A MAGAZINE

Czech Academy of Sciences



TOXIC

2026

Lurking everywhere: From parchment paper to functional textiles

On aliens, insomnia, and the origin of life on Earth

How to master a foreign language

Lightning on Jupiter through a Japanese lens

Top research in the public interest







Czech Academy of Sciences

Dear readers,



Photo: Jana Plavec

You are holding the third English-language issue of the official magazine of the Czech Academy of Sciences. Continuing the tradition of our first two English-language releases, we have selected the best pieces from the past year's quarterly issues of the Czech *A / Magazín*, bringing our latest scientific advancements to readers worldwide. We are pleased to offer a detailed look at the work being carried out by scientists at the largest research institution in the Czech Republic.

For this English issue, we have chosen a rather explosive topic: toxins. The first thing that might come to mind is cyanide from a detective story or a viper bite. Few, however, would think of everyday items such as frying pans, parchment paper or hamburger wrappers. The toxins hiding there are inconspicuous, but that makes them all the more insidious. We are talking about chemical compounds known by the acronym PFAS – also known as "forever chemicals". Scientists have recently been focusing intently on this serious issue, as you will see on the following pages.

I am pleased that *A / Magazine* is becoming increasingly popular among readers. The quality of our publishing is also recognized by industry experts – this September, our publications swept the top spots in the External Printed Magazine and Newspaper category of the prestigious *Zlatý středník* competition for communication projects.

Wishing you an inspiring read,

Radomír Pánek
President
of the Czech Academy of Sciences

Photo: Jana Plavec

Cover image: Shutterstock (2)



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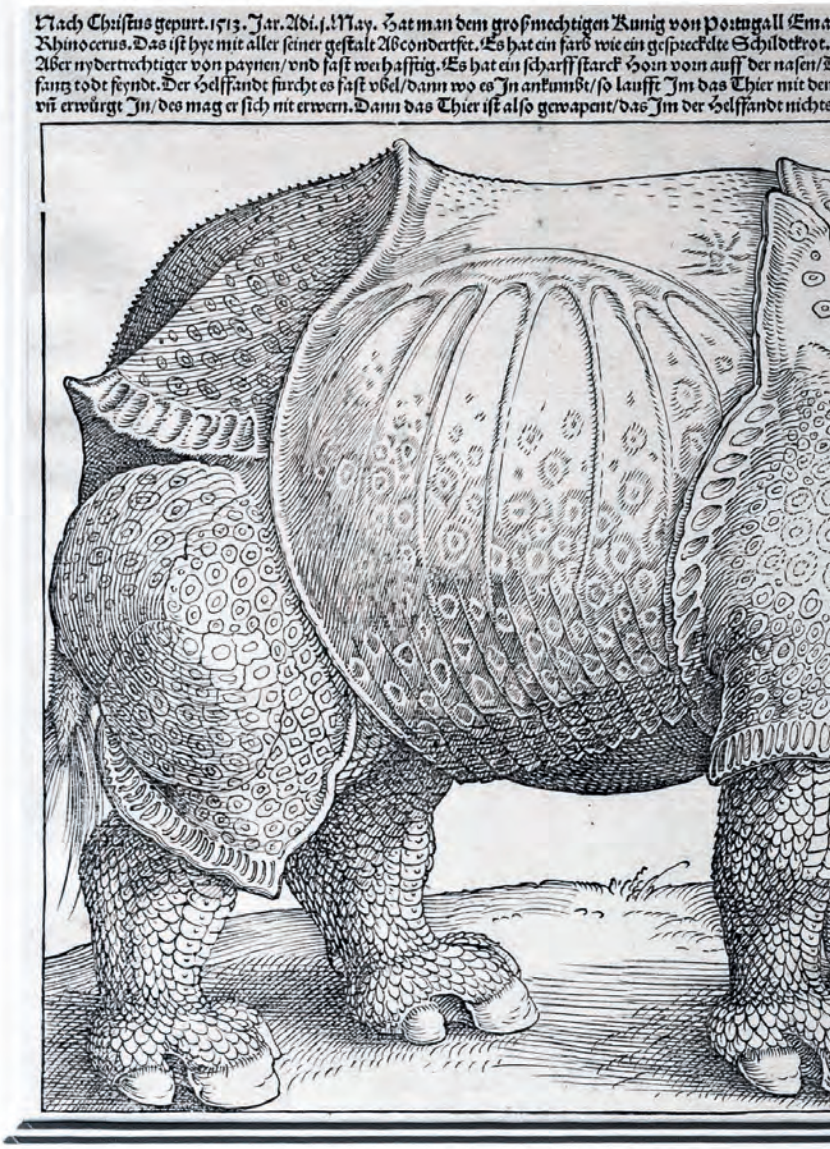
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Text: Leona Matušková \ Photo: Jana Plavec





UNEXPECTED WORLD-CLASS DISCOVERY

The Library of the Czech Academy of Sciences owns a rare first edition of Albrecht Dürer's woodcut *Rhinoceros*

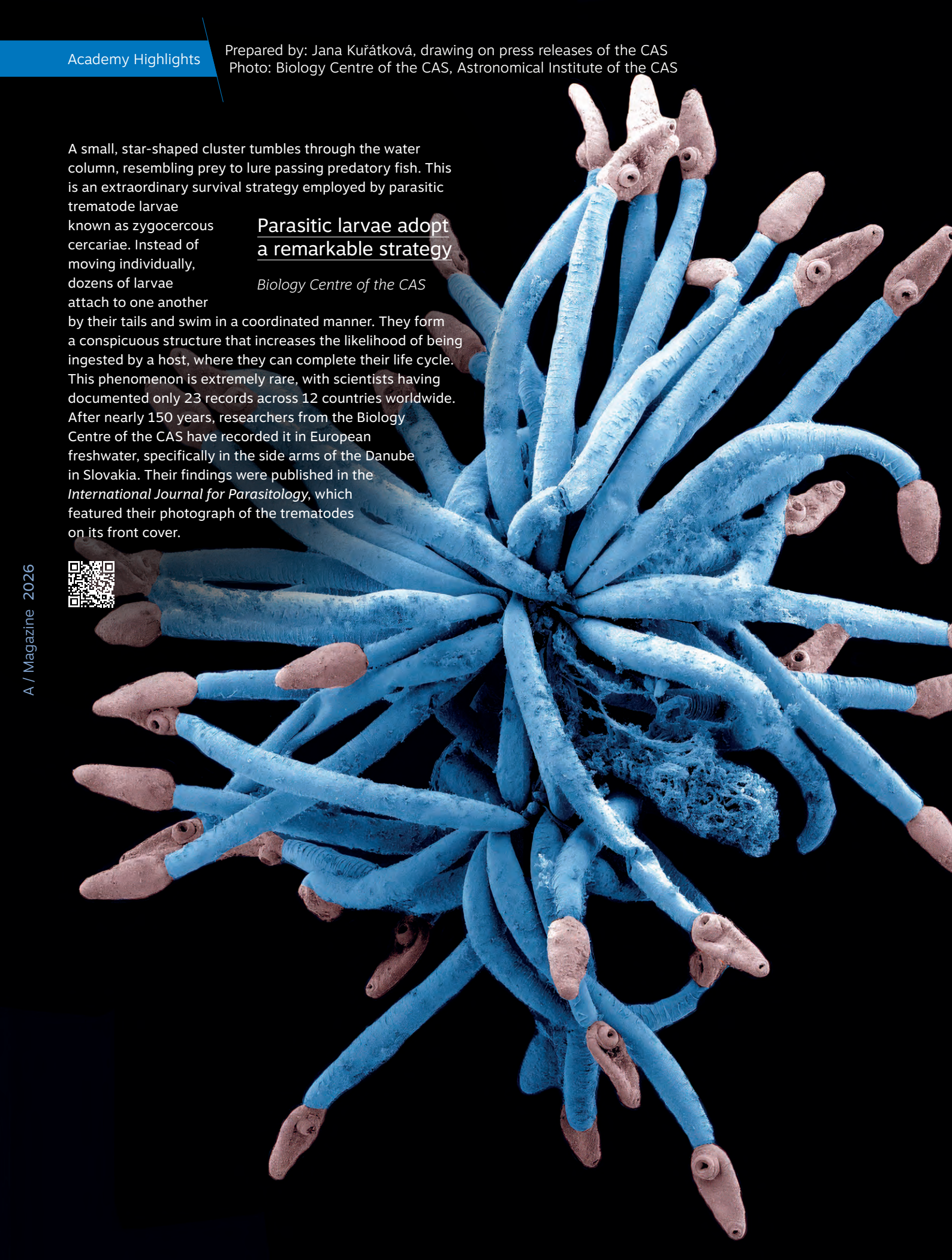
"It has the color of a speckled turtle, and is covered with thick, very rigid scales. It is as big as an elephant, but lower to the ground and very well-armed. On its nose, it has a strong, pointed horn, which it sharpens on stones..." This is how Albrecht Dürer described the rhinoceros on his woodcut, which he created in 1515 based on a description and a sketch depicting a live animal gifted to the King of Portugal. Although the depiction and accompanying text contain inaccuracies, they became the defining template for the appearance of the rhinoceros for more than 250 years. "Dürer's print symbolizes the power of the image at a time when Europe was only just learning to understand the world through experience, while also showing the power of imagination," says art historian Sylva Dobalová from the Institute of Art History of the CAS, who identified the unique first edition of Dürer's *Rhinoceros* within the holdings of the Library of the CAS. Further impressions of the first edition are held, for example, by the British Museum, the Louvre, and the Metropolitan Museum of Art in New York.

Prepared by: Jana Kuřátková, drawing on press releases of the CAS
Photo: Biology Centre of the CAS, Astronomical Institute of the CAS

Parasitic larvae adopt a remarkable strategy

Biology Centre of the CAS

A small, star-shaped cluster tumbles through the water column, resembling prey to lure passing predatory fish. This is an extraordinary survival strategy employed by parasitic trematode larvae known as zygocercous cercariae. Instead of moving individually, dozens of larvae attach to one another by their tails and swim in a coordinated manner. They form a conspicuous structure that increases the likelihood of being ingested by a host, where they can complete their life cycle. This phenomenon is extremely rare, with scientists having documented only 23 records across 12 countries worldwide. After nearly 150 years, researchers from the Biology Centre of the CAS have recorded it in European freshwater, specifically in the side arms of the Danube in Slovakia. Their findings were published in the *International Journal for Parasitology*, which featured their photograph of the trematodes on its front cover.



Industrial production of nanodiamonds is within reach

Institute of Organic Chemistry and Biochemistry of the CAS

Nanodiamonds are particles smaller than a virus, used in advanced diagnostics to measure charge, temperature or magnetic fields. They function as highly sensitive sensors thanks to a light-emitting quantum center – a nitrogen atom located next to a carbon atom vacancy in the diamond lattice. An international team of scientists from three continents led by the Institute of Organic Chemistry and Biochemistry of the CAS has developed a method capable of creating these quantum centers in just a matter of minutes. Diamond powder is placed in a press that generates extremely high pressure and temperature, reproducing the conditions found deep within the Earth's mantle. To prevent the particles from fusing together, ordinary table salt is added. It melts during heating, creating a protective environment. After the process, the salt is simply removed with water. In just one week, the process can yield as much material as conventional methods would produce in more than forty years. Moreover, the resulting nanodiamonds show improved optical and quantum properties.

Researchers capture the immediate immune response of plants

Institute of Experimental Botany of the CAS

For the first time ever, it is possible to observe in real time how plants activate their defenses against pests and diseases, thanks to a unique protein sensor developed by scientific teams from the Czech Republic, the United Kingdom, Germany, and Sri Lanka. The discovery, published in the journal *Science*, offers an entirely new perspective on salicylic acid, a natural substance known from willow bark which functions as a key hormone in plants, triggering and regulating their immune responses. Salicylic acid also plays a role in a state called systemic resistance, which helps the plant defend itself against subsequent attacks. A better understanding of this mechanism can contribute to breeding crops with natural and long-lasting resistance, thereby reducing the need for chemical sprays.

Forget mammoths: In Oman, they hunted sharks

Institute of Archaeology of the CAS, Prague

Prehistoric shark hunters – that is how one might describe the communities inhabiting the Nafūn region seven thousand years ago, for whom marine predators were a key dietary component. Researchers from the Institute of Archaeology of the Czech Academy of Sciences in Prague uncovered the oldest megalithic collective tomb in southern Arabia, where they found human teeth showing distinct wear patterns, suggesting the inhabitants used them as tools. Furthermore, carbon, oxygen, strontium, and nitrogen isotope analyses of the bones and teeth demonstrated that shark meat may have been one of their primary food sources. Neolithic communities in southern Arabia thus combined hunting, gathering, and pastoralism with the systematic utilization of marine resources. The study's results, published in the journal *Antiquity*, illustrate how these populations adapted to climatic conditions and confirm that Nafūn served as a central ritual site for over three centuries, unifying diverse groups across the entire region.

Cellular “safety switch” protects DNA from damage

Institute of Molecular Genetics of the CAS
Institute of Biophysics of the CAS

Whenever a cell divides, it must first copy its entire genetic code, which consists of billions of DNA “letters”. If errors occur during copying or if the DNA breaks, the cell becomes genetically unstable, which can lead to the development of cancer.

Researchers from the Czech Academy of Sciences have described a previously unknown control step in DNA replication in the journal *Nature Communications*. They found that the protein DCAF12 oversees the timing and quality of this process. Without this safety switch, the cell behaves dangerously – prioritizing speed over accuracy. Tumors are then much more likely to develop from such cells. In follow-up studies, the researchers aim to test the direct link between the disruption of this control pathway, genomic instability, and disease development.

How do tick-borne *Borrelia* burrow into blood vessels?

Biology Centre of the CAS

So tiny, yet so clever: bacteria of the genus *Borrelia*. Using advanced electron microscopy, parasitologists from the Biology Centre of the Czech Academy of Sciences have discovered how the microbes responsible for Lyme borreliosis, a serious illness, make their way from the site of a tick bite into blood vessels. Their strategy adapts to their environment: in blood capillaries, they use surrounding cells (pericytes) as landmarks, whereas in lymphatic vessels, they carefully enter cells to cross the barrier without disrupting it. These new findings pave the way toward a better understanding of the early stage of infection and highlight potential targets for prevention and treatment. By offering a detailed look at how borreliae interact with vascular cells, the research enables scientists to explore ways to slow the bacterium’s spread or prevent it from reaching critical parts of the body. The study was published in the prestigious journal *Nature Communications*, which featured it as one of the top 50 papers of the year in microbiology and infectious diseases.

Biosensors detect a silent killer before it strikes

Institute of Macromolecular Chemistry of the CAS

Joint replacement surgery brings relief, but it also carries the risk of severe infections, which can lead to painful swelling, sepsis, or in extreme cases even amputation. To solve one of modern orthopedics’ greatest challenges, scientists at the Institute of Macromolecular Chemistry of the CAS are developing smart biosensors designed for the early and reliable diagnosis of inflammation. These devices can detect pH changes and specific inflammatory markers in bodily fluids much earlier and more accurately than current diagnostic methods. Since January 2026, the research team has focused on miniaturizing these biosensors and enhancing their sensitivity. This will allow clinicians to monitor patients in real time, precisely identify the causative agent of the infection, and deliver targeted treatment to prevent implant rejection and further complications.

Young exoplanetary system undergoes dynamic evolution

Astronomical Institute of the CAS

TOI-201 is a very young star located 365 light-years from the Sun. It hosts two planets: one resembles Jupiter and orbits TOI-201 every 53 days, while the other, only slightly larger than Earth, completes an orbit around its host star in 5.8 days. Czech astronomers operating the PLATOSpec spectrograph at the La Silla Observatory in Chile helped characterize this second planet. In addition to these two planets, the researchers detected a transit across the star by another body on a 7.9-year orbit. With a mass roughly 16 times that of Jupiter, it fits the definition of a brown dwarf – an object that developed into neither a star nor a planet. The inclination and alignment of the planets' orbits relative to the brown dwarf point to a highly dynamic evolution, offering unique insight into the formation of planetary systems. An international team, including researchers from the Astronomical Institute of the CAS, presented the findings in the journal *Nature*.



Text: Jana Kuřátková, Markéta Wernerová \ Photo: Shutterstock, Ball Aerospace

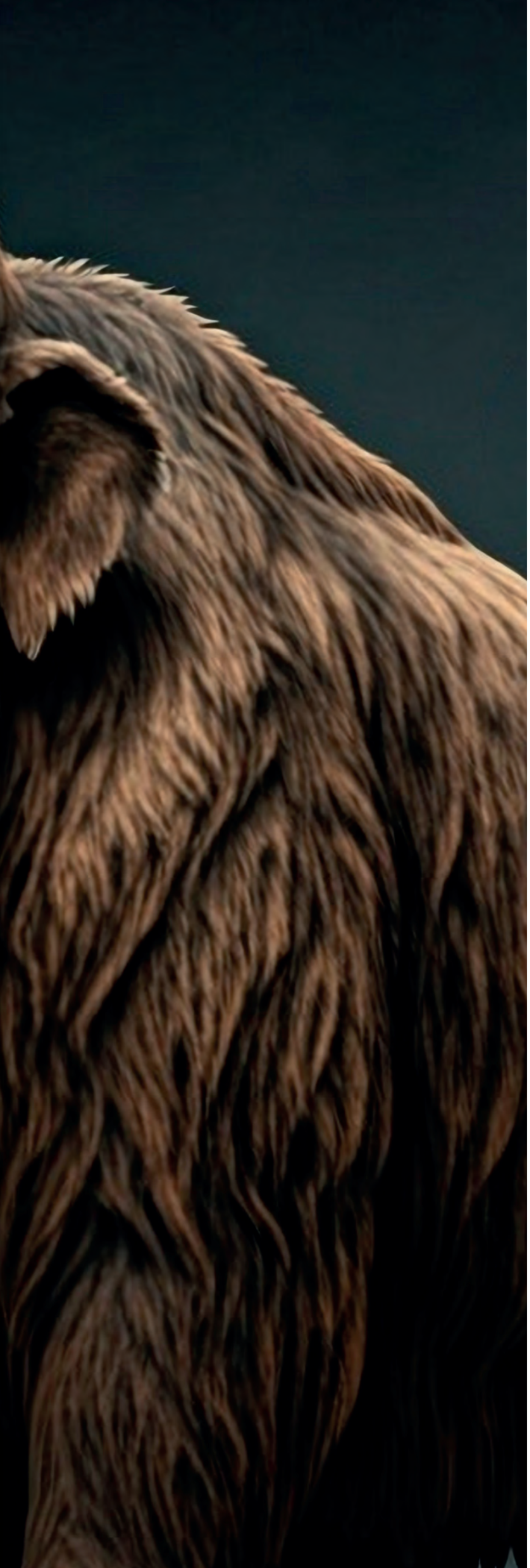
IS IT RIGHT TO BRING EXTINCT ANIMALS BACK TO LIFE?

In 2010, mammoth tusk hunters in Siberia discovered the best-preserved frozen mammoth to date. The calf, named Yuka, provided researchers with its "testimony," including extensive genetic data. Based on published research, Harvard University geneticist George Church decided to pursue an ambitious idea: bringing the extinct animal back to life. He intends to apply a cloning method based on genetic engineering, utilizing new findings about mammoth DNA and RNA provided by Yuka. In collaboration with entrepreneurs and investors, he founded Colossal Laboratories & Biosciences, which has announced that the first mammoth calf will be born as early as 2028. However, is it ethical to bring extinct species back into the world?

COMMENTARY: ROSINE KELZ

Institute of Philosophy of the CAS

The biotechnology company Colossal Biosciences advertises the "de-extinction" of long-lost species. To make a "mammoth", they are planning to implant the genetically modified DNA from an elephant skin cell into an elephant egg cell. This involves highly invasive procedures. For elephants, egg cell retrieval and artificial impregnation are complex medical interventions with high failure rates. Failures will likely also occur in the genetic modification and cloning processes. If genetically modified offspring were successfully produced, these animals would have to undergo repeated examinations. Finally, genetically modified and cloned animals may develop unforeseen health issues later in life. Given the suffering involved in any form of animal experimentation, potential benefits need to be weighed carefully. Even if a herd of mammoth-like elephants could be created, however, the advertised nature conservation benefits are unclear. At best, letting these animals roam across vast Arctic tundra ecosystems may have a minor effect in terms of carbon sequestration, but the actual long-term effects of introducing a novel species into these ecosystems are extremely difficult to predict. Colossal Biosciences' "mammoth" project advertises developments in technologies that have marketable animal breeding and biomedical applications. Just as the genetic modification of humans remains a controversial topic, however, we need a broader democratic debate about whether potentially far-reaching biotechnological interventions involving animals are ethically justifiable. Decisions about how humans alter the evolutionary future of non-human species – and potentially whole ecosystems – should not be left to small groups of scientists and investors.



WAS ALBERT EINSTEIN WRONG ABOUT BLACK HOLES?

