A MAGAZINE

Czech Academy of Sciences

BUGS

Long-lived termites, invasive hornets, and rare butterflies

2025

Reviving ancient Egyptian perfumes

Gold and diamonds refining microscopy

Biodegradable metal alloy implants

A / Magazine 2025


Top research
in the public interest
Czech Academy
of Sciences

Dear readers,

You are holding in your hands the second English issue of the official magazine of the Czech Academy of Sciences. Like last year, we have selected the best from the past twelve months of our quarterly *A / Magazine* and put together a special issue to bring not only international audiences the latest in our scientific advancements. We are pleased to be able to show you, in detail, the work being carried out by scientists at the largest research institution in the Czech Republic.

Our feature this time is insects. Termites, the most socially successful of them, are studied – perhaps surprisingly – at our Institute of Organic Chemistry and Biochemistry, as it is chemistry that lies at the heart of termites' efficient communication. For butterflies, on the other hand, we traveled south to our Biology Centre in South Bohemia, where these beautiful invertebrates are being studied by a scientist originally from Peru.

Many researchers from abroad work at the Academy, and we are happy to host them. Insect visitors from overseas, however, are usually less welcome – such as invasive Asian hornets, which you can also read about in this issue.

Nonetheless, invasive animals and plants remind us that the world is not a static place but one that is constantly changing. The same, of course, holds true for our society, politics, and technology. The Academy itself is also undergoing change – since this spring, it has new leadership, and I was elected to head the institution. I look forward not only to the challenges that lie ahead, but also to staying in touch with you via this magazine or my LinkedIn profile, where you can follow the latest news and developments at the Academy.

Radomír Pánek
President
of the Czech Academy of Sciences

Cover image: Shutterstock

IN FOCUS

Gorillas in Zoos 6

ACADEMY HIGHLIGHTS

New Scientific Discoveries from the CAS 8

GLOBAL SCIENCE HIGHLIGHTS

Commentary by CAS Researchers 12

18

FEATURE

Long Live the King and Queen:
The Story of Immortal Termites

Not all bugs live fleeting lives. Royal termite pairs can survive for decades, setting records for longevity in evolutionary terms as well – their advanced colonies have been around since the dinosaur era.

Unwelcome Visitor from Asia 26

The Flutter of Butterfly Wings 28

Bugs Up Close 34

INTERVIEW

Tinkering with Jewelry

Vladimíra Petráková

38

HISTORY

In the Wehrmacht Uniform 46

Even eighty years after the end of World War II, stories locked away in memory are still coming to light – like the overlooked past of the many thousands of Czechoslovaks who served in the German army.

CHEMISTRY & SOCIAL SCIENCES

Scent: The Intoxicating Power of Cleopatra 50

The Egyptians, Greeks, and Romans used fragrant oils and perfumes in rituals, medicine, and cosmetics. More than 2,000 years later, researchers in Prague are working on “reviving” these ancient scents.

PHOTO STORY

Fossilized Memories 60

BIOLOGY & ECOLOGY

Beauties from the Kingdom of Ice 66

You can find them in ponds, rivers, and in seas and oceans, too. Diatoms (microalgae) are highly adaptable and thrive almost everywhere – including in the extreme environment of Antarctica.

PHYSICS

The Rusting Human Body

72

FROM THE ACADEMY

The Latest News 78

Text: Markéta Wernerová \ Photo: Oliver Le Que, Prague Zoo

GORILLAS IN ZOOS

How is the gut microbiome linked to heart disease?

One of the leading causes of death among the largest living primates in zoos is cardiometabolic disease – heart problems, diabetes, obesity, or hypertension (high blood pressure). Experts from the Institute of Vertebrate Biology of the Czech Academy of Sciences contributed to a new study that looked into why this is the case. Working with colleagues from European and American research institutions, they analyzed stool samples from wild lowland gorillas and compared them with samples from gorillas living under human care. They found striking differences between the two groups, which suggests that the development of these diseases is closely tied to the composition of the gut microbiome and metabolome. This means that a gorilla's health is heavily influenced by its environment and diet – for instance, the amount of fiber it consumes. The new findings could one day help improve the quality of life for this great ape both in zoos and in the wild. (Photo: One-year-old lowland gorilla Gaia with her mother Kijivu at the Prague Zoo.)

Prepared by: Jana Bečvářová, drawing on press releases of the CAS
Photo: Shutterstock (2), Institute of Physics of the CAS, Biology Centre of the CAS

The neutrino is lighter than expected

Nuclear Physics Institute of the CAS

This elementary particle, part of the subatomic world, is sometimes called mysterious or elusive. Silent and invisible, neutrinos permeate everything around us – and even us. They are smaller than atoms, protons, and electrons – so tiny, in fact, that it's impossible to "weigh" them directly. It would be like trying to set the wing of a fruit fly on a kitchen scale. That's why scientists can only establish an upper limit for the mass of the neutrino – until now 0.8 electronvolts (eV). But the international KATRIN experiment has proven the neutrino to be even lighter: just 0.45 eV, about a million times less than the mass of an electron. The findings, with a major contribution from the Nuclear Physics Institute of the CAS, were published in *Science*.

