and her colleagues also consists of a set of mirrors and lenses through which laser light passes.





The sample of the fluid under examination (e.g., cell secretion, blood plasma) is applied to a nanofluidic chip (bottom photo). The chip is a square plate containing a series of larger microscopic channels that guide a drop of fluid into smaller nanofluidic channels. This is where the interaction, scattering, and interference of light with the molecule occur.

The sample of the examined fluid – whether it's cell secretion or blood plasma – is applied to the nanofluidic chip. This square plate, roughly one centimeter by one centimeter in size, contains a series of larger microscopic channels that guide a drop of fluid into smaller nanofluidic channels. Here, the interaction, scattering, and interference of light with the molecule occur. The molecule is then visualized on a computer screen as a moving dark "blot."

To the untrained eye, this may appear as a mere smudge, but according to Špačková, biophysicists and biochemists are thrilled. Not only does observing the movement and interactions of molecules brings unique insight into the life of biomolecules, but this method also enables the detailed analysis, measurement, and weighing of individual molecules.

As a result, the first promising collaborations with labs of research institutions and pharmaceutical companies are already in the making. A spin-off company, Envue Technologies, was founded in Sweden to facilitate the transfer of this discovery into practical use. Špačková is also working on the next generation of the instrument, which will offer both better resolution and additional functionalities, such as the ability to manipulate individual molecules or measure their charge.

Špačková is continuing the development in the Czech Republic, where she returned with her family in 2022. She found a home at the Institute of Physics of the CAS where, since July 2024, she has been leading the Dioscuri Center for Single-Molecule Optics, initiated and supported by the Max Planck Society. The new center will employ six scientists, and so far, doctoral students from abroad have been the primary applicants. Thanks to generous funding, the hired researchers will have adequate pay, which is not always a given in Czech science. The center aims to attract young researchers with a foundation in physics who also have knowledge of biochemistry, biophysics, and experience with microscopy or nano/microfluidics.

ACROSS THE NANOVERSE

"We are embarking on a journey across the biological nanoverse, like nanoscale explorers discovering the fundamental building blocks of life," Špačková notes. But the work won't stop at merely marveling at the hidden corners of the nanoworld. In collaboration with molecular biologists, her team plans to focus on specific issues related to molecular transport within cells and processes linked to the development of diseases such as Alzheimer's.

While current brain research won't help Auguste Deter, who passed away more than a century ago, the number of people facing a similar fate is continually growing. In the Czech Republic alone, an estimated 150,000 people suffer from Alzheimer's disease, and by 2050, this number is expected to nearly double.

Whether scientists will be able to reverse this grim prediction remains uncertain. However, it is clear that with discoveries like the nanofluidic scattering microscope and the holographic endoscope, researchers may "shed light" on Alzheimer's disease in ways previously unimaginable.

> Light sometimes behaves like a wave and other times like a stream of particles, known as photons. During diffraction, light exhibits wave-like properties. During the photoelectric effect, light acts as a stream of photons.

INSPIRED BY SHA

Bacteria-resistant shark scales, sticky gecko feet, or lotus leaves that repel water – nature designs ingenious surfaces. But can we replicate them?

Text: Leona Matušková \ Photo: Shutterstock, Jana Plavec (3)

RKS

Catheters are essential for patient care, drug delivery, and drainage of bodily fluids, but prolonged use can lead to dangerous infections, with life-threatening bacteria appearing on their surface. That's why researchers are exploring ways to modify or improve the materials used in such medical devices, often drawing inspiration from nature. Surprisingly, light – specifically, lasers – plays a key role.

Shark skin, with its rough scales, is naturally resistant to bacteria. Its surface has structures shaped in a way that cause foreign substances to slide off. If bacteria do manage to adhere, their cells bend between sharp ridges or are pierced and killed. Similar sophisticated surfaces are found on cicada wings and those of other insects.

And then we have lotus leaves with their water-repellent surfaces, snake skin that minimizes friction, and gecko feet that can cling to almost any surface. But how can we replicate these natural marvels and create micro- or nanoscale superstructures?

LASERS AS PRECISION TOOLS

Material surfaces are conventionally modified through machining – a process of shaving off or removing fragments to achieve the desired shape. Traditional machining tools include saws and scrapers, while more advanced methods use lathes and milling machines. For micro- and nanoscale work, lasers are the perfect tool.

Current techniques typically use a single laser beam, which moves across the surface using motorized mirrors or sliding tables. However, processing fine details on the microscale is extremely time-consuming. This slowness, along with high costs, explains why "shark skin" or "lotus leaf" surfaces aren't being mass-produced yet.

To put it in perspective, creating one square centimeter of water-repellent surface with a high-powered laser would take about one minute. Producing one square meter would thus take seven days. "For industry purposes, this speed

Ing. PETR HAUSCHWITZ, Ph.D., MBA INSTITUTE OF PHYSICS OF THE CAS

Petr Hauschwitz studied laser technologies and physical engineering at the Czech Technical University in Prague. His dissertation on 'large-area functionalization of surfaces using laser-created micro- and nanostructures' earned him first place in the category of Best Doctoral Thesis at the Werner von Siemens Awards in 2022. In 2023, he received the Otto Wichterle Award, awarded by the CAS to young, talented scientists. He has worked at the HiLASE Center since his studies, leading a research group there since 2019. Together with his team, he holds two world records in productivity and the number of laser beams used in nanomachining (both from 2021).

is utterly unprofitable. We're working on ways to make laser machining faster and more efficient and to transfer our findings from the lab into the real world," explains Petr Hauschwitz, leader of the laser micromachining team at the HiLASE Center, which is part of the Institute of Physics of the Czech Academy of Sciences (CAS).

LIGHT-SPEED INNOVATION

During his doctoral research, Hauschwitz focused on designing superhydrophobic (water-repellent) surfaces. He drew inspiration from the lotus leaf, which is covered with nanostructures that give it remarkable properties, like self-cleaning: water droplets form spherical shapes and roll off the leaf, carrying away dirt and dust. This phenomenon is known as the "lotus effect."

A cleaner leaf is better protected from algae, bacteria, and fungi, reducing the risk of disease while improving access to sunlight, thus enhancing photosynthesis. The technology to produce such surfaces has been known for some time, but Hauschwitz's goal was to simplify and speed up the process.

The researcher experimented with different methods of making production more efficient. The breakthrough came with parallelization – splitting one laser beam into multiple functional parts. In his dissertation, he demonstrated that it is possible to machine surfaces using over 700 laser beams simultaneously.

His innovative approach caught the attention of the Werner von Siemens Award jury, which awarded him the prize for best dissertation in 2022. A year later, he received the Otto Wichterle Award from the CAS that recognizes talented researchers under 35.

MACHINING AT THE NANOSCALE

Under a microscope, shark scales resemble a neatly arranged grid

HOW TO SPLIT A LASER BEAM

Creating 1 cm^2 of functional structure with a single laser beam would take one minute. To produce 1 m^2 would require 7 days. To speed up the process, Petr Hauschwitz's team uses three main methods, selected based on the specific application:

DIFFRACTION BEAM SPLITTING

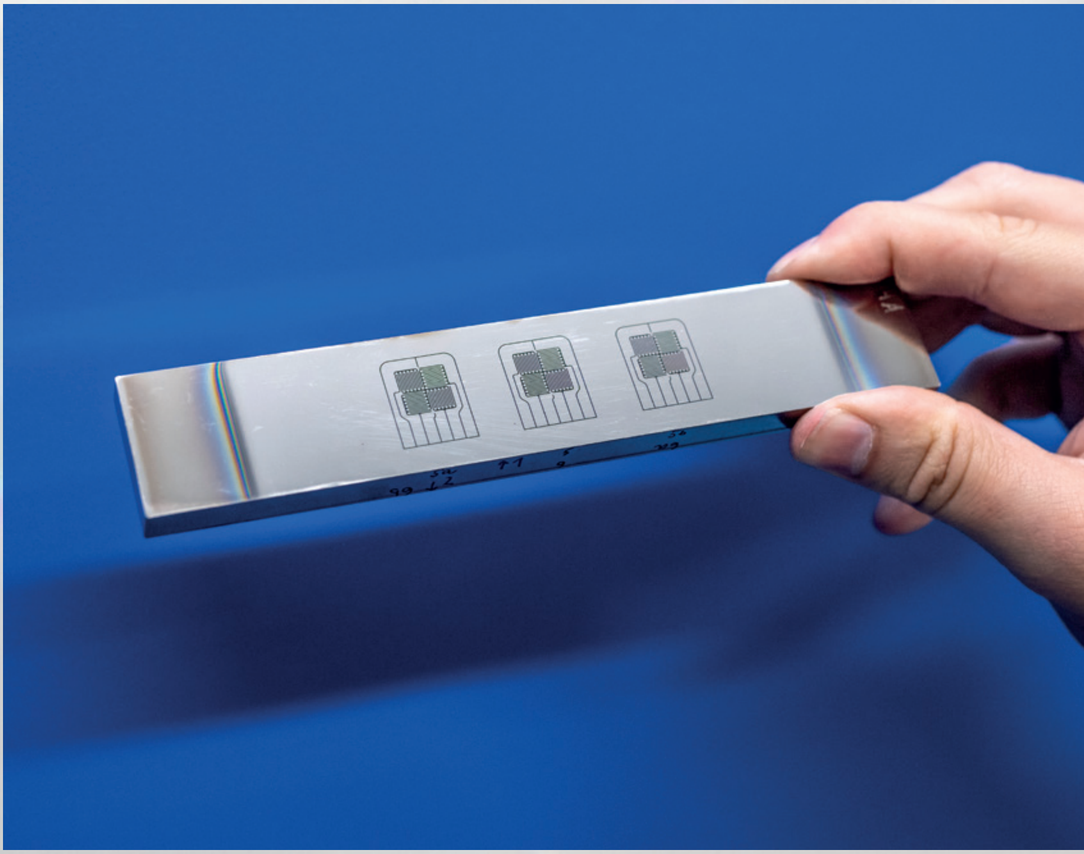
The beam is split by a pre-designed diffraction grating. Its simplicity is an advantage – the grating is just placed into the optical setup. It can withstand very intense laser beams, but it is expensive. Designing and manufacturing a grating costs around 10,000 to 20,000 EUR. Reproducing the element is about five times cheaper.

INTERFERENCE STRUCTURING

Similar to diffraction, but more flexible. By changing the angle at which beams intersect, the period of the interference pattern (the distance or size of individual points) can be adjusted. This method can bypass the diffraction limit of the optical lens and create structures smaller than the wavelength of the laser beam.

DYNAMIC BEAM SHAPING

This method allows real-time shaping and splitting of beams using a liquid-crystal spatial light modulator. By rotating the crystals, the wavefront of the input device changes, shaping the beam. While flexible, liquid crystals cannot handle high laser energy or power.



The photo shows a prototype of a strain sensor, used in fields like robotics. It is the result of extremely precise micromachining, where the laser had to evaporate a layer just 250 nanometers thick without damaging the underlying ceramic layer.

›

of grooved rectangular tiles, while the surface of a lotus leaf, covered in tiny protrusions, looks like a volcanoscape. The microstructure of gecko feet resembles a shaggy carpet with frayed tips, and snake skin consists of dense clusters of sharp micro-spikes.

To replicate these surfaces, one must first create a 3D computer model or grid of the desired structure. This model is then used to program a laser machining tool, which uses beams of light to remove tiny fragments from the material, layer by layer.

Unlike traditional machining, which generates a significant amount of waste, laser micromachining produces minimal waste – often in the range of mere micrometers. The removed material either melts or, more commonly, vaporizes. Since the process occurs on a microscopic scale, to the naked eye, the finished product might appear identical to the raw material. The difference, however, is detectable under a microscope or when a precise weighing scale is used.

Despite the high precision involved, functional surface machining doesn't require a massive laboratory. The lab at HiLASE, for example, is comparable in size to a small bedroom. Even the machining equipment is surprisingly compact. At its core is a laser, in this case the PERLA laser, developed in-house by the scientists and engineers at HiLASE. It boasts an exceptionally high beam quality and high pulse energy, enabling the parallelization of production across multiple beams.

Speed and efficiency in production, however, don't depend on the laser's power alone. The key is to skillfully split the laser beam so it can work on multiple areas simultaneously. Hauschwitz's team has already broken several world records in this regard. "Our current record is over 40,000 beams working simultaneously. We've reduced the time needed to machine one square meter from seven days to just five minutes, and we are now able to structure details smaller than a micron," the researcher says.

"I got into this field thanks to my grandpa, who taught high school physics and math. He insisted on reviewing every one of my assignments, which could get annoying, but it helped spark my interest in these subjects."

Petr Hauschwitz

To be precise, 40,401 laser beams were used in parallel to machine a single material. The project involved creating a superhydrophobic surface resistant to ice, corrosion, and air resistance – perfect for use on aircraft wings. This level of beam division was achieved using a special diffraction grating, custom-made for the HiLASE team by the Israeli company HOLO/OR.

FROM SPACE TO MICROBES

The breakthrough in laser beam-splitting technology and the dramatic acceleration in producing superfunctional surfaces has caught the attention of industry leaders and innovative startups alike. The HiLASE team is making a name for itself, and exciting collab opportunities are emerging. Recently, a Canadian company approached the team to create a superhydrophobic surface for a 650 × 300 mm metal sheet for use in cooling systems. The company had been unable to find anyone in North America capable of doing so.

The unique methods developed by Czech researchers are also being applied in space technology. One of their successful projects involved drilling micrometer-sized holes in graphite and ceramics for use in satellite engines. Hauschwitz has also highlighted strong partnerships with local innovative companies like IQS, which manufactures holograms for ID cards, among other products. In a joint project currently in development, they are working on creating antimicrobial catheters and other medical devices at high risk of bacterial infection. These are often long, closed-off tubes, and forming a controlled functional nanostructure on their inner surfaces is particularly challenging. "We've figured out a way to do it, and if we succeed, we could be the first in the

PROJECT LASAPP

The development of antibacterial surfaces, a collaboration between the laser micromachining lab and the Faculty of Science at Charles University's BIOCEV Center, is now supported by the interdisciplinary LasApp project. "We'll be developing functional bacteria-resistant surfaces, while Zdena Palková's team at BIOCEV will study how microbes react to these surfaces," Petr Hauschwitz explains. LasApp builds on the recently completed Strategy AV21 program, *Light in the Service of Society*. It involves institutions with a history of developing the first Czechoslovak lasers in 1962–1963. The project is coordinated by the Institute of Photonics and Electronics of the CAS, a leader in fiber laser development in the Czech Republic. The main goal of the project, which stood out among 66 others in the Excellent Research call of the Johannes Amos Comenius Operational Program, is to advance both fiber and thin-disk laser technologies. Its application potential spans beyond medicine into aerospace and defense industries.

world to master this technique," Hauschwitz adds.