For more than a century, Einstein's theory of relativity has been the foundation of our understanding of space and time. It predicts the existence of black holes and event horizons – the boundary beyond which nothing, not even light, can escape. However, there are also alternative theories. Scientists from Goethe University Frankfurt, together with Chinese physicists, have proposed a new way to test them. Their work, published in the journal *Nature Astronomy*, recommends an in-depth analysis of black hole shadows, which can be captured in great detail by the Event Horizon Telescope (EHT), a global network of large radio telescopes. New simulations and ultra-sharp images could eventually challenge the validity of the famous equations.

COMMENTARY: WILLIAM BARKER

Institute of Physics of the CAS

A remarkable prediction of Einstein's general theory of relativity is the existence of black holes; regions of spacetime where gravity is so strong that the future itself is bent inward. We can now image some of the last light emitted by hot matter before it falls into black holes, allowing Einstein's theory of gravity to be tested. There are a handful of credible alternatives to Einstein's theory. The work published in *Nature Astronomy* simulates infalling matter (and outflowing light) through the strong magnetic and gravitational fields neara "general" black hole, in which spacetime is bent in different ways according to the predictions of different gravity theories. The simulations thus provide a black hole image for each alternative to Einstein's theory, demonstrating that in the next five to ten years, new telescopes will be able to detect significant departures from Einstein's model. Ultimately, the "inverse" problem is more exciting: given a black hole image, can we constrain the theory of gravity? To solve the inverse problem, we need sophisticated statistical techniques and a big collection of these simulated images, for which this work is an excellent foundation – machine learning might also help in this process. For experimentalists, this work helps motivate funding for better telescopes. For theorists, the biggest question will be about generality. For example, some theories of gravity also change the behavior of matter and light, not just the bending of spacetime.

DOI: 10.1038/s41550-025-02695-4

PAPER-THIN CHIP CONNECTS BRAIN TO COMPUTER

The new BISC brain implant represents a revolution in neuro-technology. Experts from Columbia University have developed a silicon chip just 50 µm thick that fits between the brain and the skull. Featuring 65,000 electrodes and a wireless transmission speed of 100 Mbps, it enables a seamless connection between the human mind and AI. Unveiled in the journal *Nature Electronics*, the system offers hope to patients with amyotrophic lateral sclerosis (ALS), paralysis, or epilepsy by decoding intentions and sensory perceptions. BISC combines advanced medicine with supercomputer performance in a miniature package, reshaping how we will communicate with machines in the future.

COMMENTARY: NIKOLA JAJCAY

Institute of Computer Science of the CAS

American scientists have unveiled a new brain implant called BISC. Brain–computer interfaces are certainly nothing new – we have known about Neuralink and similar projects for years. Here, the real breakthrough lies elsewhere. The entire system – sensors, electronics, power management, and wireless transmission – fits onto a single chip measuring just 3 mm^3. No boxes mounted on the head, no cables protruding from the skull. Most importantly, its 100 Mbps transmission speed is unmatched by any existing BCI. Rather than merely measuring brain waves, it effectively "streams" neural activity in real time. Miniaturization and speed are the two keys unlocking the door to practical applications. For patients with paralysis, ALS, epilepsy, or those recovering from a stroke, they represent immense hope. Communicating with the outside world again, operating robotic limbs by thought alone, or regaining sight through visual cortex stimulation are just a few examples of what this technology can enable patients to do. A person trapped inside their own body can regain autonomy. Any technology capable of restoring control over one's life deserves both admiration and support. Yet every tool can be misused, and the more powerful it is, the greater the risk. Once reading brain activity becomes routine and inexpensive, who will guarantee that the data stays strictly between patient and doctor? Insurers, employers, state authorities – virtually everyone will want a glimpse into our most intimate sphere. Once that happens, there will be no turning back. The privacy of the mind has always been humanity's last untouched frontier. We may have just begun to cross it.

DOI: 10.1038/s41928-025-01509-9





WHERE IS FRESHWATER DISAPPEARING TO?

Less than one percent of the water on our planet is suitable for drinking, yet even this amount is under threat. A study by an international team of researchers published in the journal *Science Advances* reports that the loss of water on continents is caused by rapid drying, with the affected area expanding annually by roughly twice the size of California. This predominantly impacts the Northern Hemisphere. Furthermore, vast amounts of continental freshwater are being lost to the oceans, contributing to sea level rise even more than the melting of ice sheets.

COMMENTARY: MILAN FISCHER AND VÁCLAV RÁRA

Global Change Research Institute of the CAS

The study offers a global perspective on changes in terrestrial freshwater storage while revealing stark regional differences. Although some areas – particularly in tropical Africa – have experienced increasing water storage in recent decades, drying is far more widespread and severe overall. The Northern Hemisphere, home to most of the world's landmass and population, is affected the most – the area of drying land grows by hundreds of thousands of square kilometers every year. Dry regions are losing water faster than wet regions can accumulate it, partly because some of the water evaporated from land subsequently falls as precipitation over the oceans instead. Excessive groundwater extraction plays a central role in this drying process; according to the study, it accounts for roughly two-thirds of terrestrial water storage loss over non-glaciated continental regions, impacting areas where the majority of the global population resides today. The authors also emphasize that at current extraction rates, groundwater in many areas will not be replenished on human timescales. Retaining water on land would, at the same time, help slow the rate of sea level rise. It must be noted, however, that satellite observations from GRACE and GRACE-FO have only been available since 2002, meaning some regional trends cannot yet be considered fully established, which is also the case for Central Europe. The Czech Republic is among the countries showing a drying trend, although this part of Central Europe does not fall within the regions where drying was robustly identified by the study. Nevertheless, the study clearly highlights the urgent need for adaptation measures, particularly protecting groundwater, retaining water in the landscape, and transforming water management practices.

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TOXIC FOREVER



PFAS. These so-called "forever chemicals" are everywhere – in our soil and water, in our blood, even in developing fetuses. The reason? Our love of nonstick pans, parchment paper, and waterproof clothing.



West Virginia in the 1990s. Wilbur Tennant, a farmer from the town of Parkersburg, cannot believe his eyes. His once docile cows have suddenly started to behave like aggressive monsters, foam dripping from their mouths, their teeth turning black, rapidly losing weight, and dying one after another in terrible pain.

At the time, the desperate farmer had no way of knowing that the same substance which had kept scrambled eggs and pancakes from burning for millions of American homemakers would gradually cost him his herd of nearly two hundred cattle. The chemical compound in question was perfluorooctanoic acid, known as PFOA (or C8), which the company DuPont used in the production of Teflon, giving pans their nonstick properties. What it somehow neglected to mention to enthusiastic consumers was that this miracle "ingredient" was highly toxic.

And Tennant's livestock showed just how much so. The animals had been drinking from a creek into which toxic sludge had leaked for years from a landfill where DuPont disposed of hazardous waste from a nearby plant. The farmer suspected a connection between the company's activities and the deaths of his herd, but no one wanted to pursue his claims. After all, who would be willing to take on a chemical giant employing thousands of people in the region?

But Tennant refused to be silenced, and thanks to the persistence of his lawyer, Robert Bilott, the USA eventually found out – after years of legal battles – what it had unknowingly been poisoning ›

Freshwater fish, especially those from downstream stretches of rivers, rank among the most contaminated aquatic life (and foods).

itself with for decades. And that PFOA was just one member of a family of more than ten thousand per- and polyfluoroalkyl substances, known as PFAS, which industry had already flooded the globe with.

"PFAS are also called forever chemicals, which perfectly captures their nature. They contain a carbon–fluorine bond, the strongest in organic chemistry. Thanks to this human invention, they're incredibly stable and virtually don't break down in nature," explains environmental chemist Tomáš Cajthaml from the Institute of Microbiology of the Czech Academy of Sciences (CAS).

FROM TANKS TO KITCHENS

The potential of the carbon–fluorine bond was discovered by chance in 1938 at DuPont laboratories, where chemist Roy Plunkett was experimenting with refrigerant gases. The extremely durable polymer PTFE (later known as Teflon) that he created proved invaluable during World War II and was used inside tanks and in the development of the atomic bomb.

After the war, however, Teflon quickly found peacetime applications and, in the form of nonstick cookware, conquered American – and eventually global – kitchens. Under normal cooking conditions, the polymer itself was relatively safe, but DuPont soon began using the problematic compound PFOA to improve its production, supplied by another chemical giant, 3M. At the same time, 3M flooded the market with a related substance – PFOS (perfluorooctane sulfonate) – designed to make clothing waterproof and carpets stain-resistant.

Customers were delighted, and the billion-dollar business of nonstick and water-resistant products was running full speed ahead. All the while, both companies had known since the 1970s, based on their own animal testing, about the extreme toxicity of these innovations. They managed to keep the world in the dark for an astonishing four decades – the general public, that is. The scientific community had suspected something was wrong with these widely used materials since the early 2000s.

The turning point didn't come until around 2011–2012, when an independent panel of researchers finally published the results of a unique study initiated by lawyer Robert Bilott after seven years of work. Focusing on the residents of Parkersburg, whose water had been contaminated with PFOA by DuPont, it became one of the largest epidemiological investigations of all time.

"About seventy thousand people took part, among whom researchers found increased rates of several types of cancer and many other health problems," Cajthaml notes, referring to the case later portrayed in the 2019 Hollywood film *Dark Waters*.

The story from West Virginia, however, was only the tip of the iceberg. Long before its resolution, inventive chemists had already figured out how practical and versatile the carbon–fluorine bond was and had been experimenting with it extensively. Over the years, they created thousands of similarly toxic variants of forever chemicals, which have been – and still are – used to enhance everything from chips in smartphones to sofas to dental floss. Even though the Parkersburg scandal made their harmfulness something of an open secret.

A WOLF IN SHEEP'S CLOTHING

They repel water, grease, and dirt – and that's precisely why PFAS became the darlings of modern society. However, few people realized that these compounds

"The carbon–fluorine bond is the strongest in organic chemistry. That's why 'forever chemicals' virtually don't break down in nature."

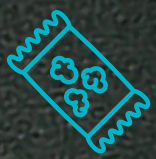
Tomáš Cajthaml

PFAS ALL AROUND US

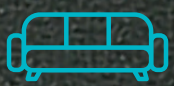

waterproof clothing and footwear

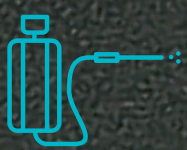

nonstick cookware


firefighting foams


microwave popcorn bags


cameras


furniture upholstery


pesticides


body care products


decorative cosmetics

were behind the remarkable properties of products that seemed to make life easier.

Beyond cookware and outdoor gear, forever chemicals have infiltrated furniture upholstery, electronics, "waterproof" cosmetics, and food packaging such as pizza boxes and coffee cups. After all, who wouldn't want a perpetually clean sofa and grease-free hands after biting into a fast-food burger?

paints

food packaging

And so, in modern households, microwave popcorn happily popped away for decades in highly toxic bags, while every grandma keeping up with the times stopped greasing sheet pans and lined them with parchment paper instead.

"Some of the earliest studies warning about the dangers of PFAS after the turn of the millennium already focused on paper muffin cups and popcorn bags. Under heat, they release toxic compounds directly into our food," Cajthaml points out.

From the very beginning, PFAS compounds also won the hearts of professional firefighters, because among ›



TOMÁŠ CAJTHAML
INSTITUTE OF MICROBIOLOGY OF THE CAS

Tomáš Cajthaml focuses primarily on environmental pollution caused by human activity, the effects of organic pollutants on ecosystems, and the development of decontamination methods. Since 2006, he has led the Laboratory of Environmental Biotechnology at the Institute of Microbiology of the CAS. Cajthaml also serves as Vice-Dean for Science and Research at the Faculty of Science, Charles University, where he headed the Institute for Environmental Studies from 2014 to 2024. He has repeatedly been ranked among the top two percent of the world's most cited researchers in his field.



THE OTTER AS A MIRROR OF OUR RIVERS

A top predator in aquatic ecosystems, the Eurasian otter feeds on fish, making it an excellent biological indicator of river water quality. Toxic substances from its diet, especially "forever chemicals," accumulate in its body. That's why researchers from the Institute of Microbiology of the CAS, in collaboration with other institutions, have decided to make use of the frequent findings of dead otters and measure levels of a broad range of PFAS in their tissues. "Based on the data we collect, we want to create a map of the Czech Republic showing the levels of contamination in different locations," says Tomáš Cajthaml, who is involved in the project.

"The combination of stability and high toxicity makes PFAS the worst contaminants humankind has ever created – and continues to produce voluntarily."

Tomáš Cajthaml

other things, they are excellent at suppressing flames. Especially in the USA, firefighting foams containing these substances were used for years to extinguish almost every major fire.

Forever chemicals also scored points among cross-country skiers, with fluorinated waxes ensuring that snow wouldn't stick to their skis. As a result, unsuspecting athletes carried large amounts of these indestructible pollutants straight into pristine mountain environments all around the world.

Ironically, the further spread of PFAS was also aided by the recent push against single-use plastics, such as straws, which began to be mass-produced from paper in the name of sustainability – unfortunately soaked with perfluorinated compounds to keep them from disintegrating in drinks.

PFAS ARE FOREVER

They have been found in snow on the summit of Mount Everest and in organisms in the Mariana Trench, the Arctic, and Antarctica. We drink them in water, and they literally rain down on us. They circulate in breast milk and in the blood of every person on the planet – even those not yet born – without them ever having seen a nonstick pan or a waterproof jacket.

So-called forever chemicals are now truly ubiquitous. They enter the environment during production and are released from products during use and after disposal – into soil, water, and air alike.

Their resilient molecules spread easily and quickly, covering vast distances with ease. And because they are virtually non-degradable, they accumulate in nature. In other words, every milligram of PFAS ever produced on Earth is still circulating somewhere in our ecosystem – and more are accruing every day.

"The combination of stability and high toxicity makes PFAS the worst contaminants humankind has ever created – and continues to produce voluntarily. Chlorinated insecticides like DDT and other inventions of the last century pale in comparison," Cajthaml says.

According to the researcher, the perfect carbon–fluorine bond that gives these compounds their properties can only be broken at temperatures above one thousand degrees Celsius. Hazardous waste incinerators can achieve such heat, but products containing forever chemicals rarely end up there. Instead, they typically make their way to landfills as ordinary municipal waste or, at best, to standard incinerators, which may not reach high enough temperatures to fully break them down.

CELLULAR SABOTAGE

And how do PFAS behave in the human body? They accumulate there as well. The body can eliminate them, but not efficiently – their half-life is roughly five to ten years. But because we ingest them daily and are constantly surrounded by them, their levels in our tissues are steadily rising, slowly but surely undermining our health.

Forever chemicals don't act like cyanide, which can kill within moments of ingestion. Their toxicity is chronic, which means that harmful effects appear only after long-term exposure to small doses – something all of us are facing to varying degrees.

"These are poisons which disrupt the normal functioning of cells – their membranes, regulation... Unlike other contaminants, they don't accumulate in fat but in protein-rich tissues, including muscles, because they bind to proteins," Cajthaml explains. "That's why they

spread so efficiently through the food chain and concentrate at its higher levels – in predators, including humans," the scientist adds.

Exactly how this cellular sabotage manifests in a given organism is hard to predict. Still, thanks to the extensive Parkersburg study and many others, it is clear that PFAS disrupt hormonal balance, contribute to declining fertility, and can cause congenital developmental defects.

They also damage the immune system, liver, kidneys, and thyroid, and promote chronic intestinal inflammation. As if that weren't enough, some PFAS are demonstrably carcinogenic, while others are at least suspected of being so.

In short, a perfect "seasoning" for everything we eat and drink. Their main transport medium is water, through which they move so deftly that truly clean water can no longer be found anywhere in the world. From water, they enter soil, crops, animal tissues – and ultimately end up on our plates.

FISH À LA TOXIC

Not surprisingly, river fish rank among the most contaminated aquatic life, especially those from downstream stretches, where pollution accumulates as rivers pass through civilization.

"In fish from the Elbe River caught in Ústí nad Labem, we detected PFAS levels so high that eating just one gram of their flesh would be enough to reach the recommended weekly intake set by the European Food Safety Authority," Cajthaml notes. Fish caught in the Vltava River in Prague fared somewhat better, he adds, but even there, given the same threshold, only a few bites can be consumed without concern.

Although food and drink are the dominant sources of forever chemicals for humans, they also enter our bodies through the air. Firefighters and professional ski wax technicians know this all too well – for years, they inhaled toxic fumes from firefighting foams and ski waxes. Researchers have measured extremely high levels of perfluorinated compounds in their blood.

Contamination has not spared the places where these people work either. Areas around airports – where firefighters traditionally train – rank among the most polluted sites worldwide, alongside regions near major chemical plants.

We also inhale PFAS in our homes, for instance when overheating older or damaged nonstick cookware. Still, far fewer pollutants enter the body through the respiratory tract than through the digestive system. Outdoor clothing can also be a significant source – impregnated synthetic fibers constantly abrade during movement, and we inhale PFAS particles as dust. In addition, they can be absorbed through the skin via sweat. Most importantly, however, they are washed out into the water cycle with every load of laundry – a process being studied by Cajthaml's team as part of the CAS Strategy AV21 program *Epicenters of Civilization – Intelligent Households, Technology, and Society*.

> Ironically, the recent push against single-use plastics has also contributed to the spread of PFAS. Paper straws, for example, have been mass-produced – often heavily treated with "forever chemicals."

TROUBLE FAR FROM OVER

After so many alarming findings, why haven't forever chemicals been banned outright? The answer is simple: so far, economic interests have outweighed health concerns. ›

NAVIGATING A TOXIC WORLD

How to Avoid Forever Chemicals in Everyday Life

IN THE KITCHEN

Get rid of old, scratched Teflon pans, sheet pans, and sandwich toasters. When overheated above 260 °C, they release toxic fumes.

If you want cookware with a nonstick surface, look for "PFAS-free" (or the older "PFC-free") labeling when buying new products. "PFOA-free" is not enough – it refers to just one of thousands of PFAS compounds, and the product may still contain others. When in doubt, choose glass, stainless steel, or enamel.

If you aren't sure about composition, avoid parchment paper (including muffin liners), disposable paper food packaging, and microwave popcorn bags.

You can reduce PFAS intake from tap water by using appropriate filters.

IN YOUR WARDROBE

Discard old, cracked outdoor gear such as jackets, shoes, and tents made before 2020 (e.g., the original Gore-Tex). Replace them with items labeled "PFAS-free" or "PFC-free" from trusted brands.

Choose waterproofing sprays for shoes and clothing based on waxes or silicones. ›

Thanks to people like Bilott and the scientific community, things have begun to move – albeit slowly. The first, rather modest step was the Stockholm Convention, which gradually banned the production and use of the highly toxic PFOA, PFOS, and PFHxS (perfluorohexane sulfonic acid) in signatory countries between 2009 and 2022.

That's just three compounds out of a family of more than ten thousand PFAS – but as the saying goes, better than nothing. Most developed countries, including the Czech Republic, have signed the agreement. The USA, however, has yet to fully adopt it.

In 2020, Denmark made headlines by introducing a zero-tolerance policy for forever chemicals in food packaging. It demonstrated that everyday life can function comfortably without them, as non-toxic alternatives do actually exist. So while Danes have been enjoying fries in global fast-food chains wrapped in paper free of hazardous additives, elsewhere the same chains are serving them in packaging infused with toxic substances.

Three years later, Denmark – together with Germany, the Netherlands, Sweden, and Norway – submitted a bold proposal to the European Chemicals Agency to ban all PFAS. The agency was immediately flooded with a record number of more than five thousand objections from industry stakeholders lobbying for exemptions, fearing the costs of changing production. As a result, the final decision keeps being delayed.

"A complete ban is the only correct solution, because there simply is no safe per- or polyfluorinated compound. Yet they are still massively overused in areas where they could be adequately replaced," Cajthaml urges.

For now, Europe has opted for gradual steps. As of 2026, stricter limits on PFAS levels in drinking water are in effect. For comparison, limits in the USA were already far stricter in 2024, but Donald Trump has sought to loosen these rules since returning to the Oval Office.



GREASED LIGHTNING IN THE SKI TRACKS

Fluorinated ski waxes appeared in the late 1980s. And while these high-performance waxes gave athletes the speed they wanted, they also released massive amounts of "forever chemicals" into the environment. "Ski tracks can be up to a thousand times more contaminated than the surrounding snow," says Tomáš Cajthaml, who also studies the distribution of PFAS in the Jizera Mountains. According to the researcher, the high PFAS concentrations found there today are caused exclusively by recreational skiers, as fluorinated waxes have been banned in professional competitions since the 2023/24 season. That's why researchers teamed up with the largest Czech supplier of cross-country equipment to launch a mountain protection campaign: anyone who hands in old fluorinated wax for safe disposal receives a non-toxic alternative at half price.

Across the pond, the EU has banned the use of PFAS in food packaging from August 2026. Next year, they are to disappear from clothing, footwear, and firefighting foams used for training and testing. According to optimistic plans, by 2030, PFAS should be eliminated from all products that are not essential to society. Unfortunately, that doesn't mean goods containing these harmful substances will stop flowing in from China and other countries where such restrictions are not on the agenda. For customs authorities, monitoring every package from e-shops is practically impossible.