Scientists develop a compound that protects bone cells

Institute of Physiology of the CAS
Institute of Organic Chemistry and Biochemistry of the CAS

People with diabetes face a higher risk of bone fractures. In the future, the newly developed compound MSDC-0602K could prove beneficial. It not only improves insulin sensitivity but also protects bones. At the center of researchers' attention is the bone stem cell, still undecided about its future path. Depending on its environment, it can become a fat cell or a bone-forming cell (osteoblast). The compound nudges the hesitant cell in a particular direction – for instance, toward osteoblast formation – thus strengthening bone and reducing its fragility. The experimental MSDC-0602K is being tested by researchers at the Institute of Physiology of the CAS and the Institute of Organic Chemistry and Biochemistry of the CAS. Their study was published in *Metabolism*.

Czech physicists capture first microscopic images of an altermagnet

Institute of Physics of the CAS

When a scientist finally gets to see with their own eyes what they've been theorizing for years, it's a thrill. Seeing, after all, is believing. An international team led by Tomáš Jungwirth from the Institute of Physics of the CAS has achieved a breakthrough in the research of the newly confirmed magnetic phase of matter – altermagnetism. In *Nature*, they published the first direct microscopic images of altermagnetic ordering in a manganese telluride crystal (image of the model on the left). Careful investigation revealed that this material does not belong among antiferromagnets or ferromagnets – the only two magnetic phases known until recently. In 2022, Czech physicists described a third kind: the altermagnet. Their research could advance future information technologies.

Bypassing faulty protein production could help treat genetic disorders

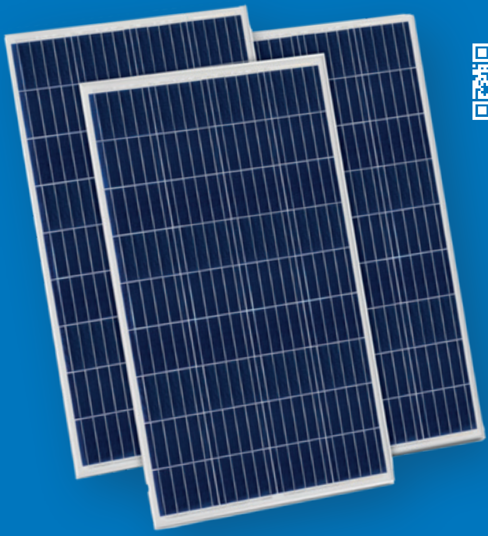
Institute of Microbiology of the CAS

The transfer of genetic information between cells is tightly controlled. Still, a fatal error can sometimes occur, leading to genetic disease. One such mistake is the insertion of a premature stop signal (stop codon) into the DNA sequence of an essential protein – comparable to a misplaced period suddenly cutting off a sentence halfway. Researchers at the Institute of Microbiology of the CAS have further decoded this molecular process, which in the future could be harnessed to treat diseases caused by so-called nonsense codons. The results were published in *Nature Structural & Molecular Biology*.

Pulsating water jet to clean ships

Institute of Geonics of the CAS

You know that saying, “Constant dripping wears away the stone”? It’s not far from the truth – water can cut or grind as well. And its potential goes even further. A new promising technology shows promise for practical applications – the pulsating high-speed water jet, developed at the Institute of Geonics of the CAS, that can clean ship hulls more effectively and ecologically, without any abrasive particles or chemical additives. Unlike the standard continuous water jet used, say, at a car wash – where a narrow stream of water cleans through sheer speed and pressure – the pulsating jet harnesses the power of individual droplets. It can be likened to a kind of water jackhammer. Czech experts, together with a German industrial partner and the Technology Transfer Center of the CAS (CETTAV), have founded a spin-off company to market the technology to German shipbuilders.



Scientists develop green, low-cost solar cells

Institute of Macromolecular Chemistry of the CAS

Saving money on energy while treating the environment more considerately – that’s the promise that keeps solar power so attractive. Researchers at the Institute of Macromolecular Chemistry of the CAS, working with Swedish colleagues, have made significant progress in the development of eco-friendly solar cells. The new organic cells contain no heavy metals and require no toxic solvents in their production. Thanks to their light weight, they can also be used where traditional silicon panels are unsuitable – such as transparent window films or roofing materials where the cells could snap together like overlapping tiles. The findings were published in *Nature Energy*.