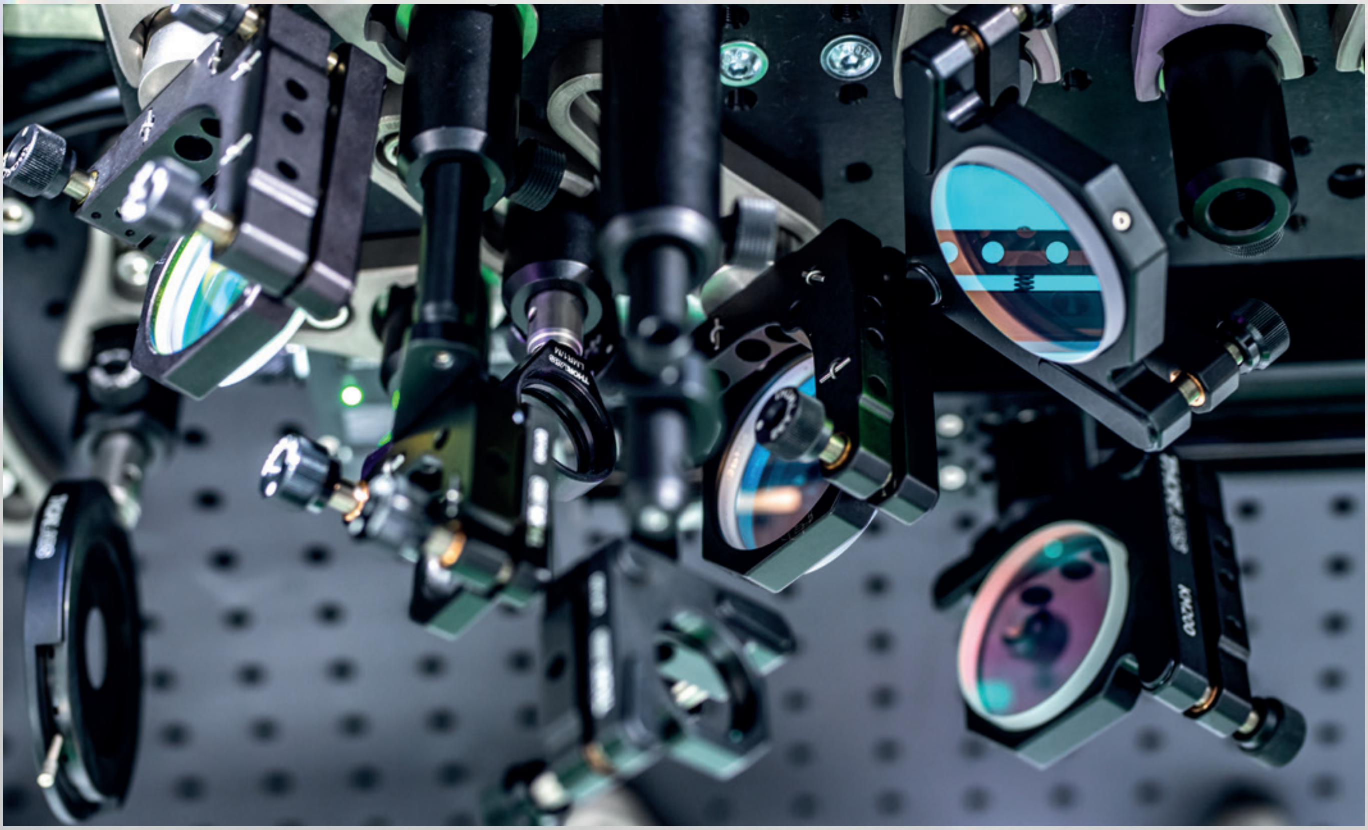
Antimicrobial surfaces, inspired in part by the unique scales of sharks, could also find use in materials for joint replacements, a project Hauschwitz's team is hoping to pursue in collaboration with the Czech company Prospon. Another HiLASE group, specializing in laser shock peening, will be involved in this project. Their methods can extend the lifespan of highly stressed components, which is especially desirable for joint implants.

Laser micromachining has proven to be valuable in medicine, industry, and space. Czech researchers are determined to be trailblazers in this field. When asked about his goals for the coming years, Hauschwitz doesn't hesitate. "When anyone in the world asks about the best micromachining labs, I want ours to be at least among the top five contenders."

LIGHT HARNESSED IN A LASER

A laser is amplified light concentrated into a highly powerful beam. The principles behind how it works were described by Albert Einstein in 1917, and the first laser was built by American physicist Theodore Harold Maiman in 1960. Over time, lasers have been continually improved, with a major breakthrough occurring in the 1980s when Donna Strickland and Gérard Mourou developed the technique of chirped pulse amplification, for which they received the 2018 Nobel Prize in Physics. This method enabled the creation of large laser systems around the world with top-tier performance. One such facility is Hauschwitz's home institution in Dolní Břežany, Czech Republic. Lasers at HiLASE generate extremely short pulses, sometimes in the femtosecond range (about 10^{-15} seconds). While this high-energy output makes extraordinary feats possible, it also poses a risk of damaging both the material being processed and the laser equipment itself. That's why researchers have developed various techniques of "taming" these high-energy beams. As a result, HiLASE has set several world records for laser performance. More about HiLASE's records:

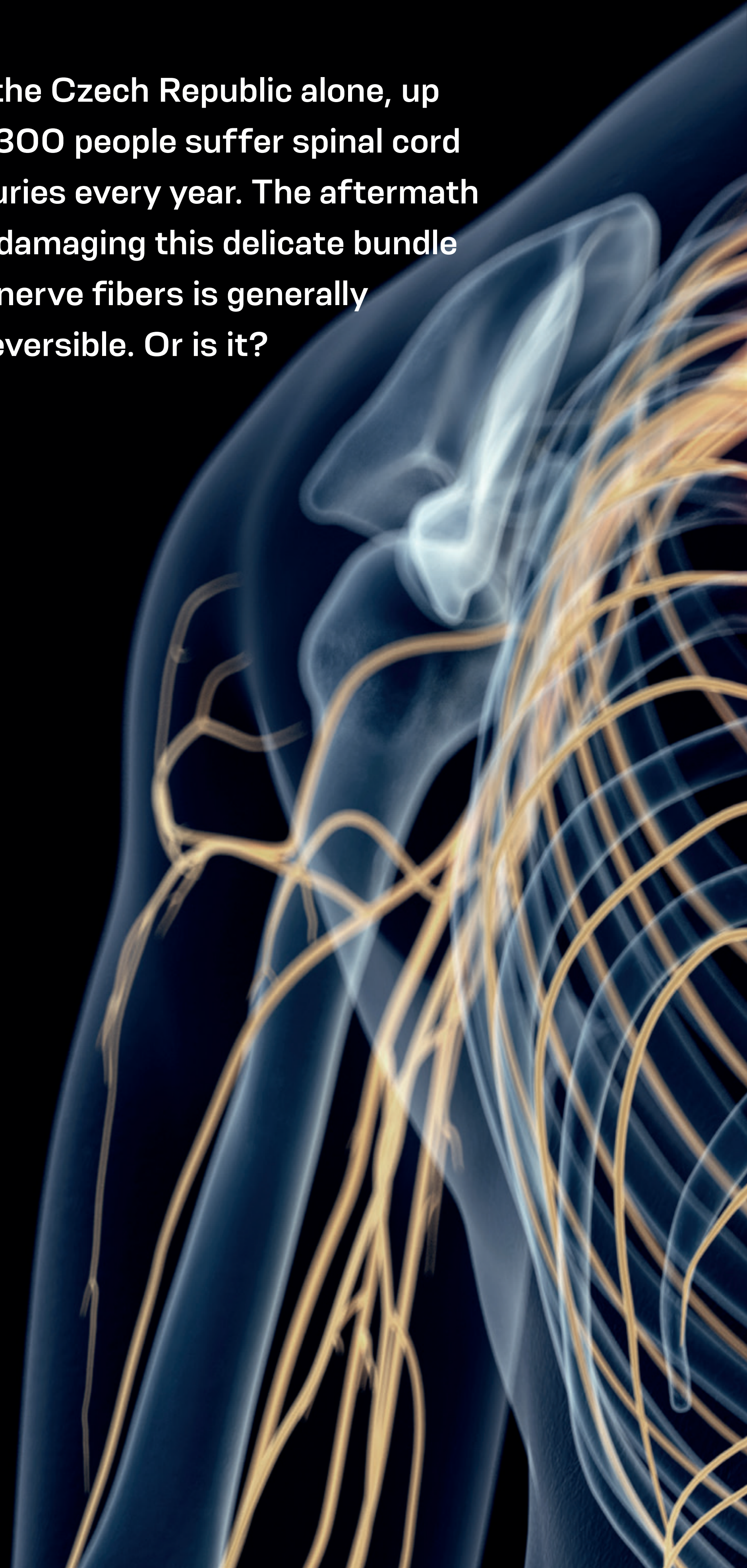
Unlike traditional machining, which generates a significant amount of waste, laser micromachining produces minimal waste – often in the range of mere micrometers.



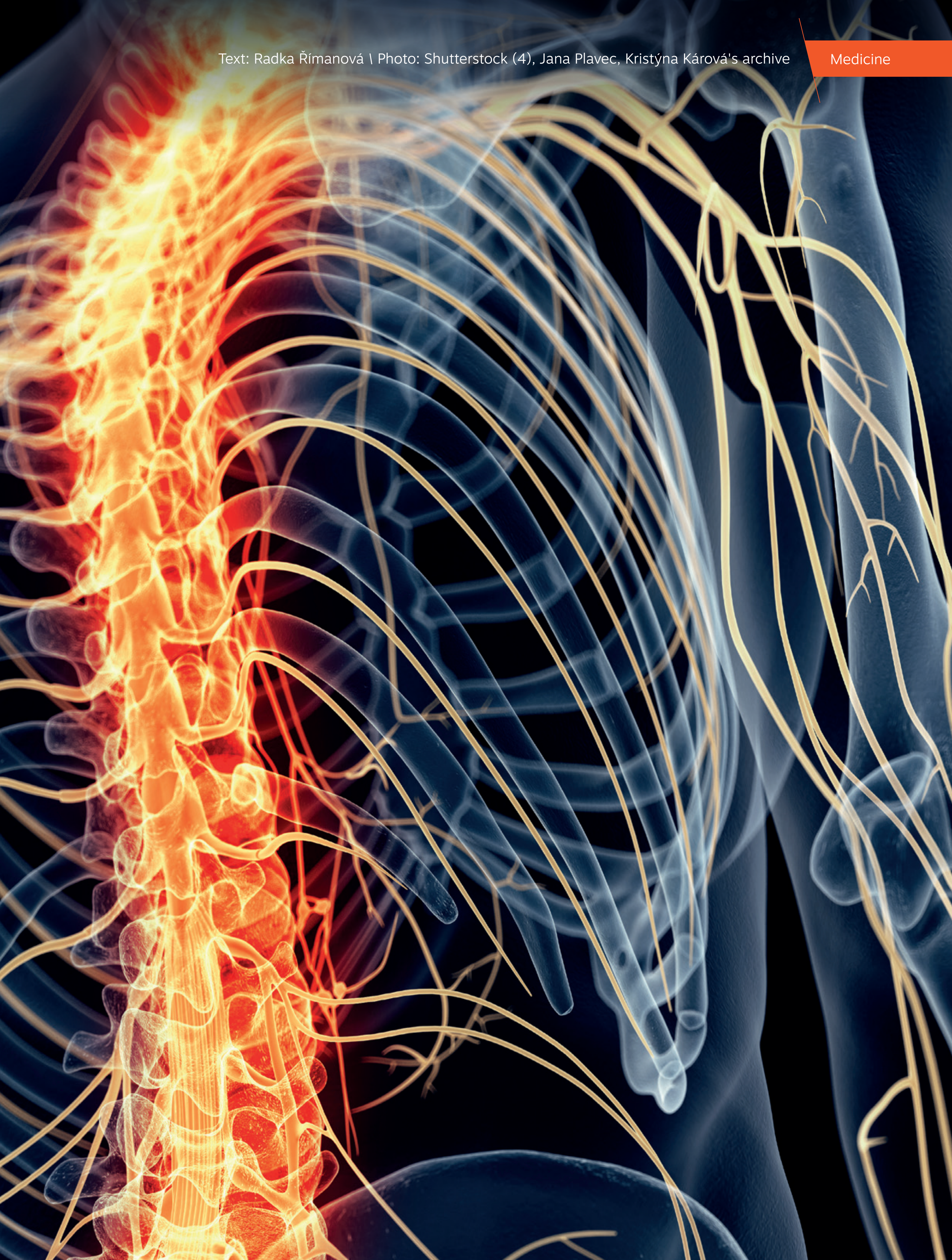
The PERLA laser, developed at HiLASE, is used for laser micromachining. It generates a high-quality beam (1,030 nanometers, 970 femtoseconds, 100 watts), which researchers split to maximize efficiency.

CAN WE REPAIR THE SPINAL CORD?

In the Czech Republic alone, up to 300 people suffer spinal cord injuries every year. The aftermath of damaging this delicate bundle of nerve fibers is generally irreversible. Or is it?