CZECHS IN BLISSFUL IGNORANCE

If you're hearing about forever chemicals for the first time, you're not alone. Despite scientists' efforts, public awareness in the Czech Republic remains low. Perhaps also because PFAS contamination here is not as severe as in the USA, Belgium, or even Denmark, where they were produced on a large scale for years. In this respect, the "brake" of the Iron Curtain had at least one upside...

"Compared to the West, Teflon, various impregnations, and firefighting foams spread here decades later. At the same time, we have the advantage of being at the headwaters, so no PFAS flowed to us from elsewhere. Whatever we find here, we released into the environment ourselves," Cajthaml notes.

As a result, concentrations in Czech waters are significantly lower than in countries downstream along major rivers. Even so, there are places where these persistent compounds have thoroughly permeated the landscape. Czech hotspots include the surroundings of Václav Havel Airport Prague and the Kopanina Stream, as well as areas near engineering plants that commonly used, for example, Teflon-based lubricants.

Yet forever chemicals have barely entered consumer awareness in the Czech Republic. So when people here see a "PFAS-free" label on a windbreaker, they might be more likely to worry

something is missing than to feel relieved they're avoiding harmful substances.

Incidentally, Cajthaml's team, together with the NGO Arnika, examined children's outerwear in 2022. They analyzed ten products found on the Czech market – and the results were far from reassuring: perfluorinated substances were detected in nine of them, including compounds banned under the Stockholm Convention in seven cases. Only one sample was free of toxic chemistry.

"Producing such clothing without PFAS is certainly possible. But with most of these products, you won't find out whether PFAS are behind their water resistance. I simply would not recommend buying them for the youngest among us. The average child probably only gets rain-drenched a few times a year – so why wrap them in toxic layers when it's not necessary?" the researcher asks.

Cajthaml and his colleagues are currently studying the extent and sources of contamination by forever chemicals in the seemingly pristine environment of the remote Svalbard archipelago. They are also investigating snow contamination in the Jizera Mountains – in a three-year study, they are tracking how levels of substances from fluorinated ski waxes change over time in cross-country ski trails. His team is also working to map PFAS pollution across the Czech Republic using analyses of tissue samples from dead otters and by measuring contaminants around landfills.

A LEGACY THAT WILL OUTLIVE US

The year is 2026. Fourteen years have passed since the fallout of the West Virginia case, and a quarter century since the first evidence of the dangers of perfluorinated compounds. Looking at the new regulations, it may seem that things are finally starting to turn for the better. A "PFAS-free" era, however, is still nowhere in sight. We have saturated our planet with these substances so thoroughly that it can no longer truly be rid of them.

"If PFAS production stopped completely right now, we'd probably be in a much better place here in the middle of the continent in a hundred years. These substances would gradually wash into the oceans. But once in the oceans, no one is getting them out of there," Cajthaml says.

For the average consumer, that leaves only one option – to try to avoid "forever chemicals" as much as possible: not surrounding yourself with them at home, not wearing them, and looking for "PFAS-free" labels on new products. For now, however, companies are not required to disclose whether their products contain these substances. Nor is there any unified, officially recognized label certifying their absence.

"If you hear that something doesn't stain, doesn't get wet, or doesn't stick, that's your cue to take notice and find out why," the researcher advises. He admits that having a detailed knowledge of the toxic cocktail surrounding us – and within us – combined with humankind's lax approach to the issue, has made him somewhat of a cynic.

"Sometimes I feel more like an environmental pathologist. But you can't let it get to you. In any case, you won't find a nonstick pan in my home, and we always grease sheet pans," he adds with a smile.

"A complete ban is the only correct solution, because there simply is no safe per- or polyfluorinated compound."

Tomáš Cajthaml



NAVIGATING A TOXIC WORLD

How to Avoid Forever Chemicals in Everyday Life

IN THE LIVING ROOM AND BEDROOM

Avoid sofas with water-repellent or Teflon coatings. If a drop of water beads up on the surface instead of soaking in, the fabric has likely been treated with "forever chemicals." These are also used in stain-resistant tablecloths, blackout curtains, and mattress protectors.

Be cautious of carpets treated with PFAS to repel dirt and dust – these substances are gradually released into the air.

If you already own such items, air out your home regularly.

IN THE BATHROOM

When choosing waterproof or other cosmetic products, check the ingredient list for substances starting with "perfluoro-" or "fluoro-" (not to be confused with fluorides in toothpaste, which protect enamel and work differently), or use a mobile app (e.g., INCI Beauty) that scans barcodes and identifies toxic ingredients.

Do not buy dental floss containing Teflon. Replace it with natural alternatives made of silk or cotton.

WHAT TO DO WITH "FOREVER CHEMICALS"?

You cannot safely dispose of PFAS-containing products at home. Throw them into mixed waste, ideally in areas where it ends up in waste-to-energy incineration plants. Never recycle them, pass them on, or (in the case of cosmetic products) pour them down the drain.

A CHEMICAL AGENT IN A STINGER

It can kill and destroy – but also heal. Bee venom contains a sophisticated cocktail of up to one hundred different substances. How is it that a nearly invisible droplet of this liquid can cause so much trouble?





A battle straight out of an action movie rages in front of a hive. The resident colony is bravely fending off a raid by robber bees, fiercely defending the key entrance to their kingdom. Within moments, the opponents lock together, pushing and grappling, but most importantly, unsheathing their most powerful weapons. Whoever stings first wins the duel and can press on with the battle. All that's left to do is swiftly pull their deadly instrument out of the limp body of their rival and launch at the next target.

Nature equipped bees with a stinger and venom precisely for fighting insect rivals, from whose bodies they can easily withdraw their weapon and keep defending themselves. Until they encounter a human, that is...

"Bees evolved in the Mesozoic, when very few mammals and birds were inhabiting Earth. That's why their apparatus isn't adapted for contact with skin. Because of barbs, they cannot free their stinger from a wound and, when trying to do so, tear off the end of their own abdomen – which usually costs them their life," explains insect physiologist Dalibor Kodrík from the Biology Centre of the Czech Academy of Sciences (CAS).

Has evolution fallen behind the times, then? After all, mammals have dominated our planet for millions of years, yet the bee's arsenal remains the same. According to researchers, however, this may very well be a matter of pure calculation – a bee stings such a large enemy relatively rarely, and the occasional loss of a few individuals is a tolerable price to pay for the safety of the hive. Moreover, worker bees do not reproduce, so they cannot pass on the "lesson" that attacking humans doesn't pay off to the next generation.

Incidentally, though hymenopteran representatives of the genus Apis are renowned for their cognitive abilities, when attacking mammals, they likely do not realize they are embarking on a suicide mission. Rather than a deliberate sacrifice kamikaze style, it probably is just instinct taking over.

LIQUID FIRE UNDER THE SKIN

Like a red-hot pin – that is roughly how a bee sting announces itself in the first seconds. Immediately after penetrating the skin, several microliters of apitoxin, one of nature's most sophisticated chemical creations, force their way into the body's tissues. According to current research, this acidic aqueous solution contains up to one hundred different components. Each has a precisely defined role.

The intense burning pain, for instance, is caused by the dominant component of the venom – the toxin melittin. This small peptide behaves somewhat like a corrosive substance, rapidly breaking down phospholipid molecules in cell membranes.

"Melittin punches holes in cells whose contents leak out and, after a while, they disintegrate. So a biochemical disruption results in the physical destruction of cells, including blood cells. And that's what hurts so much," Kodrík explains. At the same time, melittin also targets muscle cells in the victim's body, significantly damaging them.

"In skin, the movement of the stinger is possible in only one direction. The barbs lock in much like a wall plug hammered into a wall."

Dalibor Kodrík

But that's only the beginning. What follows is a cascade of reactions in which the individual components pass the baton, their effects complementing one another perfectly. Once melittin breaches the first line of cells, the enzyme hyaluronidase steps in, its role being to clear a path for apitoxin deeper into internal structures. It deftly breaks down the bonds between cells, which then separate, creating a highway for the liquid fire.

Biogenic amines such as dopamine, histamine, and others proceed to wreak further havoc in the affected system. These don't get into the wound only from the stinger itself – they're also massively released from the debris of cells shattered by melittin. Among other things, this amine surge increases heart activity, which in turn speeds up blood flow and allows the venom to spread more efficiently through the body. Under the onslaught of amines, capillary walls in the area of the sting also relax, plasma floods the tissue, and the puncture site instantly "upgrades" into a reddened swelling.

The amines also irritate nerve endings, causing persistent itching, and activate the immune system, which in sensitive individuals can make a fatal mistake and, instead of a standard defense, trigger an excessive allergic response.

NO COVERAGE FOR NEURONS

And not even that is the end of the chemical offensive. Bee venom also introduces a group of neurotoxins into the body that affect nerve activity. They can block the connections by way of which neurons pass signals – unleashing informational chaos in the affected area.

Although experts already understand the ways that many components of apitoxin act in attacked organisms, they are still in the dark about the roles of others. One example is the protein vitellogenin, which, according to some studies, increases the allergenic properties of bee venom. At the same time, it may actually extend the lifespan of worker bees themselves.

"We've noticed that in winter bees, which live up to half a year, the content of vitellogenin is several times higher than in summer bees, which die after about a month. So it seems to be linked to longevity," Kodrík notes, adding that if this mechanism could be deciphered, the protein could one day find applications in anti-aging medicine or tissue regeneration.

Vitellogenin is not the only variable in this remarkable mixture. Throughout the year, the content of individual components actually fluctuates, with bee

venom typically being most potent in spring and autumn. Researchers have also uncovered significant differences in the "formula" between bee colonies across the country. Each sting thus represents a unique signature of a given time and place.

Whether a hive resident attacks in March in one region or in July on the other side of the country, melittin remains the key ingredient. It also ties into a recent discovery made by researchers at the Biology Centre: while the entire apitoxin mixture is produced in the venom gland and stored in a sac lined with an impermeable cuticula, an additional supply of melittin is formed in the fat body – the insect equivalent of the liver. And curiously enough, it likely serves to protect against bacterial infection.

"What remains a mystery is what exactly allows the bee to tolerate its own toxin and benefit from it. It may be an inactive form which doesn't become dangerous until later," the researcher speculates. He believes that shedding light on this feat could help develop defenses against allergic reactions in humans.

Bees, however, do not use melittin's infection-resistant properties only internally, but also externally. Recent findings show that they spray one another with their venom like a repellent, and the resulting layer of this substance acts as a shield against diseases and parasites.

UNSHEATHE YOUR WEAPON!

Measuring barely one millimeter, it is one of the most complex tools in the insect world. A bee's stinger is far from an ordinary needle. The end part, called the sting shaft, consists of two barbed lancets between which the venom flows through a canal.

But the structure of the stinger is even more refined. Kodrík and his colleagues were the first in the world to cut this extremely hard structure crosswise and examine under an electron microscope the numerous sensory organs at its tip in close detail. Thanks to these receptors, the animal can sense how deep it has pierced the object in question or even how it tastes.

Before the Czech researchers, no one had thought to properly "zoom in" on the bee's combat gear. "We magnified the tip fifteen thousand times and found that it is lined with saw-like serrations that are tens of nanometers in size and dotted with pits," the physiologist says. "These ultrastructures probably enable the bee stinger to cause more extensive damage to the opponent's cells than if their surface were smooth."

This hypothesis is supported by the fact that the team found a similar design only in insects that use this organ as a weapon – such as bumblebees, wasps, and hornets. In species for which it primarily serves to lay eggs, this modification was not observed.

The stinger is, in essence, a "retrained" ovipositor. That's why in the bee world, only female bees – worker bees and queens – possess both the stinger and the venom gland. Male drone bees, which spend almost their entire lives in the hive, apart from mating, are therefore completely harmless. And so, the greatest enemies of bee colonies – such as hornets, the European honey buzzard, or the European bee-eater – must be faced by these "amazonian" forces alone.

AT THE MERCY OF BARBS

Though a bee sting itself lasts only a fraction of a second, we shouldn't imagine a smooth puncture. In reality, it is a surprisingly complex, jerky process. Initially, one barbed slide catches onto the skin and inserts into the wound. Its first barbs act as an anchor, preventing backward movement and allowing the second slide to drive itself a little deeper and lodge there with its own barbs. The two parts then alternate in this way until they completely burrow into the flesh.

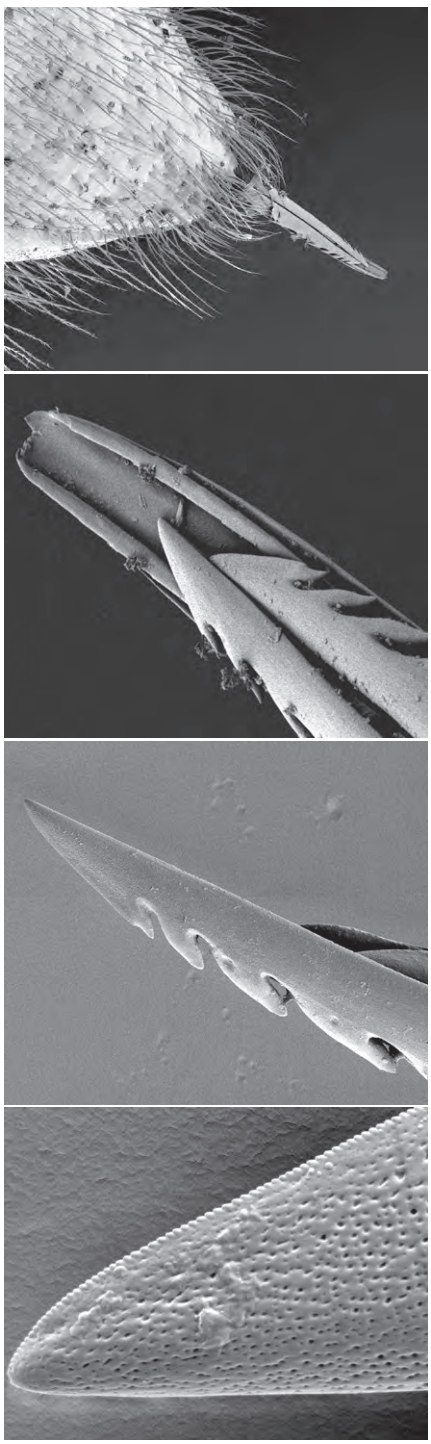
"Nature has clearly gone to great lengths to refine this apparatus – not only chemically, but mechanically. In skin, however, this movement is possible in only one direction. The barbs lock in much like a wall plug hammered into a wall," Kodrík points out.

That is why, while attempting to free its stinger from a mammal or bird, a bee usually tears off the last segment of its abdomen (unlike a wasp, whose barbs are ›

BEES GETTING THEIR BUZZ ON

Instead of the usual buzzing, the hive is filled with a loud, low-frequency hum. That's because researchers in České Budějovice have administered cocaine to one part of a bee colony and are observing what it does to them. And changes in vibroacoustic signals are how worker bees communicate that something is wrong in the hive – before driving out their intoxicated nestmates. Bees respond to addictive substances in surprisingly similar ways to mammals. Their brains even contain a reward system that operates on a principle similar to the one in humans. "On top of that, bees are a eusocial species. All this makes them an ideal model for studying the effects of drugs on individuals and society," says Dalibor Kodrík, whose team is analyzing the behavior of worker bees under the influence of psychoactive substances.





The stinger is actually a modified ovipositor, making it exclusive to the female bee population. Electron microscope images show it in minute detail: the top image shows it along with the tip of the abdomen, while others capture the stinger's stylet groove, within which two barbed lancets slide, as well as a detail of one of the lancets. The bottom image shows the tip of the stinger at an even higher resolution.

The burning pain of a bee sting is caused by the dominant component of the venom – the toxin melittin. This small peptide behaves somewhat like a corrosive substance, rapidly breaking down phospholipid molecules in cell membranes.

tiny) – and it rarely survives the injury. Even after death, however, it can complete its mission. Along with the "jab," it leaves behind in the victim a partially autonomous nerve cluster called a ganglion. This external "brain" controls the muscles that keep pumping apitoxin into the tissue for several minutes after the tiny warrior has already fallen.

The sooner we remove the pointy souvenir, the less of the itchy substance enters the body – and the milder the reaction we can expect. Grabbing the bee abdomen with your fingers and trying to pull it out, however, doesn't pay off; this squeezes the venom sac, flooding the tissue with the entire dose of toxic liquid.

The stinger needs to be scraped off with something flat, such as the blunt side of a knife or a credit card. But one rarely runs into this tiny pollinator in the kitchen or on the way to an ATM. Out in nature, a fingernail often has to suffice.

WHEN BEES SIGNAL SOS

Once the stinger is out, all that remains is to cool the wound. Or call an ambulance straightaway – if the insect has struck the tongue, where swelling can block the airway, or if the sting triggers a severe allergic reaction or anaphylactic shock.

In Europe alone, nearly four percent of the population is hypersensitive to bee venom. The allergy proves fatal for roughly two hundred people on the continent each year. A healthy adult, however, should survive up to seven hundred bee stings – although even a "mere" hundred can land them in the hospital. As for children, a much smaller dose can be critical.

That's why it's good to know that bees often do not attack alone. "When a forager attacks someone, it releases isoamyl acetate, an alarm pheromone, into the air. Its nestmates read this as a call for help in battle and swiftly swarm in to join the fight, even from quite a distance," Kodrík explains.

When this happens, the researcher says, it's important to stay calm, retreat slowly from the agitated swarm, and, above all, avoid running away frantically or waving one's arms in a panic. Abrupt movements tend to provoke the buzzing commando into further aggression.

This applies to all stinging hymenopteran insects. For humans, the most painful jab usually comes from a hornet – it has the largest stinger, which penetrates deep into tissue and delivers the biggest dose of pain-inducing substances. On top of that, just like wasps or bumblebees, it can attack repeatedly thanks to its small backward-facing barbs.

The fundamental difference in equipment may come down to simple survival math. While bee colonies number in the tens of thousands and hardly feel the loss of a few individuals, in the much smaller colonies of wasps, hornets, or bumblebees, each loss can significantly weaken the whole. Not only do these species differ in combat strategy – so does the composition of their venoms.

"When a bee attacks someone, it releases an alarm pheromone into the air, which its nestmates read as a call for help in battle – and they swiftly swarm in to join the fight."

Dalibor Kodrík

Among these common hymenopterans, only bees can boast the unique melittin.

FROM HIVES TO HOSPITALS

It helps mitigate skin conditions, inflammation, liver fibrosis, and atherosclerosis. It eases joint pain and neuralgia, slows the progression of neurodegenerative diseases such as Alzheimer's and Parkinson's, and even curbs tumor growth. Bee venom is not just a killer and source of searing pain – it is also medicine's powerful ally.

Thousands of years ago, its therapeutic potential was recognized by early civilizations, when they noticed that in small doses, the toxic cocktail has beneficial effects. Today, so-called apitherapy is used not only in folk healing, but also in modern pharmacology.

The good news is that bees no longer have to die when sacrificing their bodily fluids on the altar of human health and science. While in the past it was necessary to dissect the venom sac from a dead insect, today it suffices to gently stimulate the bee with a mild electrical impulse, without harming it.

The voltage provokes the worker bee to sting into a special membrane, where it releases the contents of its gland. The venom is then left to dry, scraped off, purified, and sent on its way to be used in various preparations or research laboratories.

JUST LIKE A HORROR MOVIE

While medicine focuses on the positive effects of apitoxin, Kodrík's team is primarily concerned with the damage this chemical arsenal can cause in the attacked body – and how to eliminate it.

Alongside bees, the Czech scientists are also aided in their research by a parasitic wasp called *Habrobracon hebetor*, whose life strategy resembles a horror flick. Unlike worker bees, it doesn't deploy its venom for simple defense, but for the total enslavement of its victims. The grim scenario involves the wasp injecting a caterpillar with a mixture of toxins that essentially "switch off" its nerves, muscles, and immune system – and then laying eggs on the surface of its body.



DALIBOR KODRÍK
BIOLOGY CENTRE OF THE CAS

Dalibor Kodrík focuses primarily on insect stress hormones and their role in controlling insect defense responses against natural and synthetic toxins. He has extensively studied the effects of venom in bees and parasitic wasps, specifically *Habrobracon hebetor*. Since 1997, Kodrík has led the Laboratory of Insect Physiology at the Institute of Entomology, Biology Centre of the CAS. In 2022, he received the Laufberger Medal for his contributions to Czech physiology.

"The caterpillar stays alive, but it can't move or defend itself against the foreign organism inside. It becomes a kind of living pantry, from which as many as ten wasp larvae can soon be suspended. They feed on it until it dies," the physiologist explains.

However, his team has found a way to mitigate – or even stop – the ordeal these involuntary hosts face. The researchers discovered that one hormone from a group of insect stress hormones (the adipokinetic hormones) can, by way of defensive reactions, reduce or perhaps eliminate the neuromuscular effects of the wasp's venom. The same substance can also prevent the muscle damage caused by apitoxin in organisms stung by bees.

At that point, the scientists wondered whether this mechanism could also be used in humans – for instance, to suppress spasms, treat cramps, or address muscle tissue degeneration. The answer will come only with additional years of testing. But perhaps the key to new biomedical breakthroughs lies hidden in paralyzed caterpillars and bee stingers.