Ecosystems depend on the partnership of fungi and plant roots

Institute of Microbiology of the CAS

Mycorrhizal fungi – invisible at first glance, yet immensely powerful. They live in symbiosis with tree roots. Using thread-like structures, they weave underground networks that circulate vital nutrients and have a profound impact on biodiversity. Every year, plants allocate 3.6 billion tons of carbon to these fungi, resulting in 75 percent of all terrestrial carbon being stored below ground. Thanks to the GlobalFungi database, created at the Institute of Microbiology of the CAS, researchers have mapped the overall diversity of these indispensable partners of plants. The results show that the regions with the greatest variety of species are not protected, making them highly vulnerable to human impact. The study was published in *Nature*.

Alga of the Year sheds light on plant evolution

Biology Centre of the CAS

At first glance, *Draparnaldia erecta* looks like moss, and it could help answer key questions in evolutionary biology – above all, how plants made the transition from water to land. The importance of this multicellular green alga was even recognized by the German Botanical Society, which named it Alga of the Year 2025. "It's the only Chlorophyte alga which has acquired a morphological complexity comparable to early land plants. It has a branched upright system resembling a tiny land plant, and elongated cells that look like a root system," explains Lenka Caisová from the Institute of Plant Molecular Biology at the Biology Centre of the CAS. The alga also has very practical traits for research: it grows quickly, reproduces readily, and is easy to cultivate in large amounts. Caisová expects noteworthy results within two years.

Text: Leona Matušková, Radka Římanová, Markéta Wernerová \ Photo: Shutterstock

LIFE MIGHT EXIST ON THE MOONS OF URANUS

It's one of the coldest planets in the Solar System and is a so-called ice giant. Yet Uranus with its five major moons may not be as "dead" as once assumed on the basis of data gathered in 1986 by NASA's Voyager 2 mission. Scientists have re-analyzed these measurements and discovered that back then, the results were distorted by a solar storm, which could have masked activity on Uranus's moons. Researchers now believe that some of them may harbor subsurface oceans suitable for life. Their study was published in *Nature Astronomy*.

COMMENTARY: PAVEL SUCHAN

Astronomical Institute of the CAS

Until now, Uranus has rarely come up in debates over extraterrestrial life. But that's hardly surprising. In the catalogue of possible places for life in our Solar System, Mars – long the focus of attention – has in recent decades been joined, and in some ways even overtaken, by the moons of the giant planets: Jupiter, Saturn, and now Uranus. These are moons with oceans of salty water hidden beneath frozen surfaces. Alongside Jupiter's moons Europa, Ganymede, and possibly Callisto (incidentally, the European JUICE probe that Czech researchers were involved with is on its way there), and Saturn's moons Enceladus and Titan, Uranus has now joined the list. The prime suspects are Uranus's largest moons, Titania and Oberon. If life ever is confirmed there – which will require a great many more measurements and won't happen overnight – we shouldn't expect higher forms of life, but rather microorganisms. While astronomers are looking for life on exoplanets far beyond our planetary system, it might turn out to be much closer to home. And one last curiosity: the subsurface ocean on Ganymede, the largest moon in our Solar System, may contain more water than all the oceans on Earth combined.

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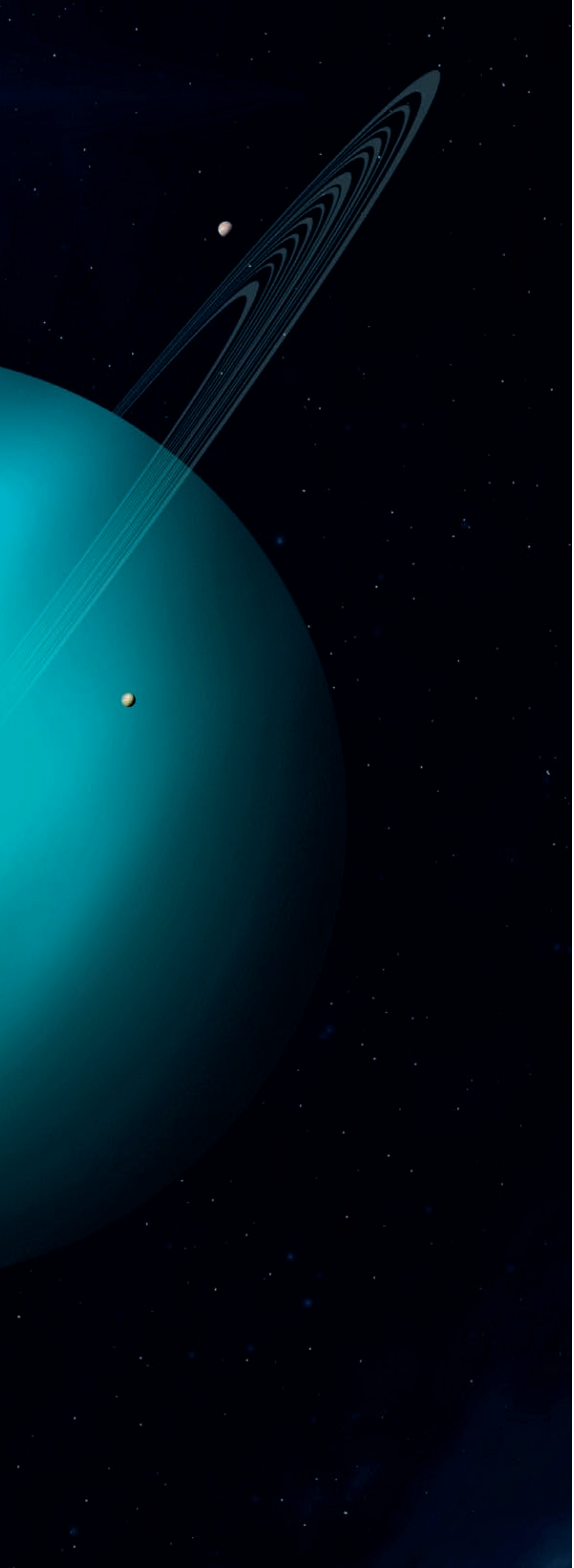