Text: Radka Římanová \ Photo: Shutterstock (4), Jana Plavec, Kristýna Kárová's archive



> "Gene therapy has enormous potential. It's a highly effective way of 'taming' specific cells and getting them to do exactly what we want."
> *Kristýna Kárová*

Your nose is itching. What happens next? Your brain evaluates the situation and sends a signal through the motor pathways of the spinal cord to the muscles in your hand, which quickly complete the task. Simultaneously, though, there's a message traveling up to your brain via the sensory pathways of the spinal cord from your toes, informing it that they are starting to feel cold. Our control center then immediately sends further commands through the spinal tracts to the body to eliminate this sensation of cold.

At any given time, there's a lot happening inside the ***medulla spinalis***. The nearly half-meter-long spinal cord, about as thick as a thumb, contains approximately 13.5 million nerve cells – neurons – responsible for transmitting information.

"We can picture a neuron as a hand. The palm represents the body of the cell, the fingers are dendrites, which are short extensions that receive signals. The forearm is like a long extension of the neuron called the axon, which connects to other neurons via synapses and transmits information," explains neuroscientist Kristýna Kárová from the Department of Neuroregeneration at the Institute of Experimental Medicine of the CAS.

While a nerve cell can have thousands of dendrites, it always has only one axon. But it's a big one – reaching up to one meter in length. Signals are transmitted between neurons thanks to a combination of electrical and chemical processes and travel through the spinal cord at speeds of up to 120 meters per second. But even on this sophisticated highway, a traffic jam can occur – when the spinal cord gets damaged, despite the protective efforts of the spine.

WRONG WAY: DO NOT ENTER

Injury, various diseases, and tumors – the most common causes of spinal cord injury, also known as spinal lesions. At the site of the injury, the flow of information between the brain and the rest of the body is interrupted, often resulting in not only motor impairments but also sensory ones, or even disruptions to the autonomic nervous system, which controls the functions of internal organs. The higher the lesion is located, the more extensive the consequences.

"A clearly defined cavity forms in the spinal cord where the signal cannot pass through. A glial scar develops around the lesion, isolating the damage from the rest of the tissue and blocking the axons' attempts to grow through the area," Kárová describes.

As a result, the affected axons typically become inactive and their ends degenerate. However, the more dynamic axons sometimes try to save the situation and grow around the lesion. But their spontaneous efforts are not enough to restore the disrupted connections – at least not in humans.

That is why researchers everywhere have struggled for decades to find ways to stimulate these inactive neuronal extensions to regenerate. Kristýna Kárová and her colleagues are also striving to initiate neuron renewal in the motor pathways of the spinal cord, aiming to restore the body's original mobility. And they are doing this with the help of gene therapy.

> In the past thirty years, approximately nine thousand people in the Czech Republic have had to learn to live with spinal cord injuries.

THE FORGOTTEN RECIPE

PI3K-delta. That is the name of a growth-promoting enzyme from the kinase group, which plays a crucial role in the development of the central nervous system. During the period when neurons are forming, this enzyme is abundant throughout the body. However, once nerve cells establish synapses and settle into the neural network, the production of this kinase naturally declines. Neurons simply transition from an active state to a more "settled" lifestyle, much like a teenager maturing into adulthood.

Back in 2007, German neuroscientists pondered this idea: "What if we reminded mature neurons of their youthful vigor and taught them how to produce the unbridled kinase again?" Interesting things started to occur in the cells stimulated by the enzyme. Researchers in Cambridge then embarked on kinase experiments with cell cultures, and years of experimentation proved that this protein promotes the regeneration of cortical neurons.

"We built on the findings of our international colleagues and tried to stimulate axon regeneration in the damaged spinal cords of rats with PI3K-delta. We essentially gave the neurons in the motor cortex of their brains the recipe for this 'active' protein, prompting the cells to start producing it again," Kárová recounts.

The experimental results confirmed suspicions about the kinase's power – Kárová's team managed to activate a signaling pathway that supports regeneration in injured rodents and modulate the transport of molecules into

Mgr. KRISTÝNA KÁROVÁ, Ph.D.

INSTITUTE OF EXPERIMENTAL MEDICINE OF THE CAS

Kristýna Kárová studied immunology at the Faculty of Science, Charles University (Prague), and completed her doctoral studies at the Second Faculty of Medicine at the same university. Since 2012, she has been working at the Institute of Experimental Medicine of the CAS. Her research primarily focuses on the potential use of gene therapy to stimulate axon regeneration following spinal cord injury. She has worked with many prestigious interna tional institutions, such as New York Medical College, the University of Cambridge, and King's College London. In 2023, she was awarded the Otto Wichterle Award for outstanding young scientists.

the axons using PI3K-delta. In other words, the researchers forced the disabled axons to grow and reintegrate.

A VIRUS AS MESSENGER

The scientists delivered this crucial recipe to the rat test subjects with a simple injection. This allowed them to introduce a specially modified viral particle containing genetic information into the relevant part of the brain, convincing the neurons to produce the kinase.

"It's a virus that doesn't pose a threat to the animal because it cannot replicate itself. However, it can enter certain cells, so it basically works like an envelope we can use to send a message to the rat's neurons," the neuroscientist explains.

So, what exactly did the kinase activity cause in the rodents' bodies? Histological analysis showed that under the protein's influence, many new axons formed in the rats' spinal cords. The damaged ones managed to overcome the injury by growing around it and reached distances of about one centimeter below the lesion. Electrophysiological examinations also revealed that the growth of these extensions didn't stop there – the axons successfully reintegrated into the neural network.

"When we stimulated the spinal tract using electrodes, we detected a signal below the lesion and even in the corresponding muscles. Simply put, the impulse overcame the obstacle of the injury and reached its destination," Kárová clarifies.

SUGAR AS MOTIVATION

Rats love sugar. Researchers exploit this fact to test whether and how the histologically documented "restart" of axons translates into improved motor abilities in these lab animals. Sweet rewards are prepared on steps at various heights or at the opposite end of a horizontal ladder with different-sized gaps between the rungs. The scientists then release the rodents into this sweet paradise and count how many sugar cubes they consume within a certain timespan or how skillfully they can navigate the ladder.

These tasks are first trained with healthy animals. Then, so-called behavioral tests are conducted on rodents with spinal cord injuries in the dorsal corticospinal tract that have received gene therapy.

"Injuries manifest in rats as deficits in their front paws. They aren't completely paralyzed but have motor control issues. They tend to slip on the ladder or steps, lack balance, and struggle with fine grips... However, our tests show that within four months of administering the kinase recipe, their motor skills significantly improve," Kárová reports.

HOPE FOR THE PARALYZED?

After five years of concentrated efforts on the project, the neuroscientist's team › is now preparing to publish the promising results of their research. They are also evaluating a long-term study on the effects of the kinase in rats' bodies a year after administering the therapy. This study also appears optimistic.

It's no wonder that the successes of this research instill hope in people with spinal cord injuries. The International Foundation for Research in Paraplegia, based in Switzerland, has even financially supported it. However, Kárová remains cautious.

"Our approach does have potential, but we are developing an experimental treatment, so the journey to applying our findings to humans is still a very long one. It involves years of further studies, especially chronic studies on rats, followed by other animal species like monkeys or pigs. And even then, success is not guaranteed," the researcher warns.

Kárová is alluding to the fact that scientists from all over the world have often found that what works well in animal models is not guaranteed to have the same effect in the human body.

"But without faith, this work wouldn't be possible. So I sincerely hope that one day, we will manage to get a person with a spinal cord injury moving again," the scientist concludes.

SENSATION IN A RAT'S PAW

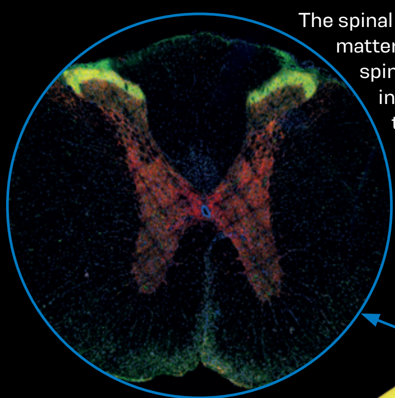
Researchers from the Institute of Experimental Medicine of the CAS are also working on reconstructing sensory pathways to restore sensation after spinal cord injuries. In 2023, as part of the Neurorecon project, they collaborated with neuroscientist James Fawcett from the University of Cambridge and successfully used gene therapy to restore hind limb sensation in rats to almost pre-injury levels. The damaged axons regrew four to five centimeters, marking an unprecedented achievement in the field.

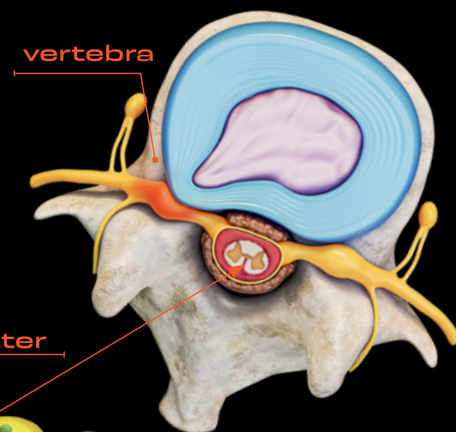
"We use the virus as an envelope, sending a message with a task to the rat's neurons."

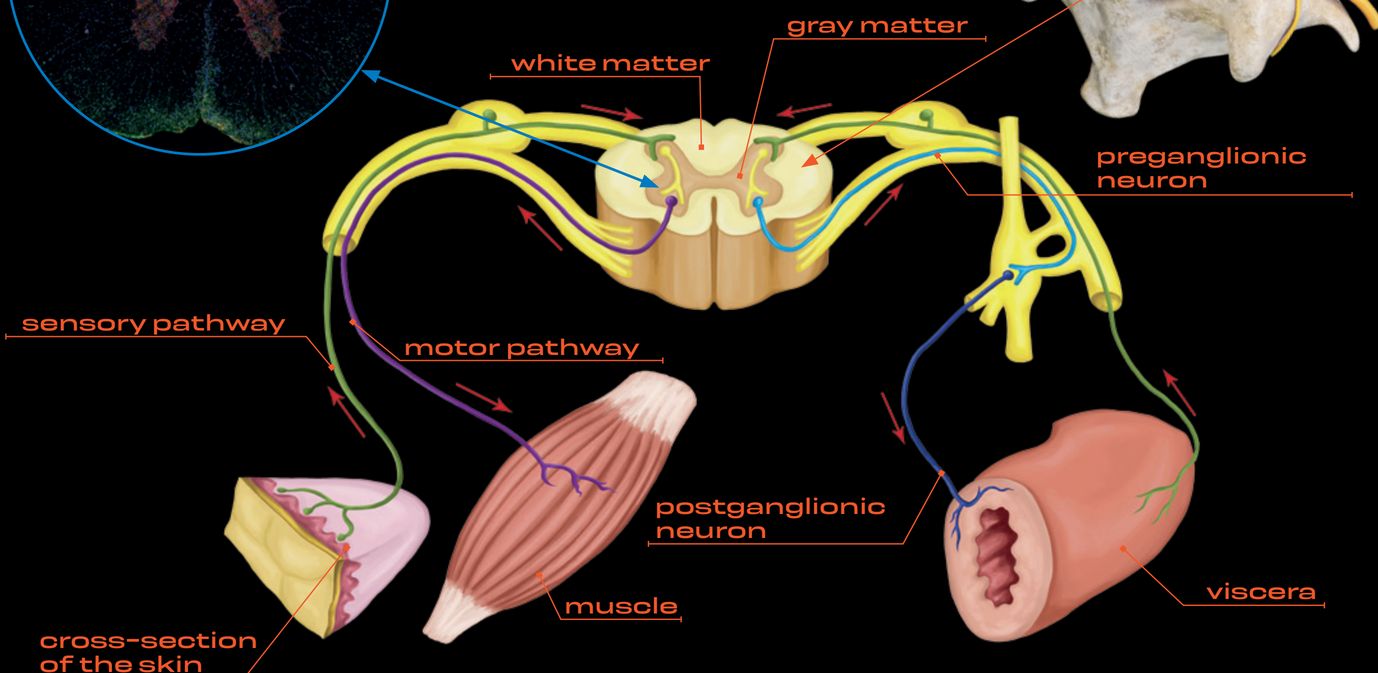
Kristýna Kárová

Cross-section

The spinal cord consists of gray and white matter. White matter is made up of nerve fibers that cluster into spinal tracts. Ascending (sensory) tracts carry information from various parts of the body to the brain, while descending (motor) tracts transmit signals from the brain to the muscles. Gray matter contains cell bodies of neurons where information is processed, and its shape resembles a butterfly.







The neural highway: the whole nine yards

The spinal cord extends from the base of the brain, continuing from the medulla oblongata, and runs through the spinal canal, ending at the first or second lumbar vertebra. It is encased in meninges and surrounded by cerebrospinal fluid. The spinal cord has 31 segments:
8 cervical (C1–C8), 12 thoracic (Th1–Th12), 5 lumbar (L1–L5), 5 sacral (S1–S5), and 1 coccygeal (Co1). Each segment corresponds to a specific region of the spine, with a pair of spinal nerves emerging from each segment.

When the spinal cord gets injured

Spinal cord injuries are categorized based on the location and extent of damage:

Tetraplegia – paralysis of all four limbs due to a cervical spinal cord injury. The higher the injury on the spinal cord, the more damage can occur.

Paraplegia – paralysis of the lower limbs and torso due to thoracic or lumbar spinal cord injuries.

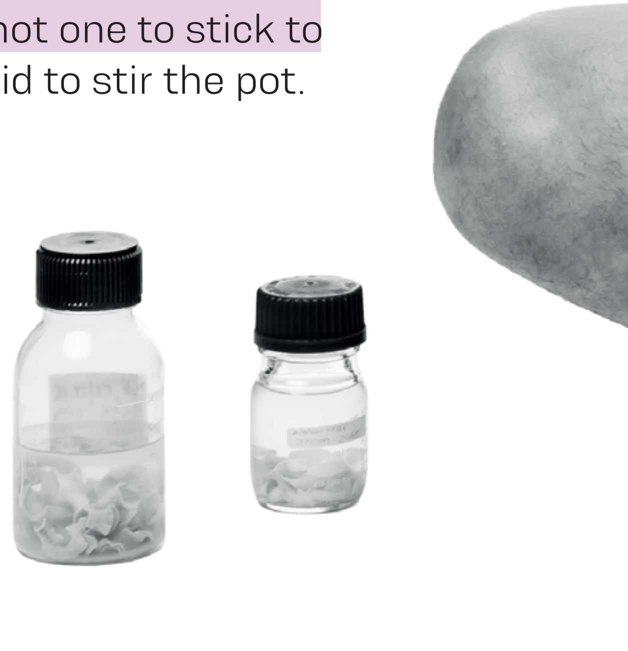
If a person injures their spinal cord above the fourth cervical vertebra, it results in paralysis of all four limbs, the diaphragm, and the torso and abdominal muscles. This condition is known as **pentaplegia**.