YOU ARE WHAT YOU SPEAK

People who speak multiple languages tend to be more flexible – and their brains resist dementia for longer. How many languages can the mind hold? And why is it worth taking inspiration from infants and toddlers when learning languages?

Text: Radka Římanová \ Photo: Midjourney, Shutterstock, Pavlína Černoch Jáchimová (6)



Včera I was at school a bylo to děsně boring, says a roughly ten-year-old girl to her friend at a bus stop in Prague, Czech Republic. An older passerby shakes his head in disapproval, muttering something about today's youth and the butchering of Czech. What he doesn't realize is that the girl has just demonstrated textbook code-switching – switching mid-sentence from one language or dialect to another – a hallmark of bilingualism. And it's something that deserves admiration rather than contempt.

"People can accommodate many languages, provided they are exposed to them sufficiently and in the right way. You cannot 'overload' on languages. Researchers haven't found any limit even when it comes to children."

Kateřina Chládková

"When someone jumps between languages, even within a single sentence, it shows they're using their cognitive resources to the fullest," explains psycholinguist Kateřina Chládková from the Institute of Psychology of the Czech Academy of Sciences (CAS), who studies language acquisition. "They're speaking Czech but suddenly reach for an English phrase or word because it comes to mind faster, is easier to pronounce, or simply fits the context better."

What exactly happens in the brain during code-switching is the subject of intensive research. We already know that speaking multiple languages affects the brain's structure. As it happens to turn out, languages are not stored separately in the brain – they coexist and constantly interact. And this metaphorical drawer in our heads appears to be somewhat expandable.

"People can accommodate a large number of languages, provided they are exposed to them sufficiently and in the right way. You cannot 'overload' on languages. Researchers haven't found any limit even when it comes to children. In Ghana, for example, it's common to speak four languages, and some people speak as many as six," the psycholinguist notes.

Africa is, in fact, the cradle of multilingualism. Around 2,000 languages are spoken there – roughly a third of all the world's languages. In a single village, dozens of them may intermingle. But multilingualism isn't unique to this continent. It thrives in Asia and the Americas, as well as in Europe. In fact, most of the world's population today speaks more than one language. The Czech Republic is no exception – due in part to Slovak, German, and Polish in its border regions, as well as Russian among older generations and English in professional settings.

HELLO, DADDY, HOLA, MAMÁ!

Let's say we have a mother who speaks Spanish, the father English. From birth, their child is in the process of acquiring both languages – though usually not evenly. Typically, the child will hear one language more often, and their first word is often spoken in that one. But it doesn't come later than in the case of children whose parents or guardians speak the same language.

"In a study last year, Polish researchers monitored hundreds of monolingual and bilingual infants and compared the age at which they began to babble. They did not detect any difference," says Chládková, debunking a common myth.

According to her, how bilingual children use their two languages changes not only over time, but also depending on the situation. As toddlers, they tend to use the language of their parent or guardian who spends more time with them; as they get older, they favor the language of daycare, school, or friends.

The advantages of bilingualism are lasting – and there are many. In addition to being able to communicate across a number of countries, multilingual



A MATERNITY WARD INSTEAD OF A LAB

"Malicherné báje zpupného oře" (The trifling myths of a mutinous steed.) or "Kmet podlehl spanilé larvě" (The peasant succumbed to a graceful larva). These are the kinds of phrases Martina Dvořáková and Josef Urbanec from the SPEAKin lab played to Czech newborns in a maternity ward in Havlíčkův Brod. They then replayed the same sentences with altered rhythm – and babies just one day old could already tell the difference! Their brains reacted more strongly to the unusual prosody. The researchers detected this using near-infrared spectroscopy, measuring brain activity through special sensor-equipped caps. They demonstrated that even immediately after birth, infants can distinguish between a native and non-native accent in their mother tongue.

> Most of the world's population today speaks more than one language. The Czech Republic is no exception.

individuals tend to be more flexible, because their brains are better at switching between tasks. Research also suggests that they develop certain social and communicative skills earlier, along with an awareness that other people may hold different opinions. Exposure to various languages – and therefore cultures – likely makes it easier for them to accept and respect otherness and diversity.

This phenomenon has also been explored by the Prague-based research group SPEAKin lab, led by Kateřina Chládková. Her colleague Lucie Válková invited Czech monolingual and bilingual toddlers into the lab, where a nursery rhyme in Czech was read to them by a native speaker as well as a woman with a French accent. Both speakers then offered the children identical toys. The result? The one-year-olds from multilingual families were more likely to take the toy from the person with the non-native accent, whereas monolingual children tended to turn to the woman speaking more standard-sounding Czech. Together with Natálie Kikoťová, the researchers observed similar tendencies among preschoolers choosing a friend.

"We develop language-based preferences from a very early age, and we often carry them into adulthood. But a more diverse verbal and cultural experience can help weaken these biases," the researcher believes.

ALZHEIMER'S CAN WAIT

Multilingualism also offers clear benefits in old age. According to some studies, learning or using multiple languages over a lifetime can delay the onset of neurodegenerative diseases by up to five years.

A recent cross-EU study likewise found that multilingualism slows brain aging. And the more languages a person knows, ›

BABYLAB: SPEECH DEVELOPMENT EXPERIMENTS

Would you like to help advance research on speech development and language acquisition? For its experiments, the SPEAKin lab is looking for bilingual and monolingual infants and toddlers – with or without a family risk of dyslexia – as well as preschoolers with and without symptoms of ADHD. The experiments take place in Prague or Olomouc. More information can be found online:



Researchers measure children's responses to language stimuli using special sensor-equipped caps that record brain activity. For other experiments, they use conventional audiovisual equipment.

the more pronounced the difference compared to their monolingual peers.

That's probably also why more and more couples from the same linguistic background are trying to give their children the advantage of a second language from infancy. Czech parents, for instance, might decide that the mother will speak with the child only in her native tongue, while the father will use only English.

Psycholinguists welcome such strategies – they believe success simply requires that the family feel comfortable with this approach. An adult's accent in a foreign language isn't necessarily an obstacle, either. The child effectively receives the tremendous gift of another language practically for free. However, the parent who gives up their native language in communication with their child should bear in mind that their second language might tend to be less emotionally charged.

"It's often easier to swear in a foreign language, for instance, because you don't fully realize the weight of the words. But when someone insults you in your native tongue, it hits harder than in a foreign one – even if you understand it. Emotions simply work a bit differently in your native versus a non-native language," Chládková notes.

Together with her colleague, Kateřina Cook, she is also exploring whether a multilingual environment could help children with a familial risk of dyslexia. Current findings suggest that dyslexia is not just about difficulties with reading and writing – its roots may lie in differences in how speech sounds are processed as early as infancy. According to one hypothesis, richer linguistic exposure could have a positive effect on children predisposed to dyslexia. Researchers at the SPEAKin lab are now testing this idea with Czech infants.

But does simultaneous bilingualism – that is, acquiring two languages from birth or very early childhood – have any downsides? A few, perhaps, but nothing alarming. For instance, it might take bilingual children a bit longer to retrieve words from a specific language on demand. If you suddenly ask them to list as many words as possible starting with "k" in one of their languages in sixty seconds, they'll actually likely perform worse than a monolingual peer of the same age. Not because their vocabulary is smaller, but because in their mind, both languages are competing for attention.

BABBLING IN SILENCE

CODA – children of deaf adults – is the term used worldwide for hearing children of deaf parents. This is far from rare: up to 95 percent of deaf couples have children that are not deaf or hard of hearing. In the Czech context, such children typically first acquire Czech Sign Language and only learn spoken Czech later, in preschool. They are therefore bilingual – bimodally bilingual, across two modalities. "Some can even sign and speak at the same time, which is incredible," says Kateřina Chládková, who also studies this type of bilingualism together with her colleague Michaela Svoboda.

LIKE STRINGING BEADS

According to a well-known Czech saying, "the more languages you know, the more lives you live." And researchers tend to agree. Each new language comes with a new culture and its specific features – and, according to research, this can subtly shape our personality.

In one American study from several years ago, Japanese immigrant women



Psycholinguists at the SPEAKin lab also study foreign language acquisition in adulthood. According to them, the key to success is to tune in to the rhythm and melody of the new language first.

fluent in both Japanese and English were asked to fill out a psychological questionnaire twice. When working in their native language, they appeared more reserved and home-oriented in their answers; in English, they came across as more assertive and goal-driven.

So learning a foreign language is not just about picking up new words – it also means trying out new ways of thinking. And when is the best time to start expanding this linguistic – and perhaps even character-trait – repertoire? According to Chládková, the earlier, the better: as early as preschool, ideally in a way that mirrors the natural process of first-language acquisition – and preschool is an age when children readily accept a new language as part of their world. Initially, it's enough to surround children with the language during everyday activities and let them absorb its melody and rhythm.

"By tuning into the sound of the language, they create this imaginary thread on which they can later string individual beads – words and grammatical rules. Without a solid thread, the beads can scatter at any moment. Melodic and rhythmic patterns also signal connections between parts of sentences, which makes learning much easier," the psycholinguist explains.

That's why nursery rhymes, songs, and clapping or tapping to the rhythm – just like in first-language learning – are such helpful tools. Engaging the body also makes it easier to internalize a new language.

IS TEXT HOLDING US BACK?

By contrast, it's better to hold off on written text, as it can distract from the melody of the language. For preschoolers or schoolchildren who are still learning to read and write in their native language, working with written material in another language may even be confusing. According to Chládková, children should encounter their first textbook only after several years of exposure to the spoken form. After all, even in our native language, we first listen, then ›



KATEŘINA CHLÁDKOVÁ
INSTITUTE OF PSYCHOLOGY OF THE CAS

Kateřina Chládková spent ten years working at universities in the Netherlands and Germany. Since 2018, she has been based at the Faculty of Arts, Charles University, and the Institute of Psychology of the CAS, where she founded her own research group, SPEAKin lab. Her work focuses on native language development from the prenatal period, language acquisition and adaptation in childhood and adulthood, and the social aspects of speech communication. In 2022, Chládková received the Otto Wichterle Award, followed in 2023 by the Lumina Quaeruntur fellowship, supporting five-year research into the brain and the rhythm of speech. She also helped develop the Mooveez app for adult language learning. Together with their three children, Chládková and her husband are building a cider house in South Bohemia.

speak, and it's not until more than five years that we cautiously step into the world of reading and writing.

For Czech children – many of whom begin learning English in the first grade while others start in the third – this could mean encountering written English only around fifth grade onward.

In the early stages of language learning, forced memorization of vocabulary, graded translations, and even an emphasis on speaking are also counterproductive. A more useful approach is to integrate the new language into school subjects like art, music, or physical education. The teacher then simply speaks English during the lesson, allowing students to absorb the language naturally – without drills or stress.

"My son had a woodshop class held in English, where they were building birdhouses. For a long time, he didn't even realize he was acquiring another language. And it worked really well," Chládková recalls.

"So, what did you learn in Spanish today?" parents like to ask their kids when they come home from school. This is precisely the kind of question, however, that psycholinguists recommend avoiding. Excessive pressure on performance undermines motivation. For the same reason, it's not a good idea to constantly correct children if they make a few mistakes singing songs in a different language.

So how can we nurture a love of languages in a way that keeps it enjoyable? One option is to watch and talk about foreign fairy tales and films in their original versions, which allow children to soak up unfamiliar expressions like sponges. For (not only) younger generations, interactive video games can also be a surprisingly powerful source – all in moderation, of course.

Don't expect miracles, though. Sitting your child in front of a TV or computer a few times a week won't make them fluent in "[insert language]" within a year. But you can't go wrong by showing them why languages matter and what they can enable them to do – travel or talk about other countries, cuisines, customs, and everyday life. Curiosity and genuine interest are often the strongest drivers of language development.

> "The written form of a foreign language can block our ability to feel out its rhythm. If we begin learning with a textbook, as is often the case, we're essentially starting from the wrong end."
>
> *Kateřina Chládková*

DO ACCENTS GET IN THE WAY?

Around one-and-a-half billion people worldwide speak English, yet only about a quarter of them are native speakers. The vast majority communicate with a non-native accent – including TEFL (English as a Foreign Language) teachers.

Whether this can affect comprehension was the focus of an experiment by researcher Monika Kučerová. One group of preschoolers listened to an English fairy tale read by two British teachers, another by two Czechs, and a third by one Brit and one Czech. The researchers then tested how many new words the children could identify in a follow-up task. "All three groups performed comparably. It seems that preschoolers can make out new words regardless of their teacher's accent," Chládková sums up.

According to the psycholinguist, Czech speakers generally find it easier to communicate in closely related languages such as Slovak, Polish, or Croatian. However, mastering the vocabulary and grammar of a language branch (like Slavic languages) can actually be more difficult than with more distant languages, where we feel less compelled to map everything onto (in this case) Czech expressions and rules.

Phonetically, languages like Italian may feel more natural to Czech speakers. Italian has a regular rhythm, a distinctive melody that's hard to miss, and a vowel–consonant structure similar to Czech.

LIKE IN THE WOMB

Imagine dunking your head in a bucket of water and trying to listen to people talking around you. That's roughly how a fetus perceives external sounds in the womb. It may not be able to make out specific words or sentences through the amniotic fluid, but it can clearly pick up on intonation, rhythm, and melody of speech. These then serve as a springboard for developing the native language.

According to the researcher, tuning into sound this way could also make language acquisition easier in adulthood. Fortunately, this doesn't mean spending nine months with your head in a bucket. A kind of "prenatal listening" to a foreign language can be tried, for instance, using learning apps like Mooveez, based on current insights into how newborns acquire their mother tongue.

"Adults tend to hunt for familiar words in a foreign language, which distracts them from its rhythm. If they gave it a few weeks and listened to it in a filtered form, they might tune into its melody more easily – and then it might stick more readily," says Chládková, who contributed to the development of Mooveez with her team.

According to Chládková, it pays off to take inspiration from infants in later stages of learning a language as well. Since babies spend months after birth simply listening attentively to language in its natural form (speech), adults should try and do the same – exposing themselves to the target language for at least thirty minutes a day, without trying to understand it. With repeated listening – for example to a favorite podcast – they should gradually begin to pick out individual words and phrases and grasp connections.

Babies start to babble at around six months of age. This activity is also worth emulating when learning a foreign language as an adult. “Don’t put off speaking. It doesn’t have to be real words right away. Try imitating the language somewhere in private, playing with its intonation. Literally just babbling. That alone will help get you talking,” the researcher recommends, adding that it’s crucial not to fear making mistakes.

Young children make countless errors in their native language – and yet, they end up mastering it perfectly, in part thanks to those very mistakes. That’s because when they communicate something different than what they intended, their brain receives invaluable feedback that helps them move forward.

MĀORI OR MALAY?

Joseph Conrad, an English-language writer and novelist of Polish origin, whose works appeared at the turn of the 19th and 20th centuries, became known for his highly refined prose. His spoken English, however, was less polished, likely because he learned the language primarily through texts, which later made it harder for him to grasp everyday speech. The extent to which the so-called Conrad phenomenon holds true is also being investigated by the SPEAKin lab.

> The earlier we start learning a foreign language, the better: as early as preschool, ideally in a way that mirrors the natural process of first-language acquisition.

“Our research suggests that the written form of a foreign language can block our ability to feel out its rhythm. We then tend to constantly compare the new language to our native one, which, in the early stages, is undesirable. If we begin learning with a textbook, as is often the case, we’re essentially starting from the wrong end,” Chládková says.

In one experiment, her team played a five-minute recording in Māori to Czech volunteers. While one group only listened, others also had access to various forms of transcription. The researchers then played all the groups different sentences in Māori and in Malay – a language with a very similar sound profile – this time in filtered versions so that individual words were unintelligible, forcing participants to rely solely on rhythm and melody. Their task was to identify which of the two languages they had heard in the initial recording. The results were clear: the participants who had also seen the written form performed worse than those who relied on listening alone.

“Even the adult brain can tune into the sound structure of language, much like babies in the womb. It simply works better when text doesn’t interfere with the process,” the researcher notes.

That’s also why, in the early stages, it may make sense to watch films without subtitles – they force us to concentrate on reading, which weakens our ability to tune in to the language and absorb its rhythm. This skill appears to be far more important for mastering a language than, say, the age at which we begin acquiring it. The brain retains its ability to form new connections – the foundation of learning – throughout life. A teenager and a sixty-year-old can both absorb Māori; the younger one will usually just do so a bit more quickly.

This raises the question of whether tone-deaf people are at a disadvantage when learning foreign languages. Researchers don’t have a clear answer yet. Available findings suggest, however, that if such learners start in the traditional way, with a textbook in hand, breaking into a new language can be more difficult for them. But if they follow the path of newborns and rely heavily on listening, even a weaker sense of musicality may not be an obstacle.

“No one who has managed to learn their native language can be ’bad at languages.’ Anyone can learn a new language, and at any age at that. You just have to take the right approach,” Chládková concludes with a smile. •



Kateřina Chládková (center) with part of her team (from left): Michaela Svoboda studies speech development in children with cochlear implants and language learning in bimodal bilingual adults. Monika Kučerová focuses on how preschool children understand both foreign and native languages. Martina Dvořáková investigates language acquisition in newborns, while Maroš Filip examines language processing in the adult brain.

Klára Hlouchová

REACHING FOR THE STARS

As a child, she struggled with insomnia. Instead of drifting off, she would spend hours thinking about the origin of life or whether we are alone in the universe. Today, Klára Hlouchová is still searching for answers – only now, sleepless nights have been replaced by her lab.




IS EARTH

\ *E.T.* or *Alien*? Has any sci-fi film managed to portray a plausible form of extraterrestrial life particularly convincingly?

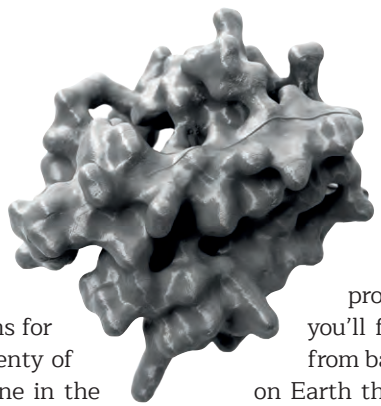
Most science fiction authors work with the idea that it would resemble life on Earth – and that we certainly wouldn't fail to notice it. But we're more likely to encounter very simple microbial life which we wouldn't be able to discern with the naked eye at all. In an altogether different environment, we might not even be able to detect it, as it could have a completely different molecular basis from organisms on Earth. Andy Weir plays with this exact idea in his book *Project Hail Mary*, whose film adaptation came out in 2026. The notion that we'll be dealing with biochemical otherness seems far more realistic to me than E.T. showing up in our shed one day.

"Today's proteins are composed of twenty amino acids, and you'll find this set of twenty in all living organisms – from bacteria to plants to humans. There is no organism on Earth that doesn't use them."

Klára Hlouchová

\ But you don't doubt that something living inhabits the universe?

I'd be surprised if it didn't. I would expect there to be an enormous abundance of life in the cosmos. On Earth, life arose relatively quickly – within roughly ten to twenty percent of the planet's total age – and it has persisted here in various forms for about four billion years. And there are plenty of similar planets out there. If we were alone in the universe, it would be, in the words of the founder of astrobiology, Carl Sagan, "an awful waste of space."



\ But it's not exactly teeming with civilizations resembling humans, like in *Star Trek*...

To date, there's no evidence to suggest that. By the way, I absolutely loved *Star Trek* as a kid. My dad and I would watch it for hours. It was very easy to get completely absorbed in it. Sci-fi fascinated me from an early age, which probably impacted my choice of scientific field – but also my sleep as a kid.

\ Did aliens keep you up at night?

I think they contributed quite a fair bit to my difficulties with falling asleep, which I had already as a small kid. At that preschool age, as children often are, I was troubled by questions such as where we came from or what happens after we die. Later, this was joined by a sense of fear and awe of the universe – what it looks like out there, who is out there, and whether someone might be watching us. These thoughts were usually triggered by watching sci-fi and would wake me up at night.

\ So you had nightmares full of aliens and little green men?

My dreams weren't that tangible yet. What frightened me more was the unknown itself. When I got old enough to watch *Alien* and other movies featuring monsters, it actually helped – the unknown took on a form and shape, and now it was something concrete that I could be scared by. *(laughter)*

\ That doesn't sound like much of a win...

Believe me, it was worse before. I remember my teachers constantly complaining that I was sleep-deprived and had bags under my eyes. And it wasn't because I was up all night gaming. My parents would send my sister and me to bed on time, they'd read to us, but it didn't help. Then they tried giving me the children's book *Karlsson-on-the-Roof* to read before bed. I think they assumed it'd be boring enough to lull me to sleep. But the same questions kept crossing my mind.

\ Today, you're trying to answer some of them in your work. What interests you most?

My research revolves around the main building blocks of life – proteins and nucleic acids. We focus primarily on proteins, which perform the vast majority of functions in our cells. Today's proteins are composed of twenty amino acids, and you'll find this set of twenty in all living organisms – from bacteria to plants to humans. There is no organism on Earth that doesn't use them. In other words, all life on Earth rests on the same molecular foundation.