VIRUSES DISCOVERED IN GREENLAND MAY SLOW GLACIER MELT

Measuring about 2.5 micrometers, they carry more genes than the smallest bacteria. These giant viruses, found on the surface of Greenland's ice sheet, seem able to kill snow algae, which accelerate melting. Ice containing these algae is visibly darker, allowing it to absorb more solar energy. According to a new study by Danish researchers, deliberately infecting snow algae with these giant viruses could help limit their spread – and with it, slow the pace of glacier melt.

COMMENTARY: KLÁRA ŘEHÁKOVÁ

Institute of Botany of the CAS

Studies of marine and freshwater ecosystems have shown that viruses play a significant role in controlling algal populations. In the oceans, for instance, viruses infect algae and other protists, affecting the size and composition of these communities. Viral infections can cause algal cells to break down, reduce the extent of algal blooms, and alter nutrient flows in the microbial food web. Infected cells release nutrients such as carbon and nitrogen back into the water. This process is known as the viral shunt – a mechanism that diverts energy and nutrients away from higher trophic levels (such as zooplankton or fish) and back into the microbial loop. In this way, viruses turn what could have been food for larger organisms into dissolved organic matter, primarily consumed by heterotrophic bacteria. The new study from Greenland shows that glacier-dwelling giant viruses have a similar impact on blooms of snow algae as viruses do on algal blooms in aquatic ecosystems. In both environments, viral infections are crucial for maintaining microbial community structure, regulating biodiversity, and shaping nutrient cycles.

DOI: 10.1186/s40168-024-01796-y

DIGITAL AVATARS AS POTENTIAL ALLIES IN TREATMENT OF SCHIZOPHRENIA

One of the symptoms of psychosis and schizophrenia is auditory hallucinations: patients hear critical, controlling, or aggressive voices that can severely disrupt their lives. For up to a quarter of patients the medication is ineffective, and long-term exposure to these voices can lead to self-destructive behavior. Researchers at the Institute of Psychiatry, Psychology & Neuroscience at King's College London explored the use of digital avatars – artificial figures with whom patients can hold therapist-guided conversations. The software animates a digital image and alters a voice so that it resembles the hallucinated one – however, what is being said is provided by the therapist. The study was published in *Nature Medicine*.

COMMENTARY: LUKÁŠ HEJTMÁNEK

Institute of Psychology of the CAS

Imagine being constantly bombarded by invisible voices – voices that never stop criticizing, bossing you around, and often threatening you. For many people living with schizophrenia or acute psychosis, such auditory hallucinations are a daily reality, and for a significant portion of patients, they cannot be eliminated with conventional treatments. Therapy is complicated by the fact that professionals disagree on how best to deal with these voices. Some fear that direct confrontation only reinforces the voices and validates their power in the patient's eyes, so treatment focuses instead on teaching patients to ignore or suppress them. Another school of thought, however, stresses the value of confronting the voices in a safe, controlled therapeutic setting. The goal is to teach patients how to cope, be prepared, and manage their hallucinations. But this approach comes with a challenge: how can you talk to something you cannot see? AVATAR therapy offers a way to give those voices a face. The same technologies that allow people to create characters in video games are giving therapists a tool to help patients confront their inner demons. Early studies suggest that AVATAR therapy is beneficial and effective in easing the distress caused by the hallucinations and improving patients' quality of life. Still, the research is at an early stage. It may not work for everyone; long-term effects are unclear, and for some patients, confronting the voices may even strengthen them and worsen symptoms. While a few patients in trials reported a reduction in the frequency of auditory hallucinations, AVATAR therapy is primarily aimed at managing symptoms rather than eliminating them. Even if it proves useful, we shouldn't ease up in the search for lasting solutions that could silence the voices for good.