Partial loss of motor function below the level of the injury is referred to as **paresis** (e.g., paraparesis, tetraparesis).

Julius Lukeš

THE ENFANT TERRIBLE OF CZECH SCIENCE

Years ago, he inadvertently made a name for himself by swallowing tapeworm eggs, nurturing the parasite inside his body for years. He lives and breathes parasitology and is considered one of the world's leading experts in the field. Julius Lukeš is not one to stick to conventions, though, nor is he afraid to stir the pot.



Text: Radka Římanová \ Photo: Jana Plavec

Most people feel a bit nauseous at the thought of tapeworms, roundworms, or pinworms. What disgusts you?
Fools, communists, and other demagogues. But in nature, I haven't yet come across anything that would make me shudder with disgust. I think parasites are beautiful organisms. Surprisingly, they evoke a lot of revulsion and, more importantly, fear in people, even though the vast majority have zero personal experience with them. At least once a week, someone emails me in a panic, convinced they have a parasite, even attaching a photo of their stool for me to examine.

Sounds like you have quite the inbox...
To me, it's no different than if it were full of smiley faces. *(smiling)* I enlarge the image, study it, and form an opinion. But it's almost never a parasite. In fact, over the past fifty years, we've practically eradicated parasites from our intestines. And by doing so, we've actually done ourselves a disservice.

What do you mean? Were people better off with worms in their guts?
Not if their intestines were full of them, of course. A hundred years ago, parasites caused our ancestors a lot of trouble. They suffered from severe infections, and on top of that, they were exhausted from hard work in the fields or forests. In the winter, they lacked vitamins because they often only had potatoes, cabbage, and maybe the occasional apple to eat. But today's Europeans live very differently. In poor African countries, intestinal parasites are still a serious problem, but in Europe, most people have an abundance of food. So we can easily share that abundance with a worm or two.

But what good could such a tenant do us?
Believe me, it would give us much more than it would take. Various intestinal helminths and protozoa are our old friends. They've lived with us for millions of years, stimulating our immune systems. So they're not true parasites, but rather what we call commensals: they take something from us, but also benefit us in return. However, until recently, medicine viewed these organisms as something that didn't belong in the body and fought hard to eliminate them. That mission was successful, but over time, it's becoming clear that their eradication has likely caused more harm than good.

Will we be missing our old friends after all?
In many ways, yes. Modern science has linked the eradication of intestinal parasites with the rise of allergies, autoimmune diseases, and even certain disorders, like autism. Some diseases that were once rare are now common. For instance, while a general practitioner might have diagnosed one case

of Crohn's disease per year thirty years ago, now it happens much more frequently. It seems that these changes are linked to the simplification of our microbiome. The "zoo" in our intestines influences far more than we used to think it does.

"Many organisms, once considered parasites, are actually what we call commensals. They take something from us, but also benefit us in return."

Julius Lukeš

So, it would benefit our children to occasionally have worms again?

I believe so, yes. There's no reason to panic if helminths show up in a kindergarten, for example. Quite the opposite. Even pinworms can have a very positive impact on kids' immune systems.

And what about lice?

External parasites, or ectoparasites, don't bring us any benefits, so it makes sense to get rid of them. But that's not the case with pinworms. I wouldn't treat them at all. In today's context, efforts to eliminate them are completely counterproductive. It's similar to the annual outraged reports from parents about their kids getting diarrhea at summer camp. These dramatic news stories always amuse me.

But those affected kids are usually not happy campers...

Maybe not in that moment, but in the long run, both the kids and their parents should be grateful for the experience. For our super-obese population, an occasional bout of diarrhea is actually beneficial. Plus, being in nature gives kids the chance to expand their intestinal zoo a bit. It is during childhood that the microbiome is formed, so kids should spend as much time as possible outside, with animals, playing in mud... Teaching them to wash their hands before and after eating is, in my opinion, nonsense. During the pandemic, it made sense, of course. But otherwise, excessive hygiene is more harmful than helpful.

Can adults also work on improving their microbiome?

Certainly. For example, by eating a varied diet. People who live on canned food or eat just bread and butter every day simplify the microscopic world in their bodies. On the other hand, those who travel a lot and try local foods or frequently visit ethnic restaurants have a richer internal zoo, which positively impacts their health.

It seems that the diversity of one's microbiome partly depends on the size of one's bank account.

You're right. A Danish study confirmed this connection. Wealthier people do indeed have a more diverse gut zoo. However, even a rich person can have a disrupted microbiome. And "fixing" it isn't as simple as snapping your fingers. It's a long process. Unless, of course, the person gets the chance to undergo a fecal transplant.

A what?

It's a procedure where a patient receives stool with a healthy microbiome via an enema. It's mainly used to treat intestinal *Clostridium* infections, ulcerative colitis, or Crohn's disease. However, it's still a relatively rare procedure, primarily because it's logistically challenging. And donating stool isn't as uplifting an activity as donating blood, after all. But fecal transplants have been proven to save lives, so expanding stool donor databases is definitely something that should be done.

Does this mean there are fecal banks as well as blood banks?

Yes. The first one in the Czech Republic was established last year at Thomayer Hospital in Prague. They store hundreds of stool samples that can be administered to suitable patients when needed. By the way, in the USA, stool has even been granted the status of a drug that can only be administered by a doctor. This is because fecal transplants were being performed widely on the black market.

Can you explain why?

In recent years, the *Clostridium difficile* bacteria, which causes severe diarrhea, has spread significantly throughout the USA, killing tens of thousands of people every year. Fecal transplants are the best treatment for this condition, but for a long time, it was taboo among doctors. That's why the affected people started trying to procure the treatment themselves. It wasn't very safe, which is why legislation was changed to deter DIY procedures. Nowadays, if you were to just donate your stool for a transplant in the USA, you'd be committing a crime.

Let's go back to the situation at home... Isn't there a more elegant way to help patients with a damaged microbiome? Without involving excrement?

We don't know how just yet. But I believe that in the future, it will be as simple as swallowing a pill containing worm eggs, which will take care of everything in the intestines. Clinical trials in this direction are ›

"A clever parasite won't kill its host, because it would die along with it. It drains the host in moderation to avoid cutting off its own source of sustenance."

Julius Lukeš

already underway in other parts of the world. The most important thing will be ensuring that the parasites can't reproduce inside the human body. Such pills could then be prescribed by doctors for certain intestinal diseases as well as various allergies.

Not all parasites have the potential to become heroes, though…

You're right. There are countless villains among them. For instance, protozoa of the genus *Plasmodium*, which cause malaria, are responsible for half a million to one million human deaths annually. They are the biggest parasitic killers on Earth. Trypanosomes are also archetypal villains. If you get *Trypanosoma brucei* or *Trypanosoma cruzi*, you either die or suffer severe lifelong consequences. Trying to find any good in these organisms would be a bit perverse. In their case, the goal of parasitology is clear: to prevent them from harming people.

And are we succeeding?

Scientists have been trying to develop an effective malaria vaccine for fifty years. Only now have vaccines developed by British researchers shown promising results. In contrast, the fight against sleeping sickness has taken a turn for the better thanks to a new Franco-Swiss drug. While hundreds of thousands used to die each year after being bitten by an infected tsetse fly, today it's only around a thousand people. That is a huge success.

I heard you have personal experience with the tsetse fly.

Yes. A colleague once needed to take detailed photos of it, so I let the fly "pose" on me. It bit me, and all I could do was hope it wasn't infected. In hindsight? Not my brightest idea. But I sometimes do things like that. I have a hands-on approach to everything, including parasites. I'm definitely not the only one – this used to be a fairly common practice in my field. Occasionally, you deliberately infect yourself with something so you can study its effects on your own body.

> "People are really bothered by the idea of parasites living inside them. Yet, our bodies contain about three times more foreign cells than our own."
>
> *Julius Lukeš*

In what ways have you used yourself as a test subject?

I've hosted about ten different types of parasites. Mostly various protozoa, but also things like bird schistosome larvae. I once also ingested tapeworm eggs, which eventually grew into three several-meter-long worms. Unfortunately, I mentioned this on a talk show years ago, and ever since, people keep asking me about it.

No wonder! Hosting such creatures in one's body is not exactly common.

But it could be. The tapeworms lived inside me for quite a few years, and I practically didn't even notice them. I had no health issues. In fact, I'm convinced that it actually benefited my body, just like my other experiments with parasites.

So your tapeworms are no longer alive?

Unfortunately, no. A few years ago, during a Canadian expedition in the Caribbean, I was goaded into tasting the fruit of the manchineel tree, which is the most poisonous tree in the world. I didn't know that at the time. It wasn't until later that I learned that one in four people dies within 24 hours of eating this fruit. The tapeworms didn't survive, but luckily, I did.

It didn't affect you at all?

I felt pretty awful – I was vomiting and hallucinating, and there was a strong metallic taste in my mouth. But by the evening, my colleagues and I were already chuckling over the whole experience.

What does your wife think about these experiments?

She would just say, "no comment!" *(laughter)* She doesn't even try to talk me out of my ideas anymore. Thankfully, she doesn't have any exaggerated fears of catching something from me. But I think she does worry about me from time to time…

Aren't you ever afraid for your own wellbeing?

Not when working with parasites. But I do get scared, for example, when I'm traveling in the tropics with a driver who's falling asleep at the wheel or going too fast. People instinctively fear parasites and consider them dangerous, but then they jump into a car, weave through traffic, and overtake on hills without a second thought. In those cases, mere seconds determine whether something terrible will happen or not, yet people accept that risk. My experiments are much safer compared to the behavior of many drivers.

You must have quite a strong constitution.

It's true that I hardly ever get sick. Even with multiple exposures to COVID-19, I managed to avoid it. I'd say my strong immunity is related to the fact that, thanks to frequent travels and my experiments, I have quite a diverse zoo living inside my body. I also do 111 push-ups every morning when I wake up and I run a lot, though it's not as easy anymore, now that I'm over sixty. *(laughter)* On top of that, I've been practicing cold exposure for years. I started in 2014 – so before it became trendy – as part of my preparation for the Tara Oceans expedition to the Arctic, which mapped microscopic life in our oceans. Since then, I've made it a habit to stop by the river and swim against the current every morning on my way to work, basically no matter the weather.

Prof. RNDr. JULIUS LUKEŠ, CSc.
BIOLOGY CENTER OF THE CAS

Julius Lukeš studied parasitology at the Faculty of Science at Charles University in Prague. Since 1987, he has worked at the Institute of Parasitology at the Biology Center of the CAS, which he led from 2012 to 2022. Lukeš has also worked at universities in Amsterdam and Los Angeles and the Canadian Institute for Advanced Research in Toronto. His research focuses primarily on the molecular biology of parasitic protozoa and marine protozoa from the diplonemid group. He has published over 400 research articles and lectures at the University of South Bohemia. In recent years, Lukeš has been elected to several scientific organizations, including the American Association for the Advancement of Science (AAAS), EMBO, and in May 2024, the U.S. National Academy of Sciences, where he is currently the Czech Republic's sole representative.

You're known for wearing only T-shirts and shorts and often go barefoot, almost year-round. Do you always feel that warm?

Too many clothes have always bothered me, and this way, life is just simpler. Plus, when I wear pants, I tend to overheat. But I do recognize that there are limits, so I will wear long pants and shoes to classical music concerts or the opera. However, it's rare to see me in a suit. And I won't give up my animal-themed T-shirts, either!

I heard you choose them based on your mood.

That's right. In the morning, I peek into my closet and my mood decides for me. Apparently, my students held this belief that if I showed up on exam day wearing a shark on my chest, I tended to be tougher. But if I had a dolphin on my shirt, the exams were supposedly more relaxed. I'm not so sure about that, though.

Has your unconventional way of dressing ever gotten you into trouble?

A few times, yes. For instance, I was once escorted out of an honorary doctorate degree ceremony at the University of South Bohemia because of the dress code. The rector at the time asked me to apologize, but my dean told him the chances of that happening were about the same as being hit by a meteorite. *(laughter)*

Haven't you ever donned formal wear? Not even for your own wedding?