\ Wait – so, let's say, a rhinoceros, a *Streptococcus* bacterium, and a daisy all arose from the same "ingredients"?

With respect to proteins, yes. This fundamental basis is shared by all organisms. It's known as the central dogma of molecular biology. The enormous diversity of animal and plant species is then determined, among other things, by how these amino acids are arranged. Imagine you have twenty differently colored beads that you string together in different combinations...

\ ... and while one arrangement gives rise to a capybara, another produces a human?

It's not quite that simple. Still, this set of twenty amino acids is present in all living things. We've yet to discover a cell that uses fewer amino acids. What interests us is why

KLÁRA HLOUCHOVÁ
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Klára Hlouchová leads the Research Group of Synthetic Biology at the Faculty of Science, Charles University, and also works at the Institute of Organic Chemistry and Biochemistry of the CAS. Her research focuses primarily on the fundamental principles of life, its origin, and the possibility of its existence beyond Planet Earth. As a postdoc researcher, she worked at the University of Colorado Boulder and at the NASA Astrobiology Institute. In 2024, Hlouchová was awarded an ERC Consolidator Grant for her research. In the same year, she received the Neuron Award for promising young scientists in the field of biology.



evolution selected exactly these components. The selection is crucial, because it helped enable the perfectly coordinated interplay of chemical reactions we call life.

How do you even figure something like that out?
It's extremely difficult. Rewinding evolution to more than four billion years ago to observe what actually happened is, of course, impossible. What we can do is try to mimic various processes that may have led to this selection and monitor how they function. Meteorites and other possible sources of prebiotic chemistry tell us that early life used fewer amino acids than it does today, mainly the simpler ones, despite having an enormous number of options. There was a great deal of chemical chaos – so the prebiotic "soup" certainly offered plenty to choose from.

How did life ultimately arrive at the final top twenty amino acids?
Nature selected them to work as efficiently as possible. Early amino acids were already capable of building proteins, but the results likely weren't as impressive as what we see today. Each additional amino acid that got incorporated into the alphabet of life brought some functional or structural advantage to proteins. It was essentially a kind of evolutionary fine-tuning, during which the optimal set of twenty amino acids emerged.

But you had the idea of "removing" one of them. Why?
To find out whether life could make do with just nineteen "beads." That's why we're trying to construct a bacterial strain called LIFE-19 that would rely on a reduced number of amino acids to build proteins. Then we'll observe how such an organism performs.

Does it look promising?
It's still too early for any conclusions. We received funding for the project in the form of a five-year ERC Consolidator Grant, and we got started in July 2025. First, we identified ›

a suitable candidate for removal – the amino acid tryptophan, which likely entered our genetic code last. We've already tried removing it from one metabolic pathway, and it turned out not to have a major effect on the cell.

"I believe there is an abundance of life in the cosmos. If we were alone in the universe, it would be, in the words of the founder of astrobiology, Carl Sagan, 'an awful waste of space.'"

Klára Hlouchová

So nineteen beads might be enough?

We still need to test another hundred pathways. But based on our previous experiments, we believe it's feasible. At the cellular level, this is our first time playing this game, but we've been producing proteins from a smaller set of amino acids for years. So we know that proteins can perform their functions even with half the repertoire of beads – that is, just ten amino acids. However, removing such an important component directly from a cell is a different level entirely. In fact, we are attempting to alter the central dogma of molecular biology itself.

What if it turns out that the cell doesn't miss tryptophan at all?

That would mean that at least some organisms can exist with a reduced version of the genetic code. For us, it would be an invitation to remove additional amino acids to find out how far we can go without causing too much disruption. It would also essentially allow us to glimpse the past – to see what cells might have gone through billions of years ago when balancing on the line between life and non-life, and to map that situation more clearly. Moreover, such a discovery could be applied in biotechnology. It could serve as a guide for how much a cell can be reduced. The resulting minimal synthetic cells would be very energy-efficient, which is useful, for example, in the production of various pharmaceuticals.

Your next project seems to extend all the way into outer space. Can you tell us more?

It's called PROTOCELL, and it's one of thirteen experiments supported by the European Space Agency that are expected to become part of the mission of Czech astronaut-in-training Aleš Svoboda to the ISS in 2027. Together with colleagues from the Institute of Organic Chemistry and Biochemistry of the CAS, we'll be working with protoribosomes.

That's a term you'll need to explain.

Protoribosomes are essentially molecular fossils inside ribosomes, which are sometimes compared to the cradles of all life. In present-day cells, ribosomes function as protein factories. They read genetic information from mRNA, and based on its instructions, ribosomes assemble the individual "bead



colors" in a sequence. It's one of the key molecules of life. Its central, evolutionarily oldest part is called...

... a protoribosome.
Exactly! It consists of a complex of RNA and small proteins called peptides. We've noticed that when these components interact, they form droplets resembling possible precursors of today's cells. The aim of the PROTOCELL project is to find out whether this also happens in space, and how these droplets behave in microgravity.

WHERE DID LIFE COME FROM? RNA TO SPACE THEORIES

No one can say with certainty exactly how life arose on Earth nearly four billion years ago. Several hypotheses exist. One is the RNA world theory, which proposes that RNA molecules were at the origin of all life. Another emphasizes early metabolism. Science doesn't entirely rule out the panspermia hypothesis either, which suggests that the building blocks of life arrived on our planet from space, carried, for example, by meteorites. "Today, however, we tend to believe that the answer lies at the intersection of different lines of thought," says astrobiologist Klára Hlouchová.

Will Aleš Svoboda be putting together a "concoction" of them on the ISS?
That will be handled by small incubators he will take to the station. In these miniature labs, solutions of RNA and peptides will automatically mix to form droplets. A built-in microscope will then observe them for several hours, after which the sample will be frozen so that we can examine it thoroughly once the mission returns to Earth. This will show whether gravity is needed to initiate protocellular processes – or not. And we'll be one step closer to answering the question of whether life can evolve beyond our planet.

You've been pondering these questions since childhood. Did you ever imagine that you'd be dealing with them in your work? What did you want to be as a kid?
I come from a family of doctors, so for a while I was tempted to become a doctor myself. But I was somewhat irrationally afraid of routine, and I suspected I wasn't disciplined enough to show up at the hospital at six every morning and have my schedule mapped out weeks in advance. I also toyed with the idea of astronomy, which I later went on to study remotely.

And there's space back in the picture.
True, it's stuck with me. That connection isn't something you can just erase. My dad was an amateur astronomer, and when I was little, he often took me to the observatory in my hometown of Třebíč. There was a group of people who were learning the basics of programming, and I'd usually just sit in a corner drawing. But the "nerdy" environment somehow calmed me. And every once in a while, when the roof opened and we looked at the planets, it felt magical.

Did that lead to a restless night afterward?
Probably. It certainly affected my dreams – just like when my dad would tell me about the formation of planets and galaxies. And I kept asking him more questions.

You were clearly a contemplative child. Did you consider a career in science?
I didn't register science as a possible profession. But I did have an experimental streak from an early age. I loved brewing "potions" out of mud, sand, and pine needles, or tried to tame frogs. My sister, who is now a doctor, and I also carried out various experiments with cats.

Did that include dissection?
Fortunately not. But we would, for instance, soap surfaces the cats walked on and watch how they handled it. Or we tested whether they really do always land on all fours, as we had read somewhere.

Did you confirm that hypothesis?
I don't think we did. In any case, looking back, I'd like to apologize to them. Alongside these experiments, I also enjoyed math. In elementary school, I attended various math camps. But then I went on to an international high school in Prague, and math fell by the wayside – I became more interested in literature and even considered a career in diplomacy.

But in the end, you enrolled in chemistry...
I felt like I didn't understand it at all. It was always a mystery to me. So I thought I'd spend my gap year on it before going abroad to study physics, which had caught my interest toward the end of high school. I just wanted to figure out whether chemistry could even be understood. ›

"In the PROTOCELL project, we want to find out whether a planetary environment and gravity are needed to initiate protocellular processes – or not. We'll be one step closer to answering the question of whether life can evolve beyond our planet."

Klára Hlouchová

Clearly it can, since you stuck with it!
Already in my first year, I was captivated by the work and approach of Professor Jan Konvalinka, now Director of the Institute of Organic Chemistry and Biochemistry of the CAS. Later, I started going to his lab, and that was that – I discovered the world of science and fell completely in love with it. I also realized that biochemistry is much more creative and clearer than my beloved astronomy, where answers to various questions and hypotheses are often difficult to test. Later, it turned out that my love of the lab and my interest in space could be somewhat combined.

In astrobiology?
Exactly. I had no idea it even existed – until Jan Konvalinka told me, while I was finishing my master's thesis, about the possibility of applying to a summer school in astrobiology at the Vatican Observatory. By then, my "astro-cravings" were already well known in the lab. So I spent a month in Italy – and after that, I had no doubt about the direction my future would take.

"Every day feels like a detective story. We're solving puzzles and mysteries, coming up with experiments – it's incredibly creative. Being a scientist is my dream job."

Klára Hlouchová

But you still completed a PhD in biochemistry.
I had already applied for it before the Vatican stay. But for my postdoc, I went to Colorado to work with Professor Shelley Copley, where I focused on the evolution of metabolic pathways. Her lab is part of the NASA Astrobiology Institute – something I only found out after I got back home – but it basically served as a kind of entryway into that new world.

So you were doing a fellowship at NASA, unaware of the fact?
In a way, yes. The Astrobiology Institute is more of a virtual entity. It brings together research centers, mainly in North America, where this field is actively studied. And the lab I worked in was part of it. In reality, though, it was a university like any other. Since my husband and our young son were there with me for the postdoc, it was quite an adventure for our family. The only thing missing was the ocean I had dreamed of.

Colorado isn't exactly close to the ocean.
It's about as far away from it as you can get! I had always wanted to do a postdoc somewhere on the coast. But back then, I enthusiastically found a supervisor, wrote to her, and only afterward checked where she was based. And so we ended up practically in the middle of the USA. Still, the ocean has never stopped calling to me. It inspires me.

Is that why you wear a seashell around your neck?
That's part of it. It's a remarkable structure of life and I've worn it for many years. Maybe it subconsciously reminds me of where I feel good. When I was a kid, salt water helped with my eczema, so I associate the sea with regeneration, relief, and a kind of reset. That's why I chose the location for my six-month sabbatical much more carefully – and soon, we should be on the Japanese island of Okinawa, in the middle of the Pacific Ocean.

Will your family come with you again?
We'll see. We now have three children, and our eldest son is sixteen. He has plenty of his own activities, so I'm not sure whether he'll be able to stay with us the whole time. It will also be complicated for my husband, who has been the mayor of the Central Bohemian municipality of Tehov, where we live, for the past eleven years and is very busy. How long he'll stay with us will also depend on the outcome of the next election.

You've received an ERC Consolidator Grant and other funding, you've won the Neuron Award... Your research career is clearly going well. At the same time, you're a mother of three. How do you manage this balancing act?
Badly. I often feel guilty that I'm not doing anything as well as I should. What drives me is that I truly love both my family and my lab. I also have great support from my husband. But my passion for science definitely comes at a cost. I comfort myself with the thought that when kids see their parents passionate about their work, it can be inspiring for them.

They probably won't hear you saying "Thank God it's Friday" anytime soon...
Definitely not. This is my dream job. Every day feels like a mini detective story. We're constantly solving puzzles and mysteries, coming up with experiments – it's incredibly creative. Add to that writing, reading, traveling, and meeting interesting people, and you get a perfect mix. And if you can manage to get funding agencies excited about what fascinates you, you gain complete creative freedom. That's a kind of professional zen right there.

Still, you nearly left the world of science during parental leave.
It's true that when I was home with my second son, I felt torn. I was trying to start my own lab, which was demanding. I had also founded an after-school nature group for

small children from around Tehov, which I ran very spontaneously – a few of us parents would take, say, fifteen kids into the woods, play with them, teach them about nature a bit. And over time, cows were added to the mix.

\ Come again?
We teamed up with a group at a nearby farm and explored the world of cattle and other animals. These activities brought me a lot of joy, and for a while I could imagine living like that – being a present mother, rather than one who's always at work or traveling the world. But I soon started to miss science and the continuous intellectual challenge it gives me.



\ Will your children follow in your footsteps one day?
Probably not. My eldest son has even told me he'll never be like me. Already it's almost certain he'll become an artist. My eleven-year-old has always seen himself as an oceanographer – he probably imagines he'll just work on the beach. He definitely has an exploratory streak, though. He's also interested in space, but I deliberately don't talk to him about it too much so as not to influence him. And my four-year-old daughter will most likely be a princess. (*smiling*)

\ Do your children travel with you to conferences?
During the summer holidays, usually yes. But during the school year, I mostly go alone. That's how I recently discovered the charm of dawdling. When I step out of my packed everyday routine while traveling and suddenly don't have to rush to pick anyone up, I just sit and look at the trees or watch the bustle of a foreign city. These tend to be the most creative moments for me.

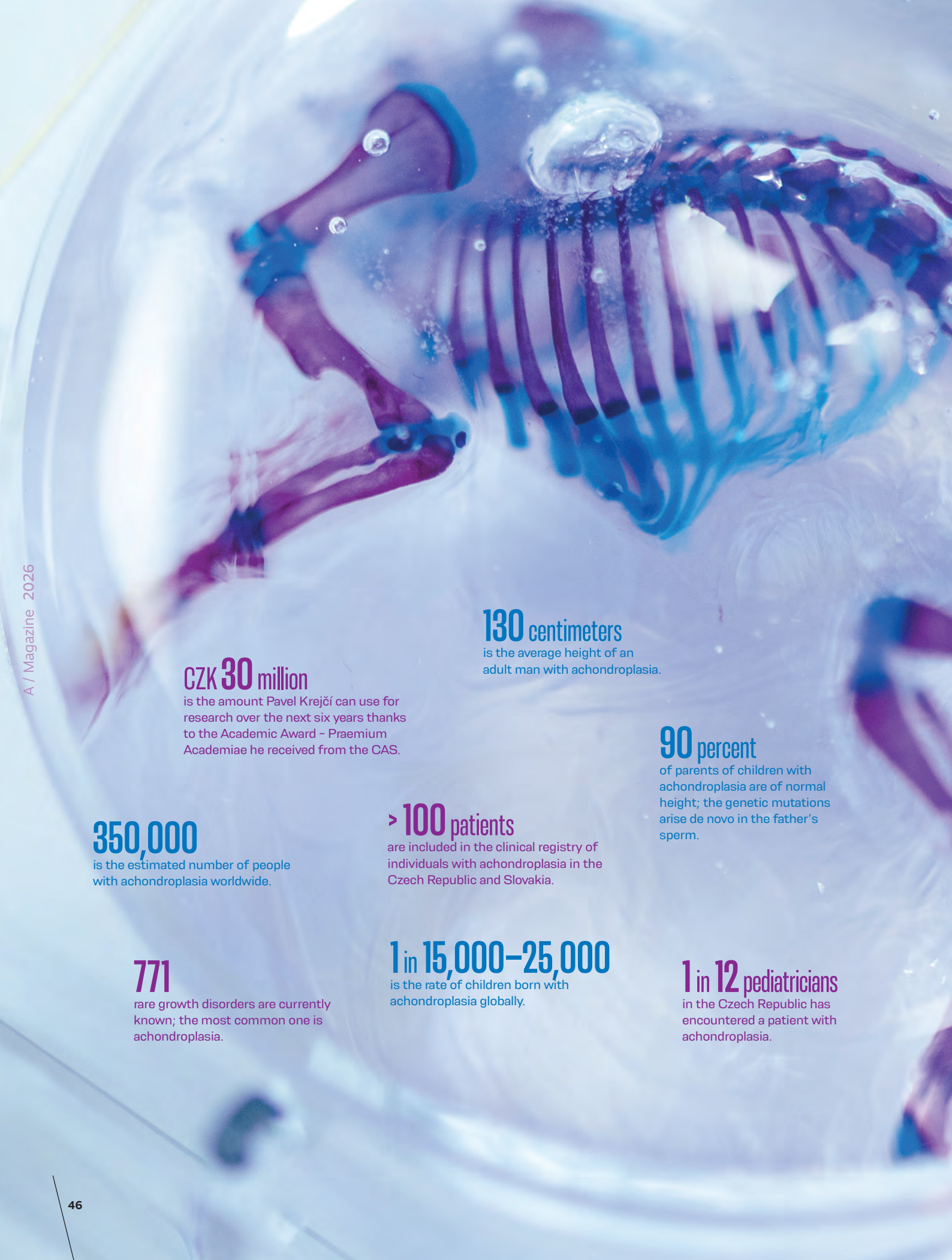
\ In what sense?
I come up with new projects and things I wouldn't think of in the lab. Of course, plenty of nonsense creeps in as well, but now, I actively seek out those idle moments.

\ What about some real downtime without any thoughts of research?
There's very little of that these days. I used to relax by digging in the dirt around our house, which I hardly have time for anymore. The forest has also always been a great refuge for me. Whenever I felt overwhelmed, I would escape there. But even though we have plenty of woods around our village, I no longer really have the time. My free time often revolves around our kids' activities – so when my son is playing in a chess tournament, I get a moment to sit down and think.

\ About grants and experiments again?
Don't worry, I'm not constantly thinking about work. Last summer, for instance, my colleagues occasionally lured me out to play tennis with them, which I used to do as a teenager. That was really nice. Sometimes I also manage to go camping with my family. And if the conditions at home align, I go to yoga on Sunday evenings. But when I really need to switch off, a hot bath wins. We even have two bathtubs at home – I don't think I'd survive without one.

\ And what about without sci-fi?
I'd be very reluctant to give up science fiction, even though I no longer escape into it as often as I'd like. I've just started another book by my favorite Isaac Asimov. I also recently rewatched the first *Avatar* film with my son. I've probably seen it three times already, and it definitely won't be the last.

\ And how's your sleep these days?
Compared to my childhood, I fall asleep wonderfully now. Usually so quickly that I don't even notice it. I regularly beat my kids at it. And when something does wake me up at night, it's no longer UFOs, aliens, or existential questions like before, but rather the stress of not having managed to solve these mysteries in the lab yet.



130 centimeters
is the average height of an adult man with achondroplasia.

CZK 30 million
is the amount Pavel Krejčí can use for research over the next six years thanks to the Academic Award – Praemium Academiae he received from the CAS.

90 percent
of parents of children with achondroplasia are of normal height; the genetic mutations arise de novo in the father's sperm.

350,000
is the estimated number of people with achondroplasia worldwide.

> 100 patients
are included in the clinical registry of individuals with achondroplasia in the Czech Republic and Slovakia.

771
rare growth disorders are currently known; the most common one is achondroplasia.

1 in 15,000–25,000
is the rate of children born with achondroplasia globally.

1 in 12 pediatricians
in the Czech Republic has encountered a patient with achondroplasia.

Text: Leona Matušková \ Photo: Pavlína Černoch Jáchimová (3), František Špoutil, Gustavo Rico-Llanos



CARTILAGE

STEP ON THE GAS

People with achondroplasia are documented throughout history – from ancient Egypt to the courts of European kings. But only now are scientists beginning to unravel what causes the condition. Will it one day be possible to completely counteract its effects?

He owned thousands of head of cattle, twenty palaces, and held numerous religious titles. Seneb, a high-ranking official in ancient Egypt in the third millennium BCE, had a beautiful wife and three healthy children. Yet he faced challenges. What set him apart from others was his unusual stature. His torso was average-sized, but his head was somewhat larger and his arms and legs were markedly short. Seneb is the earliest known historical figure with the growth disorder now known as achondroplasia.

Today, an estimated 350,000 people worldwide live with this rare diagnosis; in the Czech Republic, there are fewer than one hundred. This genetic disorder arises before birth, and although the condition can be inherited, up to 90 percent of children with achondroplasia are born to parents who don't have the disorder, as a result of a new mutation. According to some theories, the risk of errors in intricate DNA sequences increases with the father's age, though this isn't entirely clear. In fact, many questions about achondroplasia remain unanswered.

CALIFORNIA, THE CENTER OF RESEARCH

Since the early 1990s, one thing has been certain: achondroplasia is caused by a mutation in a gene abbreviated as FGFR3. "An enormous amount of research was done in the first six years after the discovery of the FGFR3 mutation in 1994. I entered the field around the turn of the millennium and, to be honest, I thought everything had already been explored. The opposite turned out to be true," says Pavel Krejčí from the Institute of Animal Physiology and Genetics of the CAS.

"The reality is that we understand perhaps ten percent of the achondroplasia mechanism. The rest remains largely unknown," adds Krejčí, who in 2001 left his alma mater, Masaryk University, to gain experience at the Cedars-Sinai Medical Center in Los Angeles. At the time, this institution was at the forefront of research into growth disorders, including achondroplasia, and it's no coincidence that the



PAVEL KREJČÍ
INSTITUTE OF ANIMAL PHYSIOLOGY AND GENETICS OF THE CAS

As a cell biologist, Pavel Krejčí has long focused on research into cell communication mediated by growth factor receptors. He studies the role of FGF receptors, which are crucial for bone growth, and how their genetic defects lead to severe disorders of the human skeleton. Krejčí spent nearly twenty years working abroad, most notably at the Cedars-Sinai Medical Center and the University of California, Los Angeles. In the USA, he contributed to the development of treatment for achondroplasia, a genetic disorder caused by mutations in the FGF receptor 3 that leads to short stature. After returning to the Czech Republic, he established a clinical registry of patients with this rare disorder. In 2019 and 2023, he received awards for medical research from the Czech Minister of Health. In 2024, he was awarded the Praemium Academiae of the CAS.

first breakthrough discoveries were made there thirty years ago.