DOI: 10.1038/s41591-024-03252-8

OLD PHONES DON'T HAVE TO END UP AS WASTE

Every year, more than a billion smartphones are produced worldwide. Most discarded devices end up on the scrap heap, and only a fraction of them are recycled. But could this electronic waste be put to further use? Researchers from the University of Tartu in Estonia have come up with an intriguing idea: transforming old smartphones into miniature data centers capable of efficiently processing and storing information. This low-cost innovation (about €8 per device) has practical applications – the team, for instance, tested the phones for monitoring marine life and counting different aquatic species. The study appeared in *IEEE Pervasive Computing*.

COMMENTARY: MILAN ZAJÍČEK AND LUKÁŠ KOHOUT

Institute of Information Theory and Automation of the CAS

MZ: Six years ago, when the European Economic and Social Committee conducted a study entitled "Identifying the Impact of the Circular Economy on the Fast-Moving Consumer Goods Industry," it concluded that in 2017, there were about 700 million phones in the EU in what was termed "hibernation" – i.e., lying unused in a desk drawer. Be honest – how many such hibernating phones do *you* have at home? I personally found seven, including my very first push-button (or "dumb") phone. The authors of the study focused on the potential hidden in older smartphones – specifically those where Android can be replaced with a Linux operating system (namely PostmarketOS). Picture a cheap device that can communicate, knows its precise location, has a tilt sensor, thermometer, and camera, along with plenty of memory and computing power. With the right configuration, such autonomous devices can also be networked together. What would you use them for? And how many of these ideas might even grow into successful start-ups – assuming you can get hold of hundreds of old devices? As it turns out, a suitable phone can serve as a computer that manages a set of sensors via a web interface, processes their readings, and stores the data. Given how many of these small but powerful helpers are lying idle, bringing them back to life is surely a worthy endeavor. Of course, every idea has its limits – in this case, higher energy consumption compared to specialized IoT devices, or the need to standardize the hardware. For reliable operation, using the same model is ideal; otherwise, multiple software versions may need to be maintained.

LK: Current estimates suggest that electronic waste will more than double by 2050. The authors of the study describe how to repurpose old mobile phones so they can serve applications beyond their original purpose. Mini data centers can, for instance, act as gateways for IoT sensors, since they offer sufficient data-handling capacity. Comparative testing suggests their performance is more than adequate. While the study centers on mobile phones, the same approach could be applied to virtually any electronic device – essentially anything with a display, buttons, and a microprocessor. The real question would simply be: what level of computing power and communication capability does the target application require?

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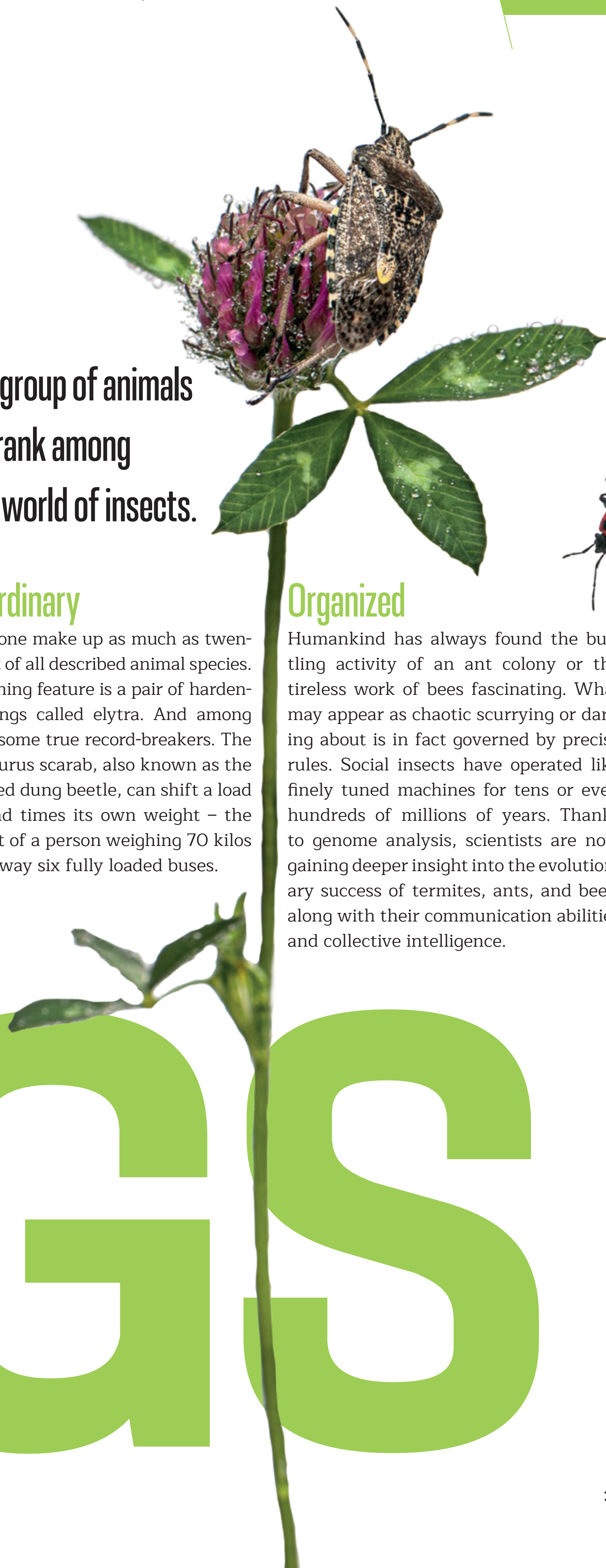
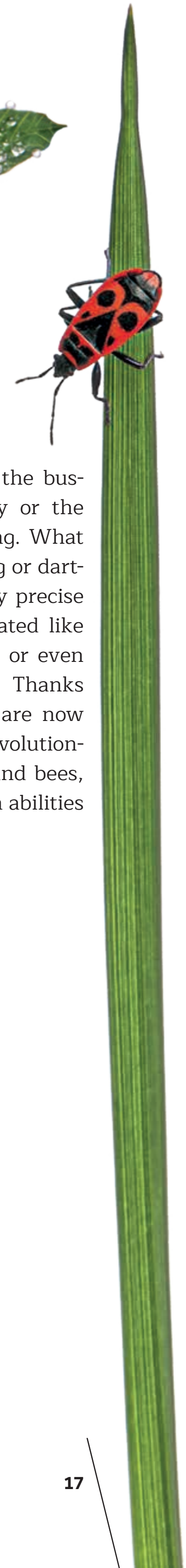
BY THE NUMBERS