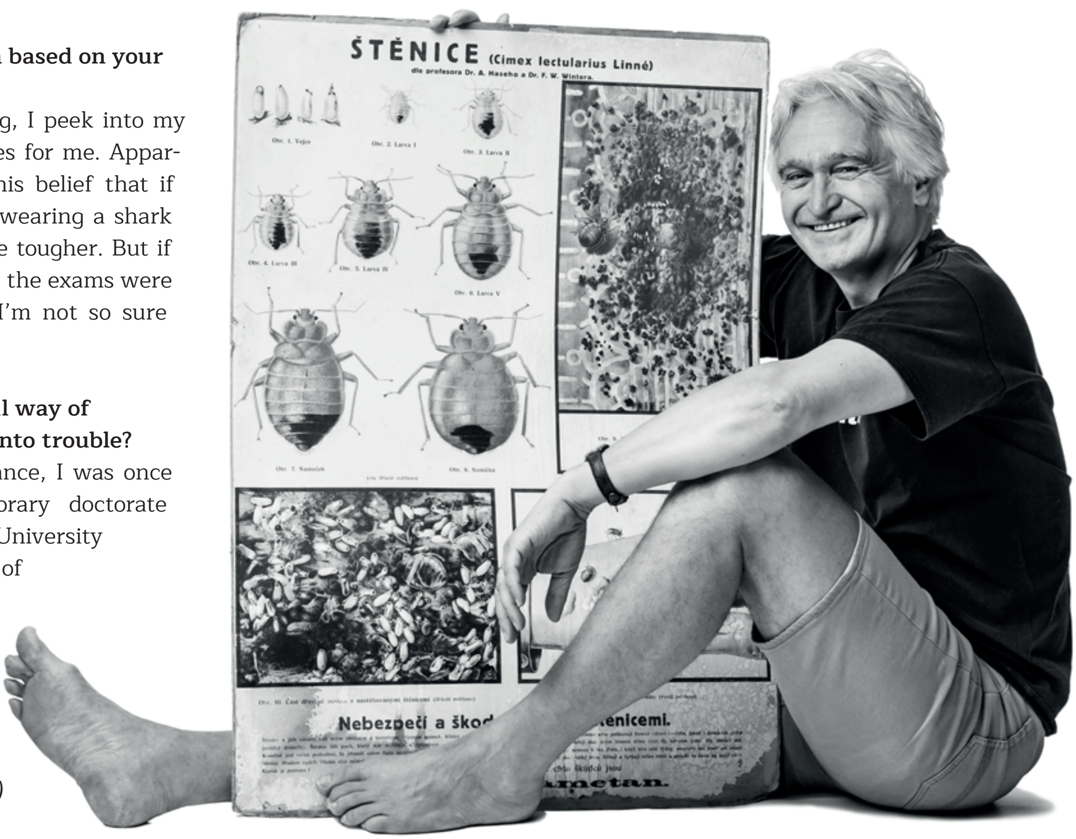
For my wedding, I did. I got married in 1989, and I've only been wearing shorts consistently for about the past twenty years. Before that, I would occasionally wear a pre-WW2 tailored suit inherited from a wealthy uncle. The last time I squeezed into a suit was in 2016 when I was invited to the Czech Lion Awards ceremony. My plan had been to run to the restroom right before going on stage and quickly change into shorts, but my wife vetoed it. It could've been pretty funny, though.

One could say you're somewhat of a provocateur.

I guess, but to me, it's not about seeking attention. It's more of a resistance to authority, something my father instilled in me. I grew up in Czechoslovakia during the height of socialism, and the authorities of that time were tragically laughable. I felt the need to push back against them, and that's likely stuck with me since. My dad also advised me to always take a different path than the majority, and I've taken that to heart.

So you swim against the current not just at dawn in the Vltava River... No wonder some of your colleagues call you the enfant terrible of Czech science. Does that label fit you?

Maybe in the past, but I'm much calmer nowadays. The years have sort of "mellowed" me. *(laughter)* Even on expeditions, I don't do as many crazy things and don't take as many risks as I used to. I've traveled to 111 countries, and my experiences ›



> **"Modern science has linked the eradication of intestinal parasites with the rise of allergies, autoimmune diseases, and even certain disorders."**
>
> *Julius Lukeš*

have taught me to recognize warning signs and avoid unnecessary dangers. But I have enough wild stories from my travels.

Tell us...

In Gambia, for instance, they threatened to slit our throats open, and in Papua New Guinea, we narrowly avoided an ambush thanks to pure instinct... I also vividly remember a time in 2009 when, after a month-long expedition in Ecuador, I was supposed to fly to Canada. I didn't realize until I was at the airport that I had taken my other passport by mistake, the one without the visa. The situation looked dire, but I actually managed to smuggle myself onto the plane and eventually made it to Canada.

How? Did you sneak under the turnstiles like in the movies?

Exactly. They didn't discover it until we landed in Atlanta, and it caused quite a commotion, but the Academy had my back at the time. In fact, the Academy has helped me out of tight spots more than once during my career. I'm not one to dish out praise lightly, but I think it's one classy organization. It's apolitical, stable, and respected worldwide. And I'm not just saying that to curry favor with the popular science magazine the institution publishes. *(laughter)* I'm simply glad I work for the Academy, and I wouldn't change a thing.

Did you always know this was what you wanted to do? Were you drawn to science from a young age?

According to my mom, yes. In our family, the butcher's trade had been passed down for two hundred years, but since I always loved animals, it was clear I wasn't going to be slaughtering cows anytime soon. Nature fascinated me even as a little boy – I studied bugs, conducted experiments... When I was about seven, my mom and I were walking past the university in Olomouc, and apparently, I announced I wanted to study there. But I ended up on the other side of the Czech Republic, studying natural sciences in Prague.

Why did you choose parasitology?

Shortly after starting at uni, the word on the street, specifically Viničná Street, in the student pub called Uterus, was that the Department of Parasitology had a liberal environment and good professors who didn't spew communist hogwash. Plus, its study program offered the chance to travel to tropical socialist countries, which intrigued me. Once I got the chance to check out the department, I found out this was all true, so I stayed. My classmates and I were incredibly passionate about our studies and pushed each other constantly. That's how I realized just how fascinating parasites are.

How many species of parasites are there in the world?

Millions. Every free-living multicellular animal species has more than one parasite. In fact, parasitism is the most common "lifestyle" on this planet. Tapping into someone else's energy and letting them take care of everything is simply more advantageous than having to secure all of life's necessities on your own. This strategy is so attractive that many originally free-living organisms have gradually resorted to parasitism.

How is it that a primitive parasite can outsmart a much more complex organism and feed off it so easily?

There's no simple answer to that. Each parasite has found its own way. Parasites don't have one single, unified tactic. Their only common

denominator is that they live at someone else's expense. To do so, they've developed various methods over millions of years – many of which are so ingenious that scientists have been trying to copycat them for years.

A TRUE BUG MIRACLE

In 2023, Julius Lukeš's team succeeded in isolating a previously unknown type of parasite related to trypanosomes from a true bug found in the Český ráj region, which managed to develop a unique mechanism for encoding its genetic code. The researchers decoded the genome of this protozoan and described how this deviation occurred. The discovery, which made it to the cover of *Nature*, could potentially aid in the treatment of certain human genetic disorders, such as cystic fibrosis. "We could 'repair' a whole range of currently incurable conditions using the mechanism this protozoan has devised," Lukeš explains.

What are some examples?
Take a tick, for instance. When a tick latches onto us, it needs to go unnoticed, so it injects substances that reduce pain and inflammation. A leech, however, doesn't want the blood it is sucking from its host to clot in its mouth, so it produces anticoagulants. All these substances can then be extracted and used for medical purposes.

Medicine has a lot to learn from parasites, I see…
Absolutely. Studying the biology of parasites can be of great benefit to medicine. Recently, we discovered a previously unknown parasite related to trypanosomes that has altered its genetic code in a unique way. We described how this deviation occurred, which could potentially be used to treat certain currently untreatable genetic diseases in humans. Thanks to a trypanosome from a common bug we caught in the Český ráj region, medical textbooks may need to be rewritten.

You have a particular fondness for trypanosomes, don't you?
They're my "darlings." I've studied them for most of my life, and they've been a constant throughout my career. About every five to ten years, I switch research topics and dive into something new, but I always find my way back to trypanosomes.

In other words, you take a little scientific "detour" every few years?
You could say that. In science, it's called a "lateral shift," and not many researchers take these detours since they're quite risky. In a new field, no one knows you, you have to convince your colleagues that it's not just some superficial whim, and above all, you need to secure funding despite basically being a newcomer. There's always a chance you could hit a dead end. But I have this restlessness inside me, which compels me to take the risk now and then.

> "I'm much calmer nowadays. The years have sort of 'mellowed' me. Even on expeditions, I don't do as many crazy things and don't take as many risks as I used to."
> *Julius Lukeš*

What are you working on now?
Lately, I've been fascinated by alternative genetic codes. But I always try to work on several things at once because I make better progress with some of them than with others. Besides the genetic codes, I've also been studying marine organisms called diplonemids, endosymbionts, which are bacteria living inside protozoa, and, of course, my darling trypanosomes. My colleagues probably see me as a bit of a shaker-upper, but it helps our, I'd say, decent productivity.

Do you plan to expand your scientific repertoire even further?
I'm tempted to, but I'm not sure if I'll manage another research "shift" before I retire. However, I want to continue my research at full throttle, as long as my health and mind allow it. And as long as they save me a desk somewhere in the corner at the institute. *(laughter)*

Do you ever find time to relax?
Of course! I enjoy nature, I run, I spend time with family and friends… I also love classical music. I played the piano for many years, but my imperfect playing resulted in me becoming a mere listener. I attend concerts, and my wife and I sometimes host musical performances at our house in České Budějovice for dozens of people. I also try to read something unrelated to science at least an hour every day to avoid becoming too blinkered. I particularly enjoy travel books, especially older ones.

In your emails, you always sign off with, "nazdáááárek Jula" [editor's note: byeeeee, Jula]. Do you actually have any attachment at all to the degrees that precede and come after your name?
None at all. Academic titles might play a role in the educational hierarchy, but in science, they're of little import. What matters is what a person has achieved in their field. When someone brandishes their professorships and doctorates, I lose interest. It's a waste of time during introductions. I just feel most comfortable as Jula. *(smiling)*

NO MAN'S LAND

Between March 1938 and September 1939, tens of thousands of Jewish men, women, and children struggled to survive in the forests, fields, and abandoned buildings on the borders of East-Central Europe, involuntarily inhabiting "no man's land" – a lesser-known chapter in the history of the Holocaust.

Text: Leona Matušková \ Photo: Shutterstock; Suzanne Steinberg's archive; United States Holocaust Memorial Museum, courtesy of Michael Irving Ashe; Jana Plavec; Lidové Noviny Press; Jewish Museum in Prague

On 17 April 1938, Aladar Reissner along with his 65-year-old mother, his young wife, and their two small children were awakened by the Gestapo. The family's passports had already been confiscated, and that night, Reissner was brutally beaten, called "Jewish swine," and forced to declare that "I have decided voluntarily to leave the country illegally going across the frontier." Like the Reissners, all Jews were expelled from the Austrian village of Kittsee in northern Burgenland near the Czechoslovak border. This occurred a mere few weeks after the Anschluss, which saw Austria annexed to Nazi Germany on 12 March 1938. The Gestapo transported the group by truck from Kittsee to the Danube River and, using fishing boats, sent them over to an island on the Czechoslovak side. "It was pitch dark. It was just about freezing, too. We had no coats. Some women were wearing nothing but nightgowns," Reissner later recounted to American journalist Hubert Renfro Knickerbocker in a news story on the first "no man's land."

WHAT ARE NO MAN'S LANDS?

"No man's lands emerged in 1938 along the borders of East-Central Europe. These were places of abandonment, immense suffering, and extreme exclusion," explains historian Michal Frankl from the Masaryk Institute and Archives of the Czech Academy of Sciences (CAS). Frankl is the author of the book *Občané země nikoho: Uprchlíci a pohyblivé hranice středovýchodní Evropy 1938–1939* (Citizens of No Man's Land: Refugees and Shifting Borders in East-Central Europe 1938–1939).

"For both those who got trapped in them as for border guards and humanitarian workers, these no man's lands came as a shock. They represented something that didn't belong in their vision of civilized Europe, and no one knew how to handle it. State officials lacked the language to describe these spaces," Frankl continues.

> "No man's land was no organized refugee camp; there were no guards to dictate roll calls or designate where the tents and kitchen should be. No man's land is a place where the state ceases to exist."
>
> *Michal Frankl*

Everyone turned a blind eye to the existence of no man's lands and washed their hands of responsibility. "German guards would open the gate and we were to quietly walk across the no-man's land into Poland," James Bachner recalls about October 1938 in his book *My Darkest Years: Memoirs of a Survivor of Auschwitz, Warsaw, and Dachau*. The Polish border guards refused them entry, coming out of their guardhouse with weapons drawn. The Germans behind them, meanwhile, had dogs and fired warning shots into the air.

The fifteen-year-old Berlin native, James Bachner, with Polish roots, was one of approximately 17,000 Jews living in the German Reich deported by the Nazis to the eastern border during the Polenaktion (Polish Action) at the end of October 1938.

CITIZENS – BUT ONLY PROVISIONALLY

Stories similar to those experienced by Aladar Reissner at the Austrian–Czechoslovak border and James Bachner at the German–Polish border also transpired between the Sudetenland and the Czech inland areas after the Munich Agreement (September 1938) and at the Czechoslovak–Hungarian border following the First Vienna Award (November 1938).

These forced relocations affected tens of thousands of Jews, many of whom lost their passports and citizenship. For instance, both James Bachner and his brother were born in Berlin after World War I, but their parents were from Poland, and thus the whole family held Polish citizenship. As "foreign elements," the Nazis expelled them en masse, yet Poland did not want to allow its own citizens into the country either.

In March 1938, the Polish parliament hastily passed a law stripping many Poles living abroad of citizenship. Czechoslovakia began its own revision of citizenship in January 1939, targeting especially people from the Sudetenland. Both measures

Around 60 refugees had to survive for several months on a towboat on the Danube River.

stemmed from the fear of Jewish citizens returning to their home countries.

"We can see this revocation of citizenship as a form of metaphorical no man's land," Frankl notes. Jews lost their status as Polish or Czechoslovak citizens without gaining citizenship elsewhere, leaving them stateless and unprotected.

Curiously, the revision of Czechoslovak citizenship remains a relatively unexplored chapter of modern history. "Neither historians nor legal scholars have delved deeply into it, even though it's a significant event that highlights an ethnocentric shift in the construction of citizenship," Frankl says. The harsh measure was hastily prepared, poorly formulated, and inadequately explained, leading to much confusion and uncertainty.

"The Provincial Office in Prague, by a decree dated 9 June 1939, No. 11268 of 1939, refused to grant the following under Section 5 of the Government Regulation of 27 January 1939, No. 15 Coll.; the confirmation of citizenship of the Protectorate of Bohemia and Moravia to Irma Kleinová, a teacher," reads a brief official notice, now preserved in the National Archives of the Czech Republic.

We do not know how many of the (up to) 30,000 Jews from the border regions who were required to apply for the revision of Czechoslovak citizenship shared a similar fate to the above-mentioned teacher. Overall official figures are not available because the Protectorate authorities quietly halted the review process after one year. "The Nazis insisted on its termination – not to protect Jews, but because they were questioning the Protectorate's sovereignty and its authorities' right to decide on citizenship," Frankl explains.