Researchers there had access to samples from patients with growth disorders from across the USA. Thanks to a carefully maintained and continuously updated registry, they've identified many different types of skeletal conditions in humans.

A NATURAL LABORATORY

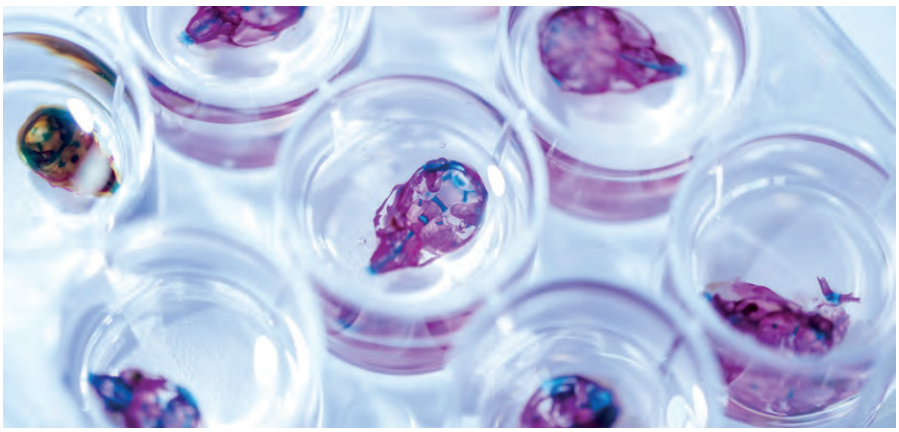
In the case of achondroplasia, one of the main suspects – and indeed the culprit – is the mutated FGFR3 gene. This gene plays a crucial role in bone development but also influences processes in other parts of the body, so its disruption can cause serious issues. It's one of the frequently mutated human genes, and some of its variants are associated with cancer, including liver cancer and bladder cancer.

Many research teams around the world study the functions and defects of FGFR3, but most focus on cancer, where FGFR3 behaves in exactly the opposite way to what we see in achondroplasia. While cancer involves accelerated and uncontrolled cell proliferation, achondroplasia is characterized by the inhibition of cell growth.

A mutation in the gene leads to dysfunction of the protein of the same name, FGFR3, which stands for fibroblast growth factor receptor 3. A receptor is a molecule on the surface of a cell that enables communication. This particular receptor is located on the surface of a chondrocyte – a cell responsible for the growth and formation of cartilage (connective tissue).

When FGFR3 malfunctions due to a genetic mutation, the transmission of information falters, and development in the body goes awry. "We can view growth disorders – and achondroplasia in particular – as an ideal lab for studying cellular communication. Pathologies actually teach us how the organism is supposed to function properly," Krejčí says.

To better understand this, we can picture FGFR3 as a modulator of bone growth that determines how quickly or slowly cartilage cells can divide and mature. Under normal conditions, it acts as a gentle brake regulating the entire process. It tells the body: "Wait, it's not yet time to lengthen the bones," or "Proceed, but gradually and steadily." However, if the guardian becomes overactive due to a genetic mutation, the brake gets stuck and cannot be released. The growth of long bones slows down or ceases altogether. This is exactly what happens in patients with achondroplasia. Their braking system is excessively active, and the bones of the arms and legs stop lengthening around the age of four.



In achondroplasia research, scientists work with mouse models. The image shows colorized skulls – purple indicates bone, blue indicates cartilage.

LESS BRAKE, MORE GAS

If scientists were able to determine how to effectively influence the inordinate activity of this braking system, they could solve the problem of halted bone growth. It sounds simple, but the entire communication system between the receptor and the cell is far more complex. Information is transmitted through intercellular signals known as ligands – in this case, growth factors from the FGF family. If we visualize the receptor (such as FGFR3) as a lock, then the ligand (FGF) is the key that opens it.

Pavel Krejčí's team, together with colleagues from Johns Hopkins University in Baltimore, is currently trying to determine how a single receptor can distinguish among four different ligands. It's similar to an ear listening to four voices at once and the brain understanding what each of them is saying at any given moment.

Some communication pathways, however, are already known, and stimulating the right signaling channels underlies Voxzogo, the first approved drug for achondroplasia, whose development Krejčí was involved in at the beginning. The drug delivers an artificially created signaling molecule into the body that reduces the inhibitory activity of FGFR3 and thus promotes bone elongation. Administered as a daily subcutaneous injection, Voxzogo is intended for children with confirmed achondroplasia whose growth is not yet complete. ›

PROUD AND INTELLIGENT INDIVIDUALS

Achondroplasia affects the growth of long bones, and people with this rare diagnosis have an average height of around 130 centimeters. It has no impact on intellect or personality traits. History and culture offer many examples of successful and well-liked individuals with this condition. In 17th-century Spain, for instance, Sebastián de Morra served at the royal court – a man with achondroplasia that the painter Diego Velázquez immortalized as a serious, proud individual with a direct gaze. People of short stature are also heroic figures in the works of J. R. R. Tolkien; another popular example is Tyrion Lannister in Game of Thrones, who won audiences' sympathy with his sharp wit and clever responses to mockery about his height.



The two mouse skeletons on this page depict healthy animals. Their marked spinal curvature is a natural feature that enables agile movement, and their jaws are typically rodent-like. The skeletons are imaged using computed tomography and subsequently colorized.

HOPE FOR THE FUTURE

The EU approved the drug in 2021, and it's also used in the USA. The results are encouraging. According to available studies, children treated with Voxzogo grew 1.5 centimeters more per year than patients who received a placebo.

"We're developing medicine for future generations. The development and testing of Voxzogo took fifteen years. A new class of treatment will be approved within a matter of years."

Pavel Krejčí

However, the drug is expensive, and its short-term effects are modest. As a result, insurance companies have been reluctant to cover it, and physicians can't prescribe Voxzogo to everyone who might benefit from it.

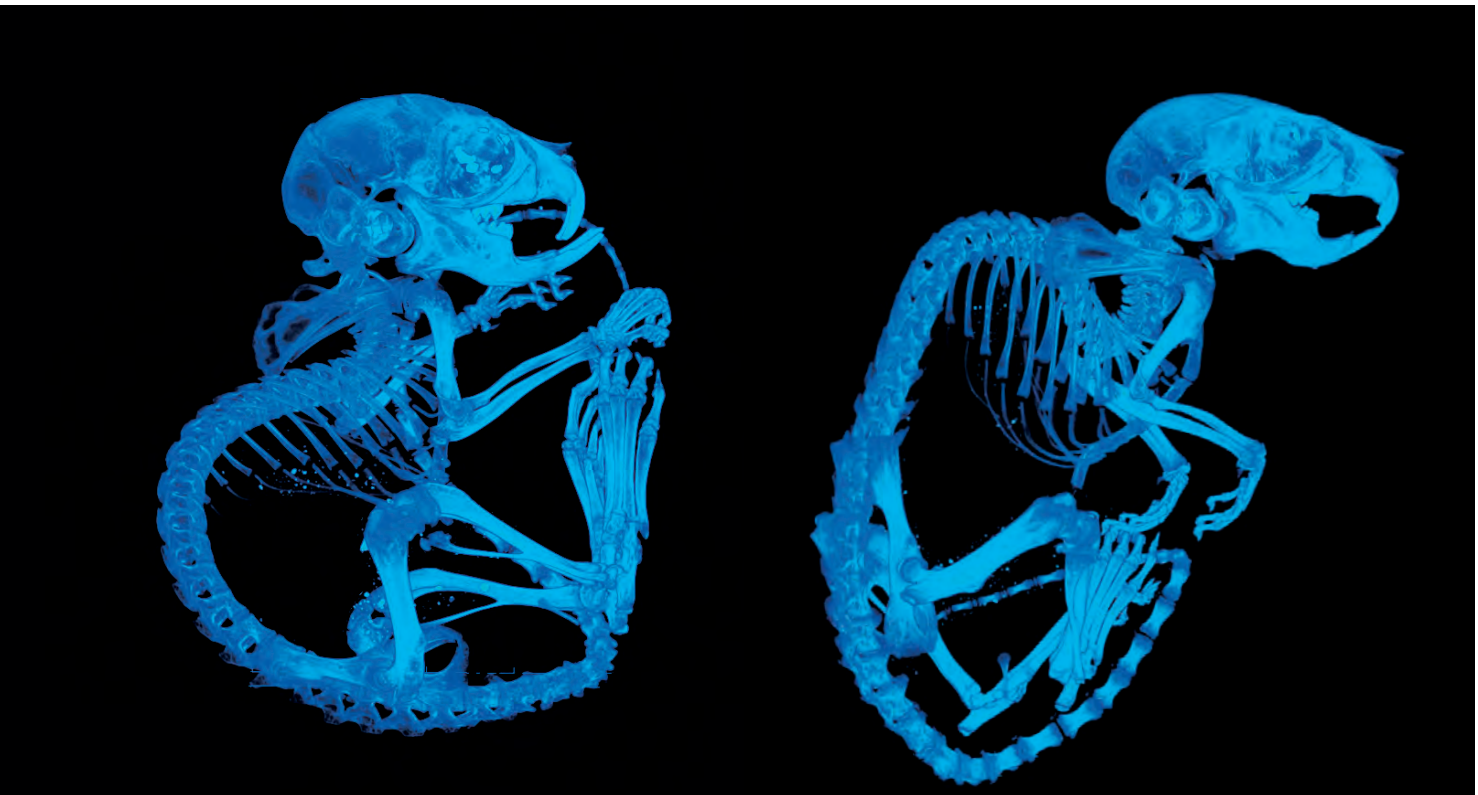
So far, most of the patients using the drug are in the USA (about 40% of children with achondroplasia). In the Czech Republic, Voxzogo is currently used by several dozen patients, and Slovakia is just beginning to administer it. Meanwhile, experts from pharmaceutical companies and scientists – including Krejčí's team – are working on a new generation of drugs that could work even better. Their aim is to find therapeutic approaches that would influence development at the earliest stages of life, maybe even prenatally. Although standard prenatal testing can't detect the genetic mutation responsible for the growth disorder, an experienced gynecologist can recognize it on ultrasound.

"A specialist in growth disorders can detect it early in the second trimester. However, it must be acknowledged that a general gynecologist won't recognize achondroplasia until much later," Krejčí adds. "Our estimate suggests that, in practice, one in twelve Czech pediatricians will encounter achondroplasia at some point in their career.

WORKING TOGETHER IN SYNERGY

A major advantage that helps Krejčí in researching rare growth disorders is the synergy between institutions. He has long been affiliated with the CAS as well as the Faculty of Medicine and the International Clinical Research Center of Masaryk University and St. Anne's University Hospital in Brno. This provides him with both top-tier facilities and direct links to physicians and patients. At the Faculty of Medicine, he established the Registry of Achondroplasia (ReACH), which currently contains records of several dozen pediatric patients from the Czech Republic and Slovakia.

The registry helps researchers better understand the medical aspects of achondroplasia. For patients and their families, it offers an opportunity to provide feedback to experts. The registry has also yielded a somewhat surprising finding.



Mouse model of achondroplasia: on the left is an untreated animal with significantly shortened limbs and altered torso proportions, on the right is a mouse treated with a next-generation FGFR3 inhibitor, showing elongation of long bones and a partial normalization of skeletal growth.

Most fathers of children with achondroplasia were of typical age at the time of conception – at least among Czech parents, the assumption that advanced paternal age is a risk factor for mutations in the growth gene hasn't been confirmed.

However, it's known that FGFR3 somehow impacts the development and function of sperm – one of many research aspects pursued by Krejčí's team. The FGF signaling system evolved over approximately 700 million years, from jellyfish to humans, and is highly complex. In addition to bone development, it regulates most other cellular processes involved in human growth and development. From this perspective, studying achondroplasia offers scientists an exceptional opportunity to understand the mechanisms of life at the cellular level.

ACHONDROPLASIA IN HISTORY BOOKS

Conducting large-scale research wouldn't be possible without adequate funding – for Krejčí's group, this has been provided since 2024 by the Academic Award - Praemium Academiae. "We're developing medicine for future generations. The development and testing of Voxzogo took fifteen years. A new class of treatment will be approved within a matter of years," Krejčí says. The drugs his team is working on now – which may one day fully resolve the skeletal symptoms of achondroplasia – are expected to become available within the next decade.

"It's a long-distance run, and in many ways, research is comparable to elite sports. You train, fight, and push yourself to the limit, you try to stay at the top and compensate for waning strength. The Award has given me the power to run another lap."

As the highest grant awarded by the CAS, the Praemium Academiae amounts to CZK 30 million over six years. Its advantage lies in its flexibility and the freedom it offers by reducing the administrative burden. Krejčí doesn't intend to spend the funds on upgrading lab equipment, not needing new instruments. Instead, he sees real value in people – their enthusiasm, intellect, and abilities – and plans to invest primarily in his team.

Krejčí knows many of the families of children with achondroplasia personally, both in the Czech Republic and Slovakia, and deeply wishes to improve their lives. At the same time, he is aware of the limitations of the current therapy – it hasn't been in use for very long, and its long-term benefits are yet to manifest.

"The ultimate goal is to relegate achondroplasia to the history books, but we aren't there yet. My main ambition is to do everyday, ordinary scientific work well. I still find that immensely enjoyable," the cell biologist says. "I'm like a car mechanic who looks forward to every new vehicle," he adds. The automotive analogy is no coincidence. In addition to being an avid motorcyclist, Krejčí has always had a strong interest in technology – he has long seen parallels between the world of engines and cellular communication. Cells are intricate mechanical systems, and there is nothing more satisfying than seeing them work like well-oiled machines – something Krejčí's work helps make possible. •

Invasive CATFISH





Text: Markéta Wernerová \ Photo: Jana Plavec

A NEW SHERIFF IN TOWN

One of Medek's fishponds near the Czech town of Kroměříž is home to the invasive black bullhead catfish (*Ameiurus melas*), which now reigns beneath the surface. Native to North America, it was introduced into Europe in the 19th century and quickly spread, becoming a major threat to aquatic ecosystems. The black bullhead is an omnivore, has few natural predators, and reproduces rapidly, overwhelming other species. In doing so, it endangers native fish populations and causes economic losses at fish farms. As such, its presence must be carefully monitored and controlled. Researchers from the Institute of Vertebrate Biology of the Czech Academy of Sciences are collaborating with fishing companies and associations to address the issue, one example being their work to improve capture techniques for this unwanted intruder.





A TALE OF TWO BULLHEADS

Alongside the black bullhead, the pond is also home to its close relative, the brown bullhead (*Ameiurus nebulosus*), though it only plays a minor role here as its numbers are nearly one hundred times lower. The black bullhead appeared in the Czech Republic in 2003, having been inadvertently introduced with carp stocking material from Croatia, while the brown bullhead has been swimming in Czech waters much longer, since around 1890. At that time, fish farmers intentionally introduced it into ponds in Třeboň. The two non-native invasive species differ slightly in appearance. The black bullhead has a greenish skin tone, while the brown bullhead is more brownish or marbled. Their tail and anal fins also look different. The fish shown in the photos (black bullhead below, brown bullhead above) are one year old and measure about 10 centimeters. As adults, they reach a maximum length of around 30 centimeters.





BEWARE THE SPINES!

Black bullheads have sharp spines in their dorsal and pectoral fins, equipped with small venom glands, which they can raise and lock in place. A sting is painful, making them unsuitable prey for other fish, whose eggs and fry they feed on, significantly reducing native populations. Their diet also includes invertebrates and amphibians such as newts and frogs, which severely disrupts biodiversity at affected sites. Freshly retrieved traps provide clear evidence, with no other fish to be found inside apart from bullheads. “Fish farmers have a major problem with this invasive species. Financial losses can amount to twenty thousand crowns ***(approx. EUR 850)*** per hectare,” says research team leader Pavel Jurajda from the Institute of Vertebrate Biology.





BANNED, FINED, AND UNDER WATCH

"Breeding, selling, and/or transporting black bullheads is illegal. It cannot be imported into the European Union or released anywhere into the wild. It is listed on the EU's official list of invasive alien species, and violations of the ban can result in fines," explains Pavel Jurajda (pictured on the opposite page, top right). Unlike countries such as Hungary or Slovakia, where the situation is already beyond remedy, it is still possible to keep this invasive species under control in the Czech Republic, where it is still only found at five locations: Kroměříž, Pasohlávky, Telč, Mělník, and Prostějov. Researchers are monitoring these black bullhead populations, conducting culls and, at the same time, designing the most effective methods and principles for regulation.











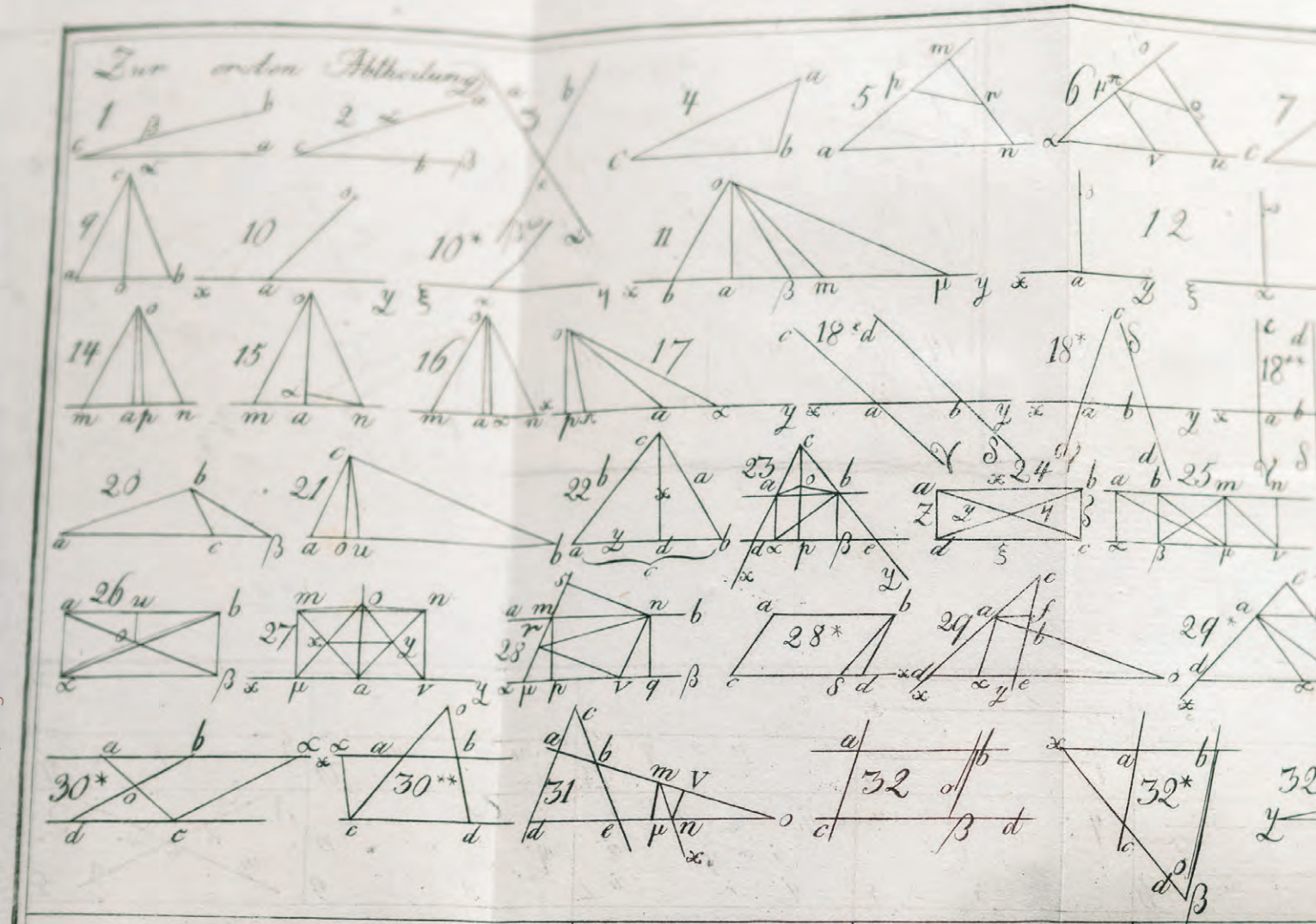


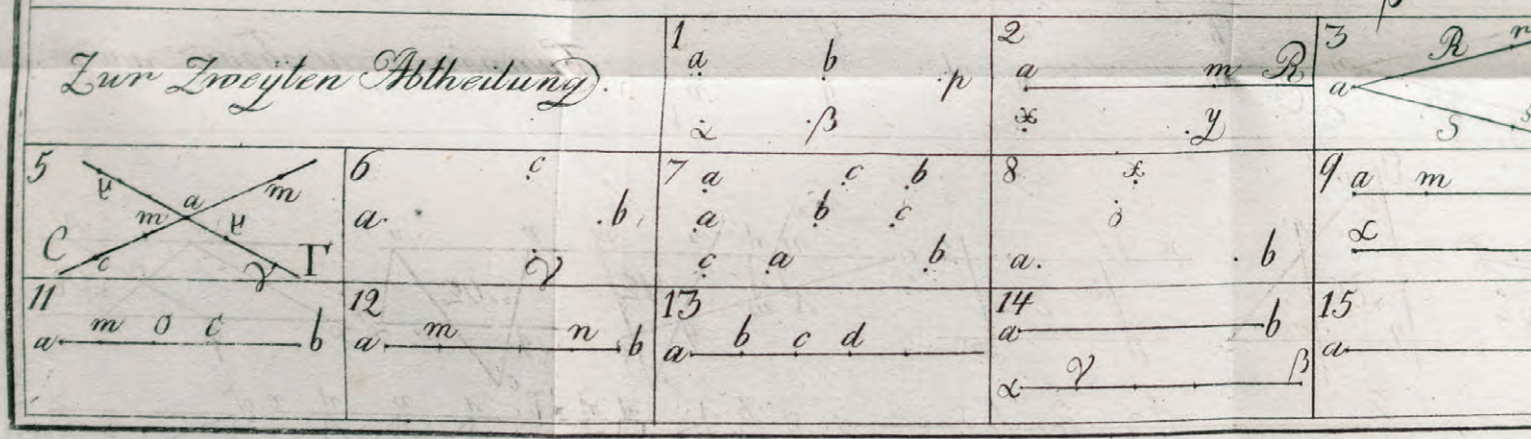


A SNACK FOR OTTERS

The fish harvest took place from Monday to Friday. On the day we visited Medek's fishpond with our photographer, the researchers, assisted by students, had hauled in more than 35 kilograms of fish. Over the entire week, the total reached a quarter of a ton. And not a single fish went to waste. Thanks to the ecological and economic mindset of the staff at the Institute of Vertebrate Biology, the entire catch (apart from a few specimens reserved for laboratory analysis) was taken by workers from the Zlín Zoo in Lešná as a healthy snack for their otters. Though the fin spines of bullheads can cause serious injury to other animals, the otter is adept at eating the fish without its head and spines.