OVER
1,200,000
SPECIES DESCRIBED TO DATE

UP TO
30,000,000
ESTIMATED ACTUAL NUMBER OF SPECIES

2.5%
OF THE GLOBAL INSECT POPULATION DISAPPEARS EVERY YEAR





They hold the title of the most diverse group of animals on Earth – and at the same time, they rank among the most endangered. Welcome to the world of insects.

Disappearing

It's estimated that one third of insect species are at risk of extinction, and nearly half are experiencing significant population decline. Some studies suggest that insects are disappearing eight times faster than mammals, birds, and reptiles. Butterflies and hymenopterans (like bees), as well as beetles, are among the most threatened. However, other experts assert that apocalyptic forecasts might be exaggerated.

Extraordinary

Beetles alone make up as much as twenty percent of all described animal species. Their defining feature is a pair of hardened forewings called elytra. And among them are some true record-breakers. The mighty taurus scarab, also known as the bull-headed dung beetle, can shift a load a thousand times its own weight – the equivalent of a person weighing 70 kilos pushing away six fully loaded buses.

Organized

Humankind has always found the bustling activity of an ant colony or the tireless work of bees fascinating. What may appear as chaotic scurrying or darting about is in fact governed by precise rules. Social insects have operated like finely tuned machines for tens or even hundreds of millions of years. Thanks to genome analysis, scientists are now gaining deeper insight into the evolutionary success of termites, ants, and bees, along with their communication abilities and collective intelligence.

UGS

LONG LIVE THE KING AND QUEEN!

The Story of Immortal Termites

Not all bugs live fleeting lives. Royal termite pairs can survive for several decades, setting records for longevity in evolutionary terms as well – their advanced colonies have been around since the dinosaur era.

The increasing availability of gene sequences from various insect species allows researchers to trace the origins and history of key genes far back in time, helping reconstruct their ancient evolutionary paths.

Text: Leona Matušková \ Photo: Shutterstock (2), Robert Hanus (2), Jana Plavec, Aleš Buček (3)

God save the Queen! And long may she reign! was a proclamation you might have heard British monarchists utter on occasion to honor Queen Elizabeth II up until 2022. It seems their wishes were granted, as the sovereign reached the age of 96, while her predecessor (and mother), Queen Elizabeth The Queen Mother, passed away at 101 years and 238 days.

Thanks to improved living conditions and advanced medicine, more people than ever – royal or not – are reaching the centenarian milestone. However, there are worlds where venerable age is the privilege of kings and queens alone – specifically, the hidden realms of termite mounds. It is estimated that in certain species, the royal pair, that is, the primary reproductive unit of the termite community, can live up to two (and possibly more) decades – an extraordinary lifespan for insects!

THE CZECH TERMITE SCHOOL

The longevity of termite kings and queens is one of the topics studied by scientists at the Institute of Organic Chemistry and Biochemistry of the Czech Academy of Sciences (IOCB Prague). They have unique conditions for this research, since they've been maintaining laboratory termite colonies in the basement of their headquarters in Prague–Dejvice for several decades.

In the early 1960s, the first specimens of this tropical bug were brought to Czechoslovakia by researcher Ivan Hrdý, remembered by entomologists and organic chemists as the founder of the "Czech termite school." He collected these insects primarily in China, Vietnam, and Cuba – places that were accessible to politically-allied countries during the Communist era.