Mgr. MICHAL FRANKL, Ph.D.
MASARYK INSTITUTE AND ARCHIVES OF THE CAS

Michal Frankl studied political science and modern history at the Faculty of Social Sciences, Charles University (Prague). From 2008 to 2016, he worked at the Jewish Museum in Prague, and since 2016, he has been working at the Masaryk Institute and Archives of the CAS. He has completed fellowships at the Vienna Wiesenthal Institute for Holocaust Studies, the US Holocaust Memorial Museum, and the JDC Archives. Along with Miloslav Szabó, he co-authored *Building a State Without Antisemitism: Violence, Loyalty Discourse, and the Creation of Czechoslovakia* (2015), and with Kateřina Čapková, he co-wrote *Uncertain Refuge: Czechoslovakia and Refugees from Nazism, 1933–1938* (2008). In 2023, with the support of the Czech Science Foundation, Frankl's book *Citizens of No Man's Land: Refugees and Shifting Borders in Central-Eastern Europe, 1938–1939* was published.

A TOWBOAT ON THE DANUBE RIVER

The Reissner family, along with other Jews from Kittsee, spent one night on the Danube island. The next day, Czechoslovak police officers sent them towards the point where the borders of Czechoslovakia, Austria, and Hungary converged. "We had to go slowly on account of the old ones, who kept collapsing. And I had to carry my 4-year-old, while my wife carried the littlest one," the young father recalls in the report by the US journalist.

The following night, the Hungarian side sent the group back to Czechoslovakia in the same manner, and the scenario repeated for another three days and nights. The elderly were no longer able to walk, the younger ones' feet were bleeding, and the children were feverish. Paradoxically, the area where the three borders met and where the group kept wandering back and forth was within sight of their home village.

Upon hearing of the situation, members of the Jewish Orthodox community in Bratislava provided assistance to the exhausted Burgenlanders. They rented a tow cargo boat owned by a French shipping company for the refugees to move into. The (Jewish) director of the shipping company, a local, had the boat equipped with straw mattresses, pillows, blankets, and lanterns.

The boat was docked on the Hungarian side of the Danube, connected to the shore by a gangplank guarded by the gendarmerie. Key aspects of care were handled by Jews living in ›

> "People left abandoned in no man's lands – whether in fields, forests, a crumbling mill, or a rusty barge on the Danube – endured real physical suffering. But they also experienced immense psychological strain, having been forced out of their homes, uncertain of what the future held, burdened with a profound sense of exclusion."
>
> *Michal Frankl*

Bratislava, while food and daily necessities were supplied by Jews from a nearby village.

"This story illustrates how no man's lands were created not by decisions made by states, but by refugees wandering along the border. They became unintended spatial manifestations of violent expulsions and the merciless closing of borders," the historian notes.

The presence of the boat with refugees attracted attention, possibly because it was the first such case. Both humanitarian workers and journalists took an interest. However, the people on the barge felt forgotten and excluded from society, becoming persons without names or identities.

There were few options how to help the displaced. They could not return home, and neighboring countries refused to accept them. The only solution was to emigrate off the continent, which was impossible without documents. Regardless, humanitarian workers attempted this nearly impossible goal. After much negotiation, they managed to gradually transport all the boat's inhabitants away, with the last group leaving in September 1938. Some succeeded in emigrating to Palestine, others to South America, and many to the USA – like the family of Aladar Reissner.

IN-BETWEEN POLAND AND GERMANY

The case of the Danube boat is exceptional. It was the first of its kind, receiving much attention, and due to the relatively small number of people involved (approximately sixty), almost all were saved. Unfortunately, most of the tens of thousands of Jewish refugees did not have such luck.

View of the flour mill in Zbąszyń, which served as a refugee camp for Jews expelled from Germany.

The largest no man's land was the town of Zbąszyń, located on the Polish–German border before World War II. From the evening of 28 October 1938 until the following afternoon, seven trains carrying about 3,000 involuntary passengers arrived at the local railway station. The waiting rooms and platforms were filled with exhausted refugees, with more arriving later. Many other arrived after long marches and tense time spent between the border lines.

The detention of thousands of Jewish refugees in Zbąszyń, a town with 5,000 permanent residents, initially intended to last only a few days, stretched to ten months. Some found shelter in former stables near the barracks, others in a multistory building of an old mill, and those with some means rented out rooms with local families.

Some managed to break through the blockade and reach the Polish interior to stay with relatives, gradually reducing the number of refugees in the town. In the summer of 1939, the Polish government decided to end the blockade, and the last refugees left just before 1 September, as Germany's attack on Poland marked the beginning of World War II.

The subsequent fates of the Zbąszyń Jews intertwined with the fates of other Jewish populations in Poland, with many perishing in concentration and extermination camps. The few surviving testimonies of Zbąszyń come mostly from children who were saved through the Kindertransport rescue operations to Great Britain.

TEREZÍN AND IVANČICE

Later recollections helped reconstruct events after the Munich Agreement along the borderlines between the Sudetenland and the Czech interior. Further "spatial traps," which were difficult to escape from, appeared near Břeclav in southern Moravia, between Lovosice in Sudetenland and Terezín in Czechoslovakia, and in other places.

Gerard Friedenfeld, the son of a local merchant, along with his mother and a hundred other Břeclav Jews, found themselves "abandoned" by an unfinished concrete road just outside their hometown. He remembered the forests lining the border well from early childhood, associating them with outings with his parents when they would go wild strawberry picking. Suddenly, the same area had transformed into a brutal, hostile, uninhabitable place.

It was mid-October. The nights were already cold, and entire families were sleeping by the roadside within sight of their own town, with German and Czech guards exchanging gunfire over their heads. For three days, the groups hid behind pieces of furniture they had brought with them. This was just one of at least three no man's lands around Břeclav – others were located between Pohořelice and Dolní Kounice.

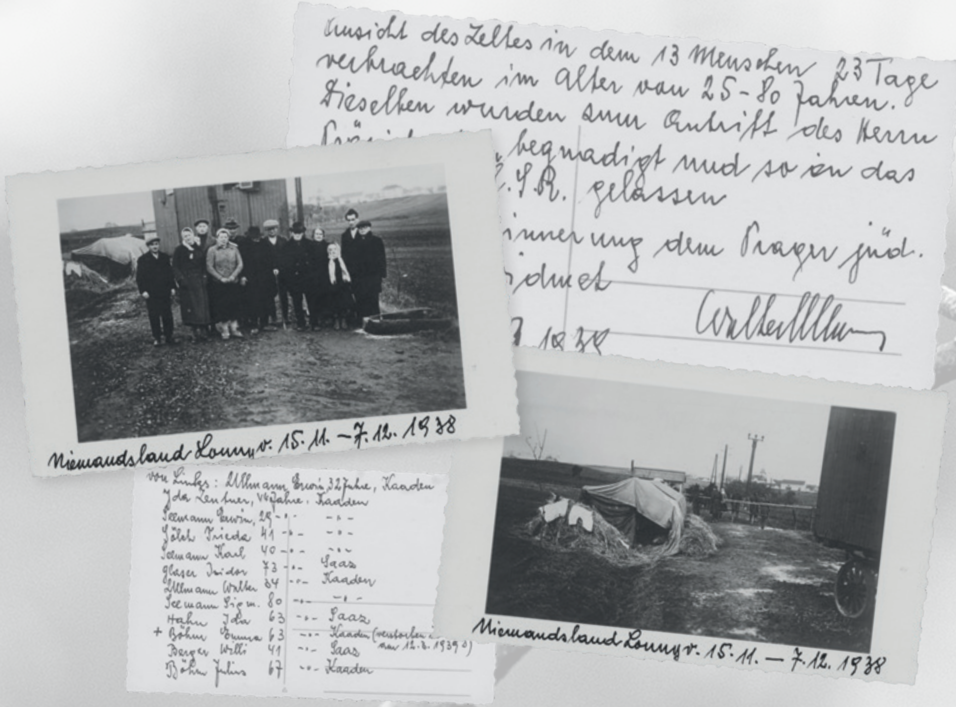
In November, additional no man's lands appeared in western and northern Bohemia. Near a dirt road outside the town of Louny, which remained part of Czechoslovakia after Munich, a group of thirteen refugees from the Sudetenland scraped by for three weeks. An improvised shelter provided some relief, along with by a caravan delivered later by the Red Cross.

Stray groups from various places along the northwestern border between the Sudetenland and Czechoslovakia later found temporary refuge in the former fortress and barracks of Terezín. Refugees, particularly from southern Moravia, including Gerard Friedenfeld, were moved to Ivančice near Brno.

"Rooms are being prepared in the rear building of the former tannery for the Jews," notes the Ivančice chronicle entry from 8 November 1938. The facility was equipped by Jewish organizations from Brno – they had rusty machinery cleared out, the basement converted into a kitchen and laundry room, the first floor turned into a dining room, and the upper floors furnished with bunk beds.

By January 1939, about five hundred people were living in the Ivančice shelter. Their living conditions drastically worsened after the German occupation in the spring of 1939, when the Gestapo took over and turned it into a concentration camp.

Moments associated with the arrival of the Gestapo were recorded by Gerard Friedenfeld. "He describes an appell accompanied by humiliation. Along with other young men, he was forced to repeatedly climb a ladder and jump off it until he broke his leg. He then had to crawl to the infirmary on his own," Frankl says. The young man eventually survived the Holocaust thanks to the Kindertransports to Great Britain.



Photos and documents capturing the situation of refugees in the no man's land near Louny.

NO MAN'S LANDS TODAY

Groups of people wander through the swampy forested land along the Polish–Belarusian border. Belarusian border guards are urging them to cross into Poland, while Polish soldiers refuse to let them in. The old, the young, children, entire families. Desperate people who cannot go back or ahead, trying to overcome barbed wire to reach safety.

But it is not 1938 or 1939. This is the current situation of the last few years, months, and days. Refugees from the Middle East, Afghanistan, Pakistan, northern and sub-Saharan Africa, all trying to cross the tightly guarded borders of (not only) the EU. No man's lands are not a thing of the past.

"This situation didn't start in 2015 with what is called the migration crisis. Similar situations were already occurring before, sometimes even in the very same places decades ago. History never repeats itself exactly, but events are often similar in many aspects, allowing us to think in broader contexts," Frankl notes.

While writing the book *Citizens of No Man's Land*, Frankl visited the tri-border area between Slovakia, Hungary, and Austria. Today, finding the exact spot where the boat of Burgenland exiles was moored in 1938 is impossible, as the landscape has changed (partly due to the construction of the Gabčíkovo–Nagymaros waterworks). However, its genius loci is still evident, the area dotted with memorials which, however, pertain to the Iron Curtain and its dismantling in 1989. Memories of this short but crucial period for Holocaust history have been overlaid by additional layers of events.

"Right at the border tripoint stands a stone memorial from the 1990s. It's a bit worn now. Even though the borders are open, the Austrian army occasionally patrols the area. The border has taken on a new, different kind of symbolism," Frankl concludes.

We usually view borders between states as fixed lines drawn on a map. However, they tend to change and shift, with states competing and sometimes even going to war over them.

But do borders represent a wall behind which all dialogue ends? Can a state renounce responsibility for events just beyond its borders? Should a nation-state consider borders through isolationism? Looking at the events of 1938 and 1939 along Europe's ever-shifting and uncertain borders offers us the opportunity to consider our current and future challenges in a broader context.

APPLES FROM PARADISE

A / Magazine 2024

Text: Markéta Wernerová \ Photo: Jana Plavec

STŘÍŽOVICE APPLE BREEDING STATION

An apple a day keeps the doctor away – and we can't help but agree. There aren't many research facilities where you can enjoy the fruits of their labor right from the source. In this case, from their very own apple orchard. We find ourselves in Střížovice in the Bohemian Paradise region at the Station of Apple Breeding for Disease Resistance, which is part of the Institute of Experimental Botany of the CAS. For almost 70 years, the experts at Střížovice Station have dedicated their efforts to breeding apple varieties resistant to pathogens, especially scab, powdery mildew, and fire blight – the most significant apple diseases. Their results are, without exaggeration, "shooting for the stars."

TINSMITH TURNED APPLE BREEDER

"The history of this station dates back to 1955 when tinsmith and fruit grower enthusiast Otto Louda decided to establish an experimental station in his native village Střížovice in cooperation with the Biological Institute of the Czechoslovak Academy of Sciences," says Jan Zima (pictured right) from the Institute of Experimental Botany of the CAS while harvesting apples. Louda is the "father" of the well-known varieties Rubín and Šampion. Shortly after founding the station, he was joined by the talented scientist and apple enthusiast Jaroslav Tupý. In 1966, they began breeding apples for resistance to scab. In time, local experts also turned to combating powdery mildew and fire blight. A resistance to pathogens allows for the use of chemicals in orchards to be significantly reduced, thereby lowering costs, producing healthier fruit, and protecting the environment. Thanks to these efforts, the Střížovice apple varieties have garnered great interest from growers from all over the world.