A / Magazine 2026

Text: Leona Matušková \ Photo: Pavlína Černoch Jáchimová, Museum of Czech Literature



BOLZANO

A TREASURE REDISCOVERED

Czech, German, Austrian or Italian? Preacher, philosopher, or mathematician? Prague's Bernard Bolzano was all these things. Now, all his works are to become accessible online.



ELÍAS FUENTES GUILLÉN
INSTITUTE OF PHILOSOPHY OF THE CZECH ACADEMY OF SCIENCES

Elías Fuentes Guillén used to run long-distance races and was considering a career as an athlete, but an injury right before a crucial race steered him to dedicate himself fully to philosophy, history, and mathematics. He graduated from the National Autonomous University of Mexico and the Spanish University of Salamanca. While researching the development of mathematics at the turn of the 19th century, he stumbled upon the story of Bernard Bolzano (1781–1848), which deeply captivated him. He turned his full attention to Bolzano and moved to Prague. Through the PragMatika project, supported by the Czech Science Foundation (GA ČR) Junior Star grant, he explores the history of mathematics in the Czech lands and digitizes Bolzano's manuscripts – including those that no one has examined in detail yet.

When the revolution broke out in France, he was turning eight. As Napoleon's armies marched across Europe, he was finishing his university studies. Throughout his life, figures like Beethoven and Goethe created their masterpieces. The era into which Bernard Bolzano was born to a German mother and an Italian father in Prague was full of revolutionary events which have helped shape our present.

Yet history is not forged by grand gestures and battles on the barricades alone. Bolzano's story shows that European scientific and spiritual culture can also be advanced through quiet intellectual work in solitude, whose significance for modern logic, mathematics, and humanism might only be fully appreciated by a generation a century or two later.

He made his mark across several fields – some might recall his mathematical theories of collections and functions, while others view him mainly in connection with the emerging Czech National Revival. Yet his influence was also powerful in Catholic circles, as well as in the social sciences, logic, and political philosophy.

Given his foreign-sounding surname, we tend to associate him less with Czech history than we do Dobrovský or Němcová. Perhaps that is for the best, though. The dust does not settle on his busts as heavily as it does on their monuments, allowing us to view him with fresh eyes from a historical distance. An unexpected perspective is now offered by a researcher who moved to Prague all the way from Mexico just because of Bolzano.

A DISSERTATION OVERHAULED

"I was working on a dissertation on the 19th-century history of mathematics, focused on its German figures, especially Georg Cantor. I wanted to explore the thought of Cantor's teacher, Karl Weierstrass, and in a transcript of his lectures, I came across an unexpected name – Bernard Bolzano," says Mexican historian of science Elías Fuentes Guillén, recalling his formative encounter with the Prague scholar. Fuentes Guillén first came to the Institute of Philosophy of the Czech Academy of Sciences in 2018.

Karl Weierstrass, sometimes referred to as the father of modern mathematical analysis, mentioned Bolzano as the author of a key theorem that both he and Georg Cantor later expanded upon. Wanting to trace these ideas back to their roots, Fuentes Guillén decided to take a closer look at Bolzano.

He set off on a six-month research stay in Paris, where he met a philosopher of Czech origin and Bolzano expert, Jan Šebestík, and began working with Hourya Benis-Sinaceur, a Franco-Moroccan thinker who translated the Prague scholar's work into French. Suddenly, a whole new world opened up to him. "The more I learned about Bolzano, the more he fascinated me. In many ways, he was completely different, to a certain extent isolated and unknown, yet his work was innovative and remarkable. He came up with certain ideas half a century before some German scholars did," he says.

Upon returning to his home university in Salamanca, he informed his advisor that he would add a chapter on Bernard Bolzano's mathematical writings to his dissertation. "In the end, though, I gathered so much material that I decided to completely overhaul the dissertation and focus solely on Bolzano," Fuentes Guillén smiles. His next professional steps led him to the Czech capital, as Prague held the key to the entire story.

A MATHEMATICIAN, OR A PRIEST?

Bernard Bolzano was born there on October 5, 1781. His mother, Cecilie, was from a traditional Prague German family, while his father, Bernard, was born in northern Italy but had lived in Prague since childhood. At the time, both northern Italy and Bohemia were part of the multinational Habsburg Monarchy, ruled by Emperor Joseph II. Joseph implemented reforms in education, among other fields. High schools and universities were to teach in German rather than the traditional Latin, and greater emphasis was placed on subjects like mathematics, geography, physics, and astronomy. At age 10, the talented Bernard entered secondary school at the Piarist Gymnasium, and in 1796 enrolled in the three-year philosophical studies at Charles-Ferdinand University, designed to prepare students for advanced study in theology, law, or medicine.

At first, math did not capture the young student's interest at all; he was put off by his teacher's rather coarse behavior, as he later recalled in his autobiography. His view shifted when he encountered a different approach to the discipline. "My special pleasure in mathematics was actually based only on its purely speculative side, or rather, I valued in it only that which is simultaneously philosophy," Bolzano writes in his autobiography, published in 1981 to mark the bicentennial of the scholar's birth.

He fell in love with mathematical thinking, while his parents instilled in him a deep respect for people and led him to help others and work for the public good from an early age. After lengthy deliberation, the young Bernard therefore decided to study theology with the goal of becoming a teacher and "publicly lecturing on the good cause of religion."

IN THE WHIRLWIND OF REVOLUTIONS

However, he was reluctant to give up mathematics, choosing to pursue both fields. After all, the concurrent roles of a priest and a scientist were not so exceptional in the past. For instance, Josef Dobrovský, who was a generation older and had been ordained in 1786, dedicated himself to research as well, specifically in linguistics and Czech studies. Bernard Bolzano completed his theological studies in 1804, and various career paths opened up before him.

Yet Bolzano entered the "job market," as one might say today, in rather turbulent times. A decade earlier, revolutionary changes in France had established an atmosphere of chaos and violence across all of Europe. Among those who met their end there under the guillotine was Marie Antoinette, the aunt of Austrian Emperor Francis II. Having ascended the throne in 1792, Francis differed from his predecessors by beginning to curb reforms, fearing that they might escalate into revolutionary madness within the Habsburg Empire as well.

To protect the monarchy, the ruler tightened his grip on power. Society was permeated by secret police, aided by a vast network of informants. Strict censorship took hold as well, which encompassed not only books and other publications, but the curricula at universities and gymnasia alike, where lectures could only be delivered according to pre-approved textbooks. One of the measures to keep the population under control was the establishment of chairs of religious doctrine at the philosophical faculties across the monarchy.

By a strange twist of fate, the fresh theology graduate Bernard Bolzano came to head this chair. It should be noted that the authorities were not very pleased with his work and practically from the beginning he faced attempts at his removal as well as legal proceedings. It is almost unbelievable that he managed to keep his position for a full fifteen years.

He may not have won over the leading figures of the church and state, but the students grew quite fond of him relatively quickly, despite initially harboring great distrust toward him. Before his opening lecture, they even plotted to start stomping their feet at the very first statement that offended them. They were expecting a planted puppet who would moralize from a position of authority – instead, a man appeared who was only slightly older than themselves and whose ideas they found inspiring.

> "The more I learned about Bolzano, the more he fascinated me. He was somewhat isolated and unknown, yet his work was innovative, and he came up with certain ideas fifty years before other mathematicians."
>
> *Elías Fuentes Guillén*

Bolzano motivated his listeners, supported those from socially disadvantaged backgrounds, and always advocated for the pursuit of truth and justice. His pupils would transcribe and share his sermons, which were also listened to and read by many Prague intellectuals, captivated by his unconventional thinking. This was all despite the fact that he did not possess rhetorical skills, which Bolzano himself noted in his autobiography. However, he carefully drafted every lecture in advance.

"Throughout his preaching career at the Prague university, he influenced entire generations of students, who went on to become doctors, lawyers, writers, civil servants, and scientists," says Fuentes Guillén, "I believe that this very aspect – his significant influence on Czech society and on European society in general – is what we should study further."

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IN SEARCH OF THE ESSENCE

Throughout his priesthood, Bolzano could only pursue science in his free time. Yet, he published his first mathematical work as early as 1804 and the next one six years later. From the very beginning, he wanted to redefine all the established concepts. He was not satisfied with them being passed down for centuries – he believed that contemporary mathematicians were working with terms and using methods that were not sufficiently defined and interconnected.

"He went to the very foundations. He wanted to understand and describe concepts such as a line, a point, or a curve anew. Thanks to this, he introduced very innovative ideas, for instance in the theory of functions," the Mexican researcher points out. Thus, in one of his 1817 works, Bolzano presented a precise definition of the continuity of a function on an interval, which he explained purely through the means of mathematical analysis without reference to traditional geometric representation.

In another treatise, he described a special function that is continuous everywhere and, at the same time, "jagged". Today known as Bolzano's function, it is depicted as a curve that is not interrupted anywhere, has a "spike" at every point, and whose direction cannot be determined anywhere. However, this very treatise on functions remained in manuscript during the scholar's lifetime – it was not published until 1930.

Somewhat earlier, yet also posthumously, the treatise *Paradoxes of the Infinite* was published, containing reflections on the possibility of actually infinite collections, such as the collection of truths in themselves. Bolzano was led to this idea by his concept of the proposition in itself (*Satz an sich*) – which is the objective content of a statement that exists independently of whether it is expressed in any language or whether anyone thinks of it. If such a proposition is true, it is a truth in itself (*Wahrheit an sich*).

Geometry, which through Euclid's *Elements* seemed to be a rigid model, also prompted new questions in his mind. He even subjected the work of the ancient Greek "father of geometry" to criticism; however, only fragments of the intended treatise entitled *Anti-Euclid* have survived, and it is not certain whether its complete version was ever created.

"Throughout his preaching career at the Prague university, he shaped generations of students. I believe we should further study Bolzano's influence on Czech society and on European society in general."

Elías Fuentes Guillén



Bernard Bolzano's manuscripts include student notes, as shown by a notebook page from the 1797–1798 school year. LA PNP, Bernard Bolzano, C II 14/2. Manuscript digitised in collaboration between the Museum of Czech Literature and the Institute of Philosophy of the CAS through the research group PragMatika (grant project GA ČR 23-06540M). Licence CC BY-NC 4.0.

FALL FROM GRACE

The repeated attempts to dismiss Bolzano, who was popular among students and the public alike, from his position as the chair of religious doctrine succeeded in late 1819. Such a volume of denunciations and "evidence" regarding his alleged anti-state activities had piled up at both the imperial court and the archbishop's palace that they could no longer be ignored. The scholar was strictly forbidden from hearing confessions and preaching, and the publication of his writings, both religious and purely mathematical, was also barred. Bolzano was not too troubled by being removed from the chair position, but the publication ban caused him deep concern.

"The only thing that truly weighs on me in my present position is that I have such poor prospects of anything I have discovered ever being published," he complains in his autobiography. "Whatever is submitted to censorship under my name is not only denied an imprimatur, but the manuscript itself is immediately confiscated, and repeated pleas for the return of my property are not even deemed worthy of a reply," he writes further.

The bright side of his forced departure from the university was the peace and time that Bolzano newly gained for developing his ideas. He found asylum on the Hoffmann family estate in Těchobuz, South Bohemia, where he spent nearly the next twenty years. It was precisely there that Bolzano's most extensive work, *Wissenschaftslehre* (*Theory of Science*), dedicated to logic, was created; after great effort, it was successfully published in 1837 in Sulzbach, Germany.

WAVES OF INTEREST

Bernard Bolzano did not favor radical solutions. Although he was dismissed from his position as a teacher of religion on the grounds of alleged sedition, he never encouraged his students to revolt nor supported them in doing so. Nevertheless, his life was framed by major upheavals – beginning with the French Revolution and ending with the series of European revolutions in 1848. He died on December 18 of that year at the age of sixty-seven.

Some of his works were successfully published during his lifetime, while others were released following a brief easing of restrictions in 1848. A second wave of posthumous publication of his works occurred in the 1880s to mark the centenary of his birth. For the first time, a Czech translation of *Purely Analytic Proof* was published in 1881, and in the same year, the Czech-language biography *Bernard Bolzano: A Biographical Outline* by Marie Červinková-Riegrová hit the bookshelves.

Czech intellectuals in particular began searching for his other works, the existence of which was known, but whose whereabouts were unclear. For instance, towards the end of his life, the scholar passed a substantial portion of his mathematical research on to Robert Zimmermann in the hopes that he might further develop his ideas, which unfortunately did not happen. Instead, the manuscripts entrusted to Zimmermann ended up in the Imperial Academy of Sciences in Vienna. They remain in the Austrian capital to this day, and for many decades Czech researchers had only limited access to them.

Bolzano's work is essentially divided into the Prague part, preserved at the Museum of Czech Literature, and the Vienna part, held at the Austrian National Library. The goal of Elías Fuentes Guillén's project is to reunite both parts – to digitize all available writings and make them accessible to the scientific community for research.

THE LEGACY IN THE MODERN ERA

The Bernard Bolzano Digital Archive is emerging nearly 180 years after the scholar's death, thanks to the patient work of the Mexican researcher's team. They have successfully digitized and reviewed 36,000 pages of the Prague part of Bolzano's writings so far, and through an agreement with the Austrian National Library, they will add another 11,000 predominantly mathematical writings. Some of these have not yet been seen by anyone today, and their contents remain a mystery.

"I am very curious about what we will find there. In some of his mathematical works, Bolzano mentioned developments he had reportedly worked on earlier. However, we don't know them, nor do we know where they are located," says Fuentes Guillén. Perhaps they are hidden precisely within those thousands of pages that are currently passing through the hands of the research team.

It is also quite possible that these works will reveal other interesting ideas that remain inspiring for the present day. The more the Mexican scholar explores Bolzano's reflections, the more convinced he is that one cannot examine the mathematical part of his work without context from other fields. He therefore plans to establish a Bernard Bolzano research center at the Institute of Philosophy of the Czech Academy of Sciences, which will allow for a better understanding of the scholar's intellectual heritage.

Bolzano never quite fit in – he was and was not a Czech, German, Austrian, Italian... In an era of rising nationalism, he often met with resistance because of this, and the 20th century, full of national conflicts, was hardly favorable to the spread of his intellectual legacy. Today, the world at times resembles a global village, borders and differences between people are partially blurring, and perhaps an ideal opportunity is opening up to dust off Bolzano's works. It is no coincidence that behind this is a scientist who hails neither from the Czech lands, Austria, nor Italy, but all the way from Mexico. •

Information about the project and a link to Bolzano's digital archive can be found on the website Prag-Matika.com.



IN NUMBERS

1786
The year the Bolzano family began living on Celetná Street. Today, a commemorative plaque marks the mathematician and philosopher's former residence there.

1849
A lithograph was created by Josef Kriehuber bearing Bolzano's life motto: "To be happy and to make others happy – that is the human destiny."

1881
The publication of the first biographical study on Bolzano, authored by František Palacký's granddaughter, the writer Marie Červinková-Riegrová.

1999
The Faculty of Mathematics and Physics of Charles University established the Bernard Bolzano Endowment Fund, which awards prizes for the best scientific work in physics, computer science, and mathematics.

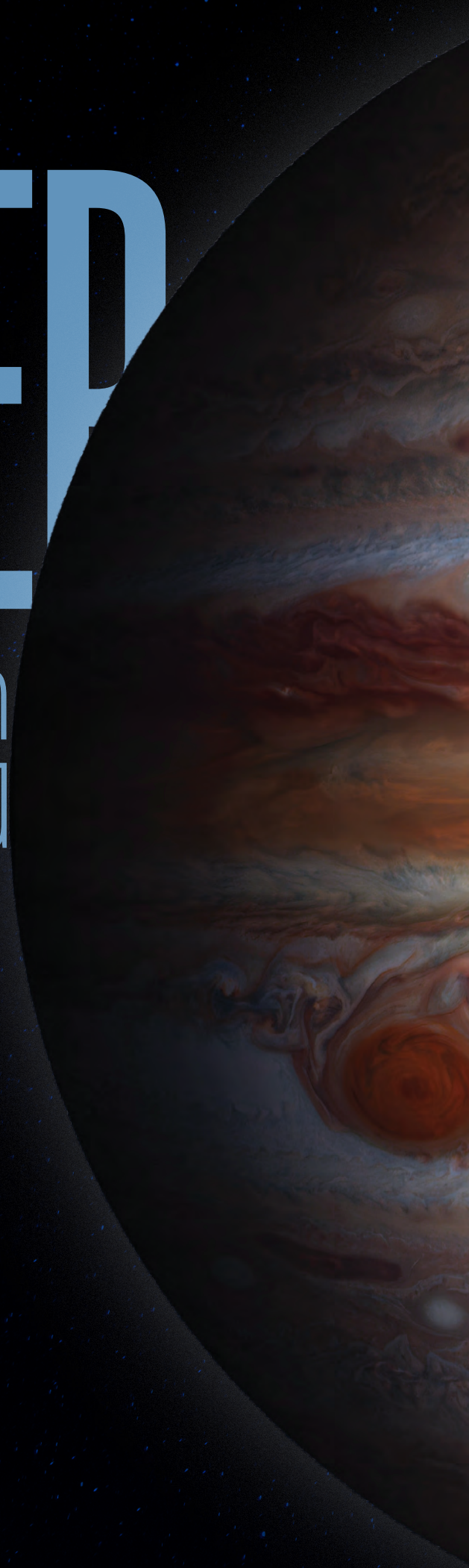
36,000
The number of pages of Bolzano's manuscripts housed in the Museum of Czech Literature that have been digitized in collaboration with the PragMatika research team.

11,000
The number of pages of Bernard Bolzano's manuscripts (predominantly mathematical writings) managed by the Austrian National Library, which will also be digitized and made accessible.

JUPITER

LORD OF LIGHTNING

The planet bears the name of a mighty ancient Roman god and is our Solar System's stormy giant. In Prague, Japanese scientist Masafumi Imai is helping uncover the nature of lightning on Jupiter.





Kōchi Prefecture lies on the southern side of the Japanese island of Shikoku. It is known for its pristine nature, high mountains, and crystal-clear rivers. A paradise not only for travelers, but also for stargazers. Light pollution and radio interference are minimal, unlike near large settlements, where observing the universe becomes more difficult.

"I was lucky to grow up in such a beautiful environment, where I could observe the night sky from an early age. I soon learned about stars and about Jupiter from my father, who was a professor at the local college and who sparked my interest in science," says Masafumi Imai in his office at the Institute of Atmospheric Physics of the Czech Academy of Sciences (CAS).

His current workplace in busy Spořilov, a Prague district hemmed in by an urban highway and the Prague ring road, presents quite the contrast to the Japanese countryside. From the third floor, however, the scientist enjoys a sweeping view of a large part of the Czech capital. Imai believes that variety is essential in life – he greatly appreciates his time in Prague, with its historic buildings and just the right amount of bustle. At the same time, he returns to his homeland about twice a year, drawn by its peace and nature.

JAPANESE DATA IN PRAGUE

The researcher has another reason to travel to Kōchi, Shikoku. Since 2023, the LWA-Niyodo radio observatory has been operating there – an initiative Imai pushed through thanks to his familiarity with the local environment, and which he now runs together with local partners and with support from the CAS. Since March 2024, eight specialized antennas have been receiving radio signals from our Sun and Jupiter, with the measured data streamed in real time directly to Prague.

The low-frequency observatory on Shikoku is part of a global network of similar facilities that monitor radio emissions from space. To cover different



MASAFUMI IMAI
INSTITUTE OF ATMOSPHERIC PHYSICS OF THE CZECH ACADEMY OF SCIENCES

Masafumi Imai comes from the Japanese island of Shikoku. His interest in science was awakened by his father, who worked as a professor at the National Institute of Technology, Kōchi College, Masafumi Imai's alma mater. Imai earned his Ph.D. at Kyoto University and completed a postdoctoral research stay at the University of Iowa in USA. Even back then, he established closer contacts with scientists from the Institute of Atmospheric Physics of the CAS and briefly stayed in the Czech Republic in 2017 and 2019. From 2020, he taught at the National Institute of Technology, Niihama College, in Japan. He has been based in Prague since April 2024, and later that year he received the Lumina Quaeruntur fellowship from the CAS.

times of day, it has proven useful to have stations distributed across various locations. While Europe and the USA are reasonably well covered, Asia and Oceania still lack sufficient observation points.

About five years ago, Imai began considering establishing an observatory in his native Kōchi. At the time, he was completing a postdoctoral stay at the University of Iowa, where he gained experience with a radio telescope in New Mexico. After returning from the USA, the researcher began teaching at the National Institute of Technology, Niihama College and started searching for a suitable site to install the antennas.

"Space music sounds like a mix of crackling, hissing, and whistling of varying intensity – with the whistling typically signaling a lightning discharge."

Masafumi Imai

"I was very fortunate to come across a family friend who was willing to lease his land and allow a research station to be built on it. He spent his whole life working in education at the local town hall and to this day has a strong interest in science, especially space," Imai explains.

A second stroke of luck that helped launch the observatory was Imai's connection to the academic community in Prague. He wanted to continue his research, but teaching at a college left him with little extra time and energy. He decided to reach out to Ivana Kolmašová and Ondřej Santolík from the Institute of Atmospheric Physics of the CAS, whom he knew from his previous short research stays in Prague.

"Ivana and Ondřej are internationally recognized experts in our field, and I wanted to consult with them how or where I could continue my research – whether in Europe or the USA," Imai says with a smile. "I was very happy when they offered me a position in their Department of Space Physics."

The Japanese researcher joined the Spořilov team in spring 2024. Just half a year later, he received the prestigious Lumina Quaeruntur award bestowed by the CAS, which comes with a financial stipend – part of which is now supporting the operation of the LWA-Niyodo radio observatory.

MUSIC FROM JUPITER

Thanks to receivers of electromagnetic radiation scattered across the globe, scientists can "listen" to sounds from space that reveal what is happening tens or even hundreds of millions of kilometers away. Radio waves reach us from both the Sun – on average 149.6 million kilometers distant – and Jupiter. The latter lies more than 700 million kilometers from Earth, but because Jupiter is enormous and possesses an extremely intense magnetic field, it emits radio waves strong enough to be detected even by amateur ground-based antennas.

Most people associate radio with music or the spoken word. Curiously enough, we can also hear electromagnetic radiation from space – when it's converted into the audible range. It sounds like a mix of crackling, hissing, and whistling of varying intensity – with the whistling typically signaling a lightning discharge. Scientists, however, usually work with visual representations of sound in the form of spectrograms, from which they can extract information about lightning and other processes that emit electromagnetic signals.

The very first "sound" of lightning from Jupiter was captured in 1979 by NASA's Voyager 1 mission. The probe recorded radio signals in the audible range of the electromagnetic spectrum, while its camera simultaneously filmed flashes in Jupiter's atmosphere. And though it was confirmed that lightning was occurring on Jupiter, there was a lack of clear data on the intensity and frequency of the discharges.

At the time, scientists already assumed that storms on the gas giant likely resembled terrestrial ones, originating in clouds composed of water in various states of matter, including ice pellets. Studies showing that reality might be somewhat more varied have only begun to appear in recent years.

NEWS FROM THE JUNO SPACECRAFT

Unlike Earth or Mars, Jupiter has no solid surface and, given its immense size, is often referred to as a gas giant. It is by far the Solar System's largest planet – large enough to fit 1,300 Earths inside. Thus, it was already noticed by ancient skywatchers and later piqued the interest of early modern researchers. In the year 1610, for instance, astronomer Galileo Galilei observed it through a telescope, discovering some of Jupiter's moons – the volcanic Io, the icy Europa, the giant Ganymede, and the heavily cratered Callisto. Today we know that nearly a hundred moons orbit Jupiter.

It was Galilei himself whom the spacecraft exploring Jupiter from 1995 to 2003 was named after. It delivered more detailed images of storms and lightning and refined our understanding of the planet's "weather" – though it remained largely limited to optical imaging of the night side. Crucial information about Jupiter's atmosphere is now being provided by the current Juno spacecraft, which is carrying two interesting instruments on board: The "Waves" instrument measures electromagnetic waves across various frequency ranges, and the Microwave Radiometer detects Jovian lightning emissions, among other phenomena.

The radio waves released during lightning discharges are extremely valuable to scientists, as they allow them to study storms even when clouds or other atmospheric components block visible light. This enables the discovery of phenomena that had previously escaped attention, either because earlier ›

spacecraft lacked the necessary instrumentation or because they did not get close enough to the planet.

So what do we know thanks to the analysis of data from the Juno spacecraft? In collaboration with colleagues from the University of Iowa, researchers from Spořilov discovered, for example, "rapid whistlers" – lightning signals that "whistled" approximately a hundred times faster than those recorded by Voyager 1. They also found that lightning occurs approximately as frequently on Jupiter as it does on Earth. Based on previous observations, they had assumed lightning activity on Jupiter to be significantly lower compared to Earth – by up to a factor of a thousand.

Short pulses captured in the high frequency band between 20 kHz and 150 kHz further indicated that Jupiter's ionosphere contains regions of significantly lower plasma density, making it resemble a colander. In the Waves instrument's spectrograms, scientists then found groups of short radio pulses spaced one-thousandth of a second apart, which led them to a surprising conclusion: lightning on Jupiter originates similarly to intracloud lightning on Earth.

Using data from the Microwave Radiometer, researchers also managed to reveal the phenomenon of stealth superstorms, not visible to other instruments. However, lightning flashes within them at an average rate of three times per second, which is significantly more than earlier measurements indicated.

One cannot help wondering whether the size of lightning bolts on Jupiter matches its gigantic proportions. In other words: are there giant lightning bolts on the giant planet? Popular science articles, such as one on the Science website, suggest that the most extreme lightning on Jupiter can release up to 10 trillion joules of energy! However, this may not reflect the reality of most storms. "Some researchers say that lightning intensity is comparable, others believe it is higher than on Earth. It is still being debated," says Imai. More insights will only come through further research.

> "Thanks to receivers of electromagnetic radiation scattered across the globe, scientists can 'listen' to sounds from space that reveal what is happening tens or even hundreds of millions of kilometers away."
>
> *Masafumi Imai*

INDOMITABLE ENERGY

The probability of being struck by lightning during one's lifetime is relatively low, but when it does happen,


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it causes a disaster with fatal or long-term consequences. In the United States and Europe, dozens of deaths are recorded annually, while in India, the numbers reach hundreds or even thousands. Generally speaking, the closer a person is to the equator, the higher the risk. Lightning also has drastic economic consequences, with damages estimated at up to billions of dollars a year.

"On Earth, lightning can truly be very dangerous, which is why we study it. However, I believe it's necessary that we also explore storms on other planets precisely because it will allow us to understand lightning more comprehensively," states Imai.

Lightning is not the only topic that interests the Japanese scientist. He has also been captivated by auroras, which occur on Jupiter as well. While they resemble Earth's auroras in some ways, they also differ from them in many aspects. On Earth, their main source is the solar wind, whereas on Jupiter, it is the moons. Jupiter itself possesses an extremely strong magnetic field – the largest in the Solar System – and a massive magnetosphere. The interaction of its own magnetosphere with particles streaming from the moons, particularly Io, is the primary cause of these auroras.

"Currently, I am mostly working on the topic of lightning and auroras on Jupiter, and partially on Saturn as well. In the future, I would like to explore the situation on the other planets in the Solar System," replies the young researcher when asked about his scientific dream. He also expresses his deep appreciation for the Academy's support in the form of the Lumina Quaeruntur fellowship, which allows him to continue and further develop his work.

Recently, he has also been finding joy and fulfillment in another activity organized by the CAS. He has become an instructor for "Otevřená věda" (Open Science), a program for talented high schoolers. Throughout a year-long internship, he teaches his interns how to receive and interpret radio signals from a small satellite called a CubeSat. It is a palm-sized device that can be built from widely available components in a relatively short time. He would also build similar devices with his students in Japan – a CubeSat created by them has been successfully transmitting signals from Earth's orbit since 2021 and another one launched this April.

"I am very happy to work with the interns because I can sense a great deal of enthusiasm from them. I have two interns, a boy and a girl. The boy is more interested in the engineering aspect, while the girl enjoys software-related matters," adds Imai. He considers supporting the younger generation's interest in science to be a truly meaningful endeavor, and he dedicates himself to it both here and in his native Japan. The pupils and students in Kōchi also participate in the operation of the LWA-Niyodo radio observatory, seeing that cutting-edge science can happen right in their neighborhood. After all, signals from space can be received and studied from all over our planet, from the mountainous regions of Shikoku Island to the Czech countryside. •





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CLOSER TO THE STARS

The Japanese observatory LWA-Niyodo receives data about the activity of the Sun and Jupiter and sends them to scientists at the Institute of Atmospheric Physics of the CAS in Prague for analysis in real time.

1 The idea to build an observatory in the Japanese mountains came from Masafumi Imai, who works at the Czech Academy of Sciences today. The station was established through cooperation with a local space exploration enthusiast, Toshimitsu Ono, who loaned the land and helped with construction.

2 The LWA-Niyodo observatory is made up of eight "bow-tie" type antennas connected to modern receivers based on technology developed for small satellites (CubeSat).

3 The observatory is located in the scenic nature of Kōchi Prefecture on Shikoku Island, which is ideal for observing the night sky thanks to its low light pollution. It was built in 2023 and has been receiving data since March 2024.



NINE RESEARCHERS RECEIVE TOP ACADEMIC GRANTS

Three experienced researchers and six scientific talents received awards from Radomír Pánek, President of the Czech Academy of Sciences (CAS), on 29 October 2025, securing funding for their future research. The Academic Award – Praemium Academiae and the Lumina Quaeruntur fellowship will help these scientists advance their fields and yield new insights. “Each of these awards targets a different group of researchers at various stages of their careers. But they have one thing in common – they are the highest form of support that the Czech Academy of Sciences provides,” CAS President Radomír Pánek emphasized. Last year’s Academic Award, which provides up to CZK 30 million in funding, was presented to Lukáš Palatinus from the Institute of Physics of the CAS, Jiří Neužil from the Institute of Biotechnology of the CAS, and Petr Škrdla from the Institute of Archaeology of the CAS, Brno. The Lumina Quaeruntur fellowship was awarded to Michal Hrbek from the Institute of Mathematics of the CAS, Filip Křížek from the Institute of Physics of the CAS, Aniruddha Mitra from the Institute of Biotechnology of the CAS, Barbora Pafčo from the Institute of Vertebrate Biology of the CAS, Jaroslav Bartík from the Institute of Archaeology of the CAS, Brno, and Václav Smyčka from the Institute of Czech Literature of the CAS. The fellowship provides each laureate with up to CZK 4 million per calendar year for a maximum of five years.



Prepared by: Jana Kuřátková, Markéta Wernerová
Photo: Jana Plavec (3); Zuzana Bönisch, Office of the President of the Republic; Josef Landergott (2); Jaroslav Tománek (2); Pavlína Černoch Jáchimová; Shutterstock; Zdeněk Rerych; Institute of Organic Chemistry and Biochemistry of the CAS; Institute of Physics of the CAS



DANA PLAVCOVÁ NAMED FIRST OMBUDSPERSON OF THE CAS

The ombudsperson role is entirely new at the Czech Academy of Sciences, making Dana Plavcová the very first person to hold the position. She has more than twenty years of experience in the non-profit sector – fifteen of them at the organization People in Need, where she served in various roles, including that of equal opportunity advisor. She also worked on the quality and advancement of humanitarian and development programs in sub-Saharan Africa. As ombudsperson, she focuses on preventing inappropriate behavior and promoting equality and respectful communication across workplaces. All employees of the CAS can turn to her with their concerns.

CZECH DELEGATION VISITS THE PARANAL OBSERVATORY

During an official visit to Chile in mid-April 2026, President Petr Pavel, accompanied by CAS President Radomír Pánek, toured facilities of the European Southern Observatory, including the Very Large Telescope (VLT) and the Extremely Large Telescope (ELT, currently under construction). As part of the CZ-ANDES consortium, Czech scientists from the Astronomical Institute of the CAS and Masaryk University are contributing to the construction of a cutting-edge spectrograph, which is expected to advance exoplanet research – including the search for a "second Earth" – as well as the study of cosmic expansion and star formation processes.





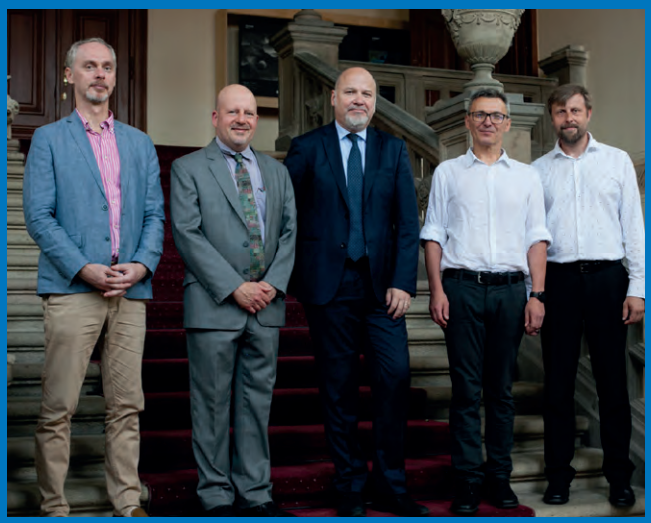
NEW UNIQUE APPARATUS FOR MATERIALS RESEARCH

The Institute of Physics of the CAS has acquired a state-of-the-art laboratory station capable of examining electronic structure, chemical bonds, and physical properties at the atomic level. The Surface Science Laboratory Station was previously operated by the European Commission's (EC) Joint Research Centre in Karlsruhe. Its relocation to Prague will strengthen international collaboration, as well as the Czech Republic's role in nuclear safety and materials research. The inauguration of the SSLS took place on 12 February 2026, and was attended by CAS President Radomír Pánek, alongside representatives from Czech ministries, the EC, and industry partners.



TWO SCHOLARS RECEIVE THE JOSEF DOBROVSKÝ MEDAL

On 29 June 2026, during the Seventh World Czech Studies Congress held by the Institute of Czech Literature of the CAS at the Academy's headquarters on Národní Street,CAS Vice President Ondřej Beránek, responsible for Research Area III, presented the Josef Dobrovský Honorary Medal for Merit in the Philological and Philosophical Sciences to scholars Neil Bermel (University of Sheffield, second from left) and Marek Nekula (University of Regensburg, center). The medal recognizes their contributions to the development of Czech studies and the international promotion of the Czech language, literature, and culture.





MILESTONE EDITION OF THE SCIENCE FAIR FEATURED OVER 100 EXHIBITS

The Science Fair, organized by the Centre for Administration and Operations of the CAS, celebrated its milestone 10th edition, held from 4 to 6 June 2026 at its traditional venue at PVA EXPO Praha in Letňany, drawing tens of thousands of visitors. What did a medieval hospital look like? How can we "read" plants? Where is robotics heading? These questions are just a small sample of the wide range of topics and scientific disciplines on display. Alongside exhibits from CAS institutes, universities, and other research institutions, the program featured lectures, panel discussions, workshops, science shows, film screenings, and a live podcast.

THREE YOUNG RESEARCHERS RECEIVE ERC GRANTS

Modern OLED displays, cellular memory and Chinese medicine will receive more attention thanks to financial support from the European Research Council. ERC Starting Grants were awarded to Ondřej Mrózek (Institute of Inorganic Chemistry of the CAS), Hana Polášek-Sedláčková (Institute of Biophysics of the CAS) and Hedwig Waters (Institute of Ethnology of the CAS). Each of them will receive up to EUR 1.5 million for their research over five years. The funding honors innovative projects and provides early-career researchers who completed their doctorates no more than ten years ago with the freedom to pursue bold scientific questions and begin building their own teams.



THE CAS TAKES THE STAGE AT COLOURS OF OSTRAVA

Science belongs in the public space, even at a music festival. The CAS proved this with its debut appearance at the 23rd edition of Colours of Ostrava in July 2026 as a main partner of the Meltingpot forum. Visitors experienced four days filled with culture, music, debates, and exploration, all in the unique industrial complex of Dolní Vítkovice. Public interest exceeded all expectations, and the Academy's Curiosity Stage, set up in the iconic control room building of the former coking plant, remained packed throughout the entire festival. Even inclement weather toward the end of the event could not dampen the public's thirst for knowledge.





EURAXESS: HELPING FOREIGN RESEARCHERS FOR OVER 20 YEARS

Researchers coming into the Czech Republic from abroad arrive in an unfamiliar environment, filled with administrative obligations, language barriers, and cultural differences. It's important they feel comfortable and find their footing as quickly as possible so that they can devote themselves to science. For over 20 years, EURAXESS Czech Republic has been guiding researchers and their families through it all, from visa formalities to settling into a new environment – to date, it has helped more than 10,000 researchers. The Czech branch operates under the Centre of Administration and Operations (CAO) of the CAS, offering reliable support to CAS institutes.

CZK 140 MILLION LABORATORY TO BOLSTER MATERIALS RESEARCH

A new 3D atom probe tomography (3D APT) laboratory located at the Institute of Thermomechanics of the CAS in Prague's Ládví district will allow scientists to better understand the behavior of smart materials for future applications and bring theoretical research closer to practical implementation. The facility will serve, among others, members of the FerrMion project consortium, which connects three institutes of the Czech Academy of Sciences and two university departments. The laboratory was officially opened on 25 May 2026, by CAS President Radomír Pánek, alongside members of the FerrMion project leadership. In addition to the atom probe, the facility is equipped with a scanning electron microscope, which researchers will use to prepare samples.





NEW OUTDOOR GAME SHOWCASES ANTIVIRAL RESEARCH

"Professor Victor Crystal has disappeared, and with him the key research behind a new antiviral drug. Time is running out, and you are the only ones who can decipher the clues hidden among ciphers, molecules, and secret messages." So begins an escape game for ages 13+ rooted in real scientific discoveries. Set in Prague's Dejvice, Mission Retrovirus highlights Czech research behind world-renowned antivirals. Produced by the Institute of Organic Chemistry and Biochemistry of the CAS in collaboration with Get Out Fun, the game marks the 90th anniversary of chemist Antonín Holý's birth.





PRESTIGIOUS AWARD HEADS TO THE INSTITUTE OF PHYSICS OF THE CAS

Tomáš Jungwirth, Libor Šmejkal (pictured), and Jairo Sinova from the Institute of Physics of the CAS have become the first scientists working at a Czech research institution to win the Europhysics Prize. They received the award for their discovery of altermagnetism, which transformed how magnetic materials are classified. Tomáš Jungwirth is among the world's most cited researchers, has built one of the leading global centers for spintronics research, and is the first Czech scientist to receive the ERC Advanced Grant twice. In 2025, his exceptional scientific achievements were also recognized by Czech President Petr Pavel, who awarded him the Medal of Merit.

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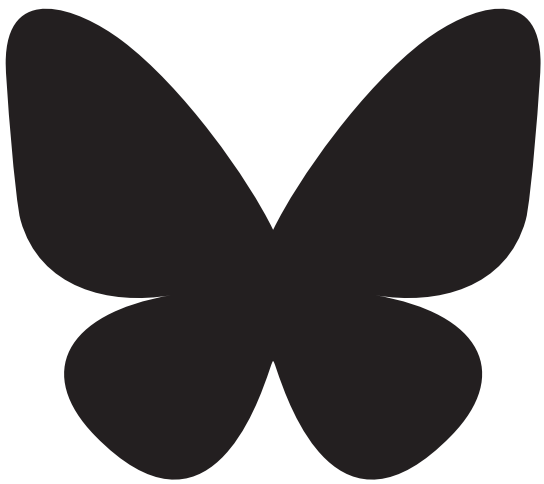
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