As surprising as the combination of chemistry and bugs may initially seem, it makes sense. In the latter half of the twentieth century, there was significant societal demand for insecticides to combat pests harming increasingly more intensive agricultural production – some might recall the campaign against the Colorado potato beetle, or the "Yankee beetle", presented as such in Cold War discourse.

At that time, there was a trend of developing synthetic insect hormones and researching pheromones – natural chemical substances used by the individuals of a species to communicate. Scientists believed that uncovering the chemical nature of these substances could lead to advancing methods for repelling bugs.

This led to a number of extremely interesting scientific projects launched in Prague, initially with significant application potential, which gradually also provided fundamental insights into basic research on insect communication.

A TREASURE IN THE BASEMENT

For nearly twenty-five years, Robert Hanus has been active in the termite lab at IOCB Prague, currently leading the Chemistry of Social Insects research group. He began working on this topic while studying at the Faculty of Science, Charles University in the early 2000s, and it was then that the story of a few particularly long-lived termite kings and queens began.

"As a master's student, I came to work one day and discovered that one of our colonies, originating from Cuba, was swarming. As a diligent caretaker, I sorted the winged kings and queens in pairs and placed them into glass containers, where they gradually formed new colonies that just kept growing and growing," Hanus recalls.

The researcher continued to monitor the new colonies, observing the condition of the royal pairs; later, his students took over the observation of the termite palaces. This resulted in a continuous series of unique data on termite "families" and the longevity of their members.

"At the time of establishing the colonies, we could only dream of advanced techniques like genome sequencing. It was only many years later that I realized what a treasure trove we had at our disposal," Hanus adds. Researchers combined the meticulously kept records of the termite nests and the ages of the kings and queens with modern genetic methods, opening up possibilities for remarkable discoveries.

LIFE IN COMMUNITIES

Entomologists and even lay observers, such as beekeepers, have long noted the longevity and fertility enjoyed by honey bee queens. Today, we know that even greater record-holders – both kings and queens – are hidden within termite mounds.

So how are bees, ants, and termites similar to each other, and what differentiates these representatives of social insects? They share a similar lifestyle in colonies – large family units. Individual members of a nest cooperate in its construction and maintenance, feeding and caring for the offspring, and defending the community. Together, they form a superorganism that operates according to clearly defined rules that have been in place for tens to hundreds of millions of years.

Remarkably, this similarly structured social behavior evolved independently. While bees and ants belong to the order Hymenoptera and are relatively closely related, termites are quite distant from both. It's somewhat ironic, since many people conflate termites with ants (termites were once called "white ants"). In reality, termites and ants are separated by tens of millions of years of independent evolution. Not only are they not "one family" – they are actually arch-enemies. Termites feed on decomposing wood and soil matter, while ants are predators that threaten termites.

The closest living "cousins" of termites are cockroaches. The separate lineage of termites diverged from their cockroach relatives approximately 150 million years ago. The oldest termite fossil dates back about 130 million years, making › termites the most ancient representative of social insects. To date, researchers have described roughly three thousand species of termites inhabiting all continents except Antarctica.

The differences between termites and social hymenopterans include the distinct role of gender. Termite individuals maintain two sets of chromosomes, like vertebrates, so what we find in a termite colony are both male and female workers, soldiers, as well as a king and queen. With bees and ants, it works differently. Most inhabitants of beehives and anthills are females. The role of males is essentially limited to fertilizing the queen. Once they've fulfilled this duty, they die.

MEET THE QUEEN

The longevity of ant and bee males is not even a topic of discussion. That is why research studies on this subject focus exclusively on queens. Only in regard to termites does the terminology also include kings.

Each termite colony typically has only one primary reproductive pair (though some species function slightly differently). "The king stays with the queen for life and fertilizes her on a regular basis. This results in essentially one massive family: a mother, a father, and sometimes millions of offspring," Hanus explains.

Species diversity in the tropics is immense. "We now know where to look – certain species live in trees, others underground. In a single day, we can find dozens of different species. Some nests are the size of a tennis ball, others are as big as a sheep and can weigh up to seventy kilograms. If the nest is too large, we cut an opening into it with a machete or ax and collect a few animals – the termites simply repair the damage. If we need the queen, though, things get more complicated, as we have to take the whole nest. And that's physically demanding work. We end up coming out of the forest looking like smugglers, with a sack on our backs," says Robert Hanus.

"Among termites, a fairly inhumane method of conflict resolution is common – cannibalism. Their main food source is cellulose, which lacks nitrogen. To make up for this deficit, they eat their own – whether individuals deemed surplus to the colony's needs, or those who have died of old age."