ATTRACTIVE POLLINATORS

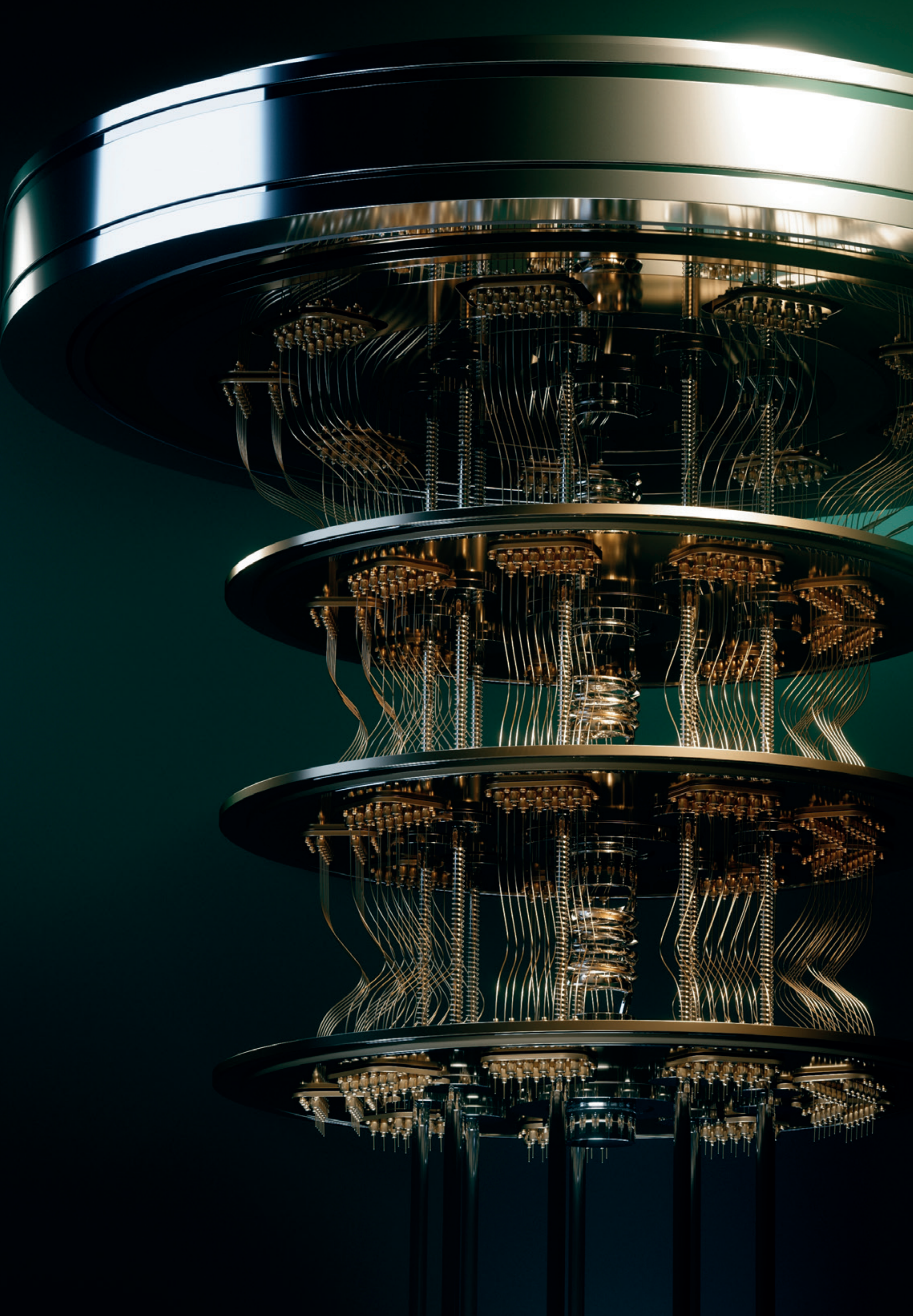
The orchard is also home to varieties with unusual appearances. They are naturally slender (columnar) and require minimal pruning. The original mutation for this growth type was discovered in Canada in the McIntosh variety. Research at the Střížovice Station focuses on two main areas: columnar table varieties, particularly suitable for home gardens, and universal pollinators/ornamental varieties with small inedible fruits intended for pollination purposes. “A slim pollinator takes up less space in the orchard, and more principal trees mean higher yields per area unit,” explains Dimitrij Tyč, deputy head of the station. The variety pictured below is disease-resistant and highly attractive especially when in bloom, but its fruits are not suitable for consumption.

FROM ORCHARD TO LAB?

"These days, the taste of the apple alone is not enough for our commercial partners. The competition is fierce," Tyč (pictured right) explains. Modern breeding relies on various measurable lab parameters. "Key factors include appearance, taste, flesh texture, firmness, sugar content, allergen content, and storability," adds Jan Zima Jr. (pictured below). If a new variety's traits closely match current market demands and trends or offers some added value, it has the potential to succeed regionally or even globally. And so you might end up taking a bite out of an apple of a Střížovice variety, imported by a retail chain from as far away as South Africa – as is being considered for the Bonita variety, mainly aimed at the European market, particularly the UK.

SPACE APPLES

Collaboration between breeders in Střížovice and global apple market traders has led to an unusual achievement. The fame of the Opal® variety has transcended not only our country's borders, but our planet's, too. In 2015, these goldenyellow, crisp, honey-sweet apples bred in Střížovice found their way to the International Space Station (ISS), making them one of the few Czech non-technical results of science and research to reach space. The variety has gained widespread global popularity, not only for its taste and texture, but also for its excellent disease resistance, aligning perfectly with modern environmental approaches to improving sustainable, eco-friendly food production and quality of life.



Text: Leona Matušková \ Photo: Shutterstock, Jana Plavec (2)

OUTSIDE THE BOX

The trial-and-error method has long been the modus operandi for developing stronger and more flexible metallic materials. Computational technology has greatly accelerated and simplified their advancement. However, even the most powerful computers have their limits. Materials physicist Martin Friák sees the future in quantum computing, which holds the key to overcoming these obstacles.

During ancient times, blacksmiths were not just craftsmen – in villages, they often also acted as dentists or horse healers, and in some places, people even regarded them as protectors against evil spirits or sorcerers. After all, blacksmiths could "work magic" with fire, transforming the shape of metals and modifying their properties.

Until recent times, the "alchemy" of working with metal alloys was still very much alive. Metallurgists would prepare up to hundreds of experimental samples with different combinations of elements, and other specialists would then measure and test their properties. This conventional process was relatively time-consuming, expensive, and inefficient. With a bit of luck, it occasionally resulted in brilliant, innovative materials, but more often than not, the experimental samples ended up in the trash.

LIKE LEGO BRICKS

The advent of computational modeling, which saw a boom in the late 20th century, helped reduce the number of unsuccessful experiments. It's no longer necessary to produce large numbers of experimental samples as before, since theoretical materials physicists can now model substances on a computer to identify the most promising ones. Only those then make it to the experimental stage. This has streamlined the entire development process for new materials.

"In modeling, we 'build' matter atom by atom, like LEGO bricks. Our methods are very reliable and precise. With today's supercomputers, we can calculate systems containing hundreds of different atoms," explains Martin Friák from the Institute of Physics of Materials of the Czech Academy of Sciences.

However, nanoparticles, which are used in medical science or for hydrogen storage, can consist of hundreds of thousands of atoms. Currently, not even the most powerful supercomputers in the world can accurately calculate and determine the properties of such materials of the future, including those that could be used in

Mgr. MARTIN FRIÁK, Ph.D.
INSTITUTE OF PHYSICS OF MATERIALS OF THE CAS

Martin Friák studied solid-state physics at Masaryk University in Brno. After completing his doctoral studies, he spent 11 years working at institutes within the Max Planck Society: first as a postdoc researcher in Berlin, then as a research group leader for eight years in Düsseldorf. In 2013, he joined the Institute of Physics of Materials, thanks to the J. E. Purkyně Fellowship awarded by the CAS. Friák, who specializes in quantum-mechanical computations and their application in computational materials science, is internationally recognized as an expert in theory-guided materials design.

a circular economy – a topic of great interest to Friák.

Materials scientists are often at the forefront of creating substances which offer not only advantages and improvements, but also sometimes burden the environment. Circular economy principles, which allow for the reuse of existing materials, could help reduce their ecological footprint.

"The issue is that such materials are often heavily contaminated with a large number of foreign atoms. We're talking about systems containing thousands of atoms. To correctly determine their properties and prepare them for reuse, you need substantial computational power," the physicist notes.

To a certain degree, the theoretical materials physics community has accepted the limitations of current computational technology. "There's this mindset of 'We have to work with these limits, we'll think inside the box.' I find that a pity. When I learned about the possibilities offered by quantum computers, I realized that they could help us break out of this age-old 'box,'" Friák explains.

> "In modeling, we 'build' matter atom by atom, like LEGO bricks. Our methods are very reliable and precise. With supercomputers, we can calculate systems containing hundreds of different atoms."
>
> *Martin Friák*

That is why he has decided to devote at least the next few years to developing software for quantum computer-based calculations of new materials. The Academy supported his vision in 2023 with the Academic Award. The grant of 30 million CZK distributed over six years will allow him to assemble a multidisciplinary team, purchase new hardware, and, most importantly, focus on his research.

WHAT IS A QUANTUM COMPUTER?

When most of us think of a computer, we picture a monitor and a keyboard. You might have even come across a supercomputer center, which looks like a large server room full of cabinets with cables and blinking lights. But what does a quantum computer look like?

A quantum computer is about the size of an American-style refrigerator – bigger than a conventional computer, but smaller than a supercomputer. However, the real difference lies in the way it functions. Quantum computers work on entirely different principles than classical computing. They harness the unique laws of the quantum world which differs significantly from the world we perceive with our own senses.

When we flip a coin in the real world, it lands either heads or tails. In the quantum world, we get a probability of either outcome. Both values can even exist simultaneously in a state of superposition. Although difficult to explain in everyday language, most scientific journalists and popularizers simplify this by saying that in the quantum world, heads and tails can occur at the same time.

In classical computing, we work with bits, which are either represented by 1 or 0. In quantum mechanics, we use qubits, which can exist in a superposition of their two fundamental states – simply put, they can be both 1 and 0 at the same time. Of course, the reality is much more complex, involving mathematical concepts like combinations and probabilities. Quantum computing actually takes into account the probability of a particular state occurring.

Nobel Prize laureate Richard Feynman explained superposition by breaking a piece of chalk in half and placing each half on opposite sides of a table. He then asked, "Where is the chalk?" The answer, in quantum terms, is that it's on both sides of the table at the same time. According to Feynman, it's impossible to explain quantum electrodynamics in just a few sentences – otherwise, it wouldn't be worthy of a Nobel Prize.

QUANTUM COMPUTING IN THE CZECH REPUBLIC

The leader in quantum computer development is the American tech company IBM. In 2019, they introduced the first commercial quantum system with a capacity of 20 qubits, and by 2021, this capacity had increased to around 127 qubits. Until recently, IBM allowed users, such as the scientific community, to experiment with their developed ›

THE FIRST QUANTUM COMPUTER IN THE CZECH REPUBLIC

One of the first six quantum computers in Europe will soon be operational in the Czech Republic – at the IT4Innovations national supercomputing center in Ostrava. It will cost seven million euros, half funded by the European Commission, with the rest covered by LUMI-Q consortium members (Finland, Sweden, Denmark, Poland, Norway, the Netherlands, Germany, and Belgium), with the Czech Republic coordinating the initiative. The quantum computer will be based on superconducting qubits with a star-shaped topology and have at least 24 qubits. It will be directly connected to the Karolina supercomputer, with plans for integration into other supercomputer systems, such as the one in Krakow. Unlike Karolina, which occupies 35 m^2, the quantum computer will require only about 4 m^2, plus an additional 20 m^2 for support technologies, including shielding from external vibrations and electromagnetic fields and measures maintaining near-zero operational temperatures.

algorithms on these quantum systems and their simulators.

"Unfortunately, as of 2024, we find ourselves in a difficult situation, since IBM is stepping away from this open approach. To be able to work on their quantum computers, we would now need to pay for a very expensive annual license," Friák notes.

Japanese firms and research institutions are also working on quantum tech, and progress in this domain is advancing at a rapid pace in China as well. Quantum algorithms are particularly useful in encryption and codebreaking, making it a highly sensitive field. The EU recognizes that it too must intensively work on developing these state-of-the-art systems.

ACADEMIC AWARD

The Praemium Academiae (Academic Award) is the highest financial support bestowed by the Czech Academy of Sciences. It is awarded to top scientists and is intended to foster the development of innovative ideas with the potential to advance their respective fields. Unlike other grants, it comes with minimal administrative requirements. It provides researchers with the funding needed to conduct research without the pressure to achieve specific results within a set timeframe – essentially, the freedom to explore. Martin Friák plans to use it primarily to expand his team and upgrade equipment, aiming to develop quantum-mechanical algorithms for quantum computers that will enable more efficient discovery of new materials.

When we flip a coin in the real world, it's either heads (0) or tails (1). But a quantum state can be both 0 and 1 or all possibilities between 0 and 1 – until measured. Then, it "collapses" into a definite state of either 0 or 1.

The good news for Czech companies and research institutions is that one of the first six European quantum computers is expected to start operating in 2025 in Ostrava at the national supercomputing center, IT4Innovations. "This is truly a huge success for our country. All academic researchers, and to some extent users from the private sector, will have access to the Ostrava quantum computer, provided they submit a meaningful project," Friák, who is also the Chairman of the IT4Innovations User Council, explains.

The Czech quantum computer is expected to have a capacity of at least 24 qubits. Compared to IBM, which currently operates a quantum computer that has at least 133 qubits, this may seem modest. However, even 24 qubits offer significant computational power. The quantum computer in Ostrava will be directly connected to the Karolina supercomputer at IT4Innovations, and there are plans to link it remotely to Europe's most powerful supercomputer, LUMI, in Finland, as well as to a new supercomputer being prepared in Krakow, Poland.

What will the Czech quantum computer look like? Imagine three large cabinets: the first a "refrigerator" housing the quantum chip, cooled to 14 millikelvins. The second cabinet will contain the compressor responsible for cooling, and the third will house the electronics that control the entire system, execute instructions, and measure the computations.

The aforementioned supercomputer, Karolina, occupies a total area of 35 m², while the new quantum computer will require just 4 m² for the machine itself, plus another 20 m² for supporting tech.

A RECIPE FOR EVERYTHING?

The internet abounds with myths claiming that quantum computers can solve practically all of humanity's problems – from curing cancer to "fixing" climate change. The truth is that while these technologies spark great hopes, their real potential still needs to be tested.

"Quantum computers may excel in a few specific areas, like prime number factorization. It's no wonder governments and intelligence agencies are extremely interested in them," Friák says. "On the other hand, we're still in the developmental phase, where we're searching for what we call quantum advantage. Research teams all over are working to identify areas where quantum tech will provide fast, accurate, and reliable solutions," the physicist adds.

Quantum computers will likely be used for specific types of tasks. In chemistry and pharmacology, researchers are testing their ability to model molecules, and in physics, their potential for developing new materials. Friák and his colleagues are currently designing and testing algorithms for quantum computing that could be applied in material science. For several years, they have been working on this with Aram Harrow's group from MIT.