Robert Hanus

The first eggs laid by the founding pair of a new termite colony hatch into minuscule larvae, initially entirely dependent on the care of their parents. In mature colonies, the older generations of siblings take over raising the young. As the larvae develop, they differentiate into workers and soldiers, each caste with a precisely defined role, knowing exactly what to do and when. The colony grows and begins to function as an egg-producing machine.

In extreme cases, the queen lays several thousand eggs daily. Over a twenty-year reign, then, she may produce around twenty million offspring. But such a lifestyle takes its toll, which soon becomes apparent in her appearance. Rather than an elegant, stately dame, a termite queen is best imagined as a bloated matron, vastly outsizing her partner. While the average termite – including "His Majesty the King" – measures just a few millimeters, the egg-producing queen can grow to the size of a human palm. She looks more like an overstuffed caterpillar than a nimble six-legged insect.

Agility, however, is not a skill the queen requires. She barely moves, permanently confined with her mate in the royal chamber, which she never leaves throughout her long life. Small openings allow worker termites to access the chamber to care for their rulers, while termite soldiers stand guard. The soldiers protect the royal pair while the workers groom and feed it and remove the eggs laid by the queen.

The bleak fate of the founding pair raises the question of whether longevity is truly a blessing or a curse. It also begs a deeper inquiry: who actually rules the colony? Is it really the king and queen? Or are they merely captives of their offspring, who exploit them to the fullest for egg production? "Evolution does not concern itself with such sentimental questions. It simply evaluates how successful its strategies are across time and space, and in regard to termites, this strategy has been undoubtedly effective," Hanus notes. Termites rank among the most populous organisms in tropical and subtropical regions, where their colonies have flourished for tens of millions of years.

THE ELIXIR OF YOUTH

Over this immense timespan, termites have evolved a host of mechanisms that together create a kind of "elixir of youth," accounting for the extraordinary longevity of kings and queens. Scientific studies have explored, for instance, the role of enzymes that counteract oxidative stress or the function of hormones in regulating development, metabolism, and aging.

Hanus's team approached the issue from a different angle, focusing on telomerase – an enzyme that functions as a biological repair mechanism for telomeres, the specialized structures at the ends of chromosomes in eukaryotic cells. Telomeres can be compared to the plastic tips on shoelaces, preventing the fraying of material. Just as these tips protect laces, telomeres secure chromosomes from damage during cell division.

When telomerase activity is low, cells age more rapidly, potentially leading to degenerative processes. Conversely, if telomerase is hyperactive, it can promote uncontrolled cell growth, contributing to cancer development – which is why understanding this enzyme is crucial in human biology.

Hanus found inspiration in the work of colleagues at the Biology Centre of the CAS, who had studied honey bee queens and discovered that their telomerase activity was significantly higher than that of worker bees and drones. ›

Mgr. ROBERT HANUS, Ph.D.
INSTITUTE OF ORGANIC CHEMISTRY AND BIOCHEMISTRY OF THE CAS

Robert Hanus studied zoology at the Faculty of Science while also pursuing sociology at the Faculty of Arts at Charles University in Prague. This unusual academic combination led him to an interest in termites as key representatives of social insects. He studies their chemical communication, unique caste systems, reproductive strategies, and the remarkable longevity of termite kings and queens. His research also focuses on the evolutionary adaptations that have made termites one of the most successful terrestrial animal groups. Since 2014, he has led the Chemistry of Social Insects research group at the Institute of Organic Chemistry and Biochemistry of the CAS. His most frequent trips to study termites have taken him to French Guiana, an overseas territory of France in South America.

While telomerase function is researched extensively in vertebrates, including humans, insect studies have been rare. “To our surprise, the link between telomerase and longevity in insects was almost entirely unexplored. The reason is simple: the fruit fly, which is the most commonly used insect model, completely lacks this enzyme and maintains chromosome integrity through alternative mechanisms,” Hanus explains.

“We reached out to our colleagues from the Biology Centre, who had made the honey bee discovery, and began collaborating. The results were astonishing. Across all studied termite species, telomerase activity in kings and queens turned out to be significantly higher than in workers and soldiers,” the scientist continues.

The researchers also found telomerase in the royal pair to be active in unexpected places – not just in reproductive organs, but also in tissues where its activity seemed unnecessary. “It was highly active in the nerve cord, an equivalent to the spinal cord and brain, even though those cells do not divide and therefore have no need to elongate their chromosomes,” Hanus adds.

Looking deeper into the cells, the scientists discovered that telomerase in termite kings and queens was active even outside the cell nucleus – and to a far greater extent than in short-lived workers and soldiers. Its extranuclear role may be linked to stress protection in mitochondria (the powerhouses of the cell) and possibly other functions, all of which contribute to cellular longevity.

LONG LIVE THE QUEEN!

Even for long-lived kings and queens, wear and tear eventually take its toll. Repair mechanisms weaken, and key biomolecules age. The effects are even visible to the naked eye. “An insect that lives for twenty years may have a missing leg or other signs of wear. In queens, aging can also be seen in