"A PhD student on my team, Ivana Miháliková, is dedicated to this work. She's programming methods that we are developing together, simulating

"The theoretical materials physics community has accepted the limitations of current computational technology and works within these limits. I find that a pity. I believe quantum computers could help us break out of this age-old 'thinking inside the box.'"

Martin Friák

The theory-driven development of new materials is followed by their preparation and detailed structural analysis. Electron microscopy methods allow magnification almost down to the scale of individual atoms but require special samples (see image).

> Imagine a superconducting quantum computer as three large cabinets: the first is a "fridge" housing the quantum chip, cooled to 14 millikelvins. The second contains the compressor responsible for cooling, and the third houses the electronics that control the system, execute instructions, and measure the computations.

quantum computer operations, and testing whether the algorithms we're designing actually work," Friák explains, describing a collaboration funded by the MIT-Czech Republic Seed Fund, which has enabled Miháliková to travel to the USA several times.

MEDICINE AND ECOLOGY

It's not yet entirely clear how quantum computing will be utilized in material physics specifically. However, it's important to prepare for the coming quantum era. "My vision is that we won't stop at just coding software, but will use it to compute new materials," Friák says. "I hope and believe that by the end of this decade, once the Academic Award grant concludes, we'll already have functional advanced quantum computers that will align with the algorithms we're currently developing."

One potential application could be materials suitable for hydrogen storage, which could offer an alternative to today's battery storage systems. Quantum computing could also assist in the development of better solar cells for use in photovoltaics.

Another possibility is nanomaterials, which could be applied in medicine, particularly cancer treatment. Researchers are working on nanoparticles that could precisely target malignant tumors in the body and destroy them.

Friák's team is also focusing on developing new types of magnets, aiming to avoid those that contain rare-earth elements, both because of their environmental impact and the geopolitical implications, as China is currently the largest producer of these elements.

In their search for new magnets, they are experimenting with rearranging individual atoms in the crystal lattices of materials, a process that is very slow and inefficient without quantum calculations. One might even say it's a return to the good old trial-and-error method.

"Once I have a quantum computer and functional software, I'll be able to account for the complexity of the system and calculate the best possible material combinations," Friák adds.

QUANTUM MAGIC

It's probably safe to assume that quantum computers aren't magical, superpowered machines that will solve all our problems. Yet the lexicon of magic, sorcery, and fairy tales is often used in the media whenever quantum systems are discussed – perhaps due to the complexity of how they work, as well as the hopes they inspire.

Friák doesn't shy away from this comparison either. "For instance, when I was explaining to my kids that, in the quantum world, the clock can go in both directions at the same time, they were flabbergasted. Harry Potter, step aside! My kids actually enjoy hearing about my work – they think we do some kind of strange quantum magic."

TRASHED **FOOD**

According to the Food and Agriculture Organization, up to one third of the food produced worldwide is thrown out each year. What are the impacts of food waste, and how can we prevent it?

Since 2020, September 29 has been recognized as the International Day of Awareness of Food Loss and Waste. This day was declared by the UN to highlight the negative impacts of food waste and promote a better, more resilient food system. The modern world faced a food crisis as early as 2008, and our planet continues to struggle with similar issues today. The causes are numerous and interconnected: climate change, drought, soil degradation, rapid population growth, the energy crisis, and last but not least, the current geopolitical situation, particularly the war in Ukraine. World leaders are aware of the problem; some are trying to address it, while others remain passive. The scientific community is also engaged in the debate on how to tackle the situation, proposing various solutions, such as targeted gene editing of plants to ensure higher resistance to diseases and pests, which can lead to larger yields.

HOW TO FEED THE WHOLE WORLD

For political leaders to make informed decisions (like allowing the use of gene-edited crops), they need to have enough relevant information based on scientifically validated data. That is why various studies, surveys, and research efforts are conducted to provide such information. The Public Opinion Research Center (CVVM) at the Institute of Sociology of the Czech Academy of Sciences (CAS) conducts regular surveys among the Czech public. These surveys investigate people's attitudes towards food waste, their shopping and consumer habits, and what they perceive are the most pressing issues in this area.

"Food waste has very serious ecological, economic, and social impacts. Every year, approximately one-third of the world's food production is wasted, which amounts to about 1.3 billion tons. This quantity could feed up to three billion people," says Radka Hanzlová from the Institute ›

> According to the Food and Agriculture Organization, approximately 96 to 115 kilograms of food waste per year can be attributed to each European. More than half of this waste comes from households (thrown out food), while the remaining losses occur in production, processing industries, food services, and retail and wholesale sectors.

of Sociology of the CAS, who also focuses on this topic within the Foods for the Future research program of the CAS Strategy AV21. The program aims to contribute on a national level to ensuring a sufficient supply of quality food and on a global level to utilizing the potential of Czech science to help developing countries. It responds to one of the most important challenges of our time: securing food for the ever-growing global population.

Compared to other parts of the world (such as many African countries), Europeans live in relative prosperity. There is plenty of food (an excess of it, actually), and store shelves are fully stocked. This abundance is likely why Europeans are among the biggest food wasters. Each year, they collectively throw out food worth an astonishing 149 billion euros. However, [as of 2022,] the average inhabitant of the Czech Republic is also beginning to feel the crisis, especially in their wallets. The prices of fruit, vegetables, bread, butter, and other products are rising, and not just by small change.

Nevertheless, as Hanzlová points out, there are not enough conclusive studies and data available globally or in the Czech Republic, nor is there an exact methodology for measuring food waste and determining what to recognize as such. Therefore, most of the figures are only educated estimates. "Even so, the numbers are alarming," the sociologist adds.

WHAT DO CZECHS THINK

In 2022, the CVVM conducted several surveys to understand attitudes towards food waste in the Czech Republic. Respondents were asked to agree or disagree with various statements. The most common agreement, at 82%, was: "When I prepare food, I make sure to use everything I can." More than three-fifths of respondents agreed that "when they waste food, they feel guilty." The findings also show that for two-thirds of respondents, the deciding factor in whether to throw out food is its appearance or smell.

Regarding the appearance of discarded food, especially fruit and vegetables, researchers investigated how Czechs have it with buying imperfect produce. Twenty to thirty percent of the total quantity of fruit and veg doesn't reach consumers at all. A survey revealed that the Czech public isn't very supportive of "ugly" produce. At the same price, 65% of consumers would choose perfect-looking produce over imperfect specimens.

Just why do consumers prefer perfect produce? It is easier to clean and cut. When researchers asked why people might buy imperfect produce, the main reason was the belief that imperfections mean naturalness and that such products are not chemically treated. Respondents also believe that the appearance of fruit and vegetables in supermarkets is heavily influenced by EU and retail chain standards.

Questions about environmentally friendly food shopping and eating habits were also raised. For the Czech public, the price is clearly the most important factor when buying food, followed by the ingredients, while the packaging material is the least important. Approximately one quarter of respondents occasionally buy organic food at least sometimes and almost three-fifths compost at least sometimes, either in their garden or using brown bins for compost (food waste).

What else do people do that's good for the environment? Most often, they bring their own bags for shopping and recycle at home. However, they don't frequently use reusable produce bags or try to limit car trips (for shopping).

BY WHEN CAN WE CONSUME FOOD?

Do you know the difference between "best before" and "use by"? The expla-

EXPIRATION DATE VERSUS BEST BEFORE

Due to a common misconception, you might be throwing out food unnecessarily. If the label on a product says "use by," it should not be consumed after this date as it could pose a health risk. Such products cannot be sold in stores after their expiration date. This mainly applies to fresh foods – meat, fish, dairy products. On the other hand, "best before" indicates products that don't spoil quickly, have a longer shelf life, and can still be sold (clearly marked) after the date, and thus consumed. This includes items such as pasta, rice, cookies, and canned goods. 64% of respondents consume food after the "best before" date at least occasionally.

HOW TO REDUCE FOOD WASTE?

- PLAN MEALS & SHOPPING AHEAD. SHOP WITH A GROCERY LIST
- AVOID "BARGAIN" SUPERMARKET OFFERS
- BUY SEASONAL AND LOCAL PRODUCE
- STORE FOOD PROPERLY. FREEZE IF NECESSARY
- USE LEFTOVERS, COMPOST THE REST
- CHECK THE CONTENTS OF YOUR FRIDGE
- SHARE OR DONATE UNUSED FOOD
- UNDERSTAND THE "BEST BY" LABEL
- SERVE APPROPRIATE PORTION SIZES

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Radka Hanzlová graduated in sociology from the Faculty of Arts at Charles University. She works as an analyst at the Public Opinion Research Center (CVVM) of the Institute of Sociology of the CAS. Her research covers topics such as personal wellbeing, happiness, life satisfaction, the environment, climate change, consumption, and food waste. She has a personal connection to the issue of food waste, with its ecological impacts being the main reason she adopted a plant-based diet.

nation is in a separate box below. Most Czechs (73%) correctly understand the "use by" label. In contrast, the meaning of "best before" is less clear, with only 46% respondents understanding it correctly. In recent years, awareness of these terms among the Czech public is on the rise. Czechs are not alone; the same trend can be observed in other EU countries. It turns out that nearly one tenth of wasted food (8.8 million tons) is discarded because consumers don't understand the labels.

Further research indicates that about half of the respondents consider food waste a major problem, although many think there are more urgent issues to address. However, it's good news that only one in ten people don't see food waste as a societal problem. Research shows that it is indeed a global issue that needs to be addressed head-on.

Supermarkets are also trying to reduce food waste. For example, Lidl offers 'Waste Not' boxes of imperfect produce, Globus and Tesco have sections for items nearing their expiration date, and Albert offers a 30% discount under a 'help us not waste' initiative. What does Hanzlová think? "Every effort should be appreciated because food waste is still not a mainstream topic. I'm very pleased that such activities are on the rise. It's great because people can also save money this way."

So, how can we avoid wasting food? We don't need to wait for top-down regulations; everyone can start making changes themselves. "For me, it's essential to follow basic rules and guidelines to prevent waste. This includes planning grocery shopping, proper food storage at home, and cooking appropriate portions. I can't even remember the last time I threw food away," Hanzlová says. More useful information can be found on the website of the Czech project Zachraň jídlo, with which researchers from the Czech Academy of Sciences' Strategy AV21 also work.

Learn more about the Foods for the Future research program of Strategy AV21 of the CAS:

NEW LABORATORY TO CONTRIBUTE TO RADIOPHARMACEUTICAL PRODUCTION

What do you get when you combine nuclear physics, particle accelerators, and radionuclides? Effective radiopharmaceuticals aimed at treating cancer. Actinium-225, which holds great potential for treating small tumors and metastases, could soon be produced using technology developed by Czech scientists. A laboratory with unique equipment was opened on 18 June 2024 at the Nuclear Physics Institute of the CAS in Řež, near Prague. The opening ceremony was attended by Lutz Helmke, Managing Director of Eckert & Ziegler Radiopharma GmbH, Eva Zažímalová, President of the CAS, and other guests. “I’d go so far as to call it the laboratory of hope, as it brings hope to thousands of patients battling cancer, especially those for whom current treatment is difficult, if not nearly impossible,” said Czech Prime Minister Petr Fiala at the opening, highlighting the importance of integrating the research and the private sector.

THREE CAS SCIENTISTS ELECTED MEMBERS OF EMBO

Three CAS researchers have become new members of the European Molecular Biology Organization (EMBO), which promotes excellence in life sciences and brings together renowned scientists from around the world: Alena P. Zíková from the Biology Center of the CAS, Zdeněk Lánský from the Institute of Biotechnology of the CAS, and Leoš S. Valášek from the Institute of Microbiology of the CAS. EMBO consists of more than 2,100 distinguished scientists globally, 20 of whom are now based in the Czech Republic. Membership in EMBO is awarded to researchers who have achieved significant success in their fields.

LAUNCH OF TWO NEW DIOSCURI CENTERS OF EXCELLENCE

After Poland, the Czech Republic has become the second country to open Dioscuri Centers, established as part of a program initiated by the Max Planck Society. Two centers are hosted by the Institute of Physics of the CAS, led by spin caloritronics expert Helena Reichlová and nano-optics specialist Barbora Špačková. The third center is headed by developmental biologist Peter Fabian (Masaryk University). The official opening of the Dioscuri Centers took place on 17 May 2024 at the CAS headquarters and was attended by leading representatives from the Max Planck Society, the CAS, and both the German and Czech Ministries of Education.

NEW FUNGUS NAMED AFTER CZECH SCIENTIST

A team of mycologists from the Netherlands and Iran has discovered a new species of fungus that causes pulmonary disease in an Iranian patient with respiratory issues. The fungus was named *Aspergillus hubkae*, in honor of Czech scientist Vít Hubka from the Institute of Microbiology of the CAS. Over the past 12 years, Hubka and his colleagues have been involved in the discovery of nearly 100 new fungal species. *Aspergillus hubkae* belongs to the group of black aspergilli, commonly found in soil, air, and organic matter. However, some of the species produce carcinogenic toxins, which contaminate fruit, vegetables, and food produce.

FIRST CZECH PRESIDENT OF EMS, THE EUROPEAN MICROSCOPY SOCIETY

Vladislav Krzyžánek from the Institute of Scientific Instruments (ISI) of the CAS is the first representative from Eastern and Central Europe to have become President of the European Microscopy Society, which brings together scientists who focus on optical and electron microscopy as well as other advanced methods of sample imaging and represents the leading edge of this field in Europe. The committee he will chair is responsible for overseeing the society's operations, including decisions on bestowing the European Microscopy Awards (this year's award went to Tomáš Čižmár, who leads the Complex Photonics Lab at ISI CAS).

RADOMÍR PÁNEK AS HEAD OF EUROFUSION CONSORTIUM

In December 2023, Radomír Pánek, Director of the Institute of Plasma Physics of the CAS, was appointed to lead the European consortium EUROfusion, whose aim is to develop a fusion-based energy source. EUROfusion unites nearly 5,000 scientists from 193 research institutions, universities, and companies across Europe. With a budget of almost one billion euros, provided by the European Commission and EU member states, the consortium's mission is to coordinate a complex research program aimed at securing an emission-free, inexhaustible, and safe energy source for Europe using thermonuclear fusion.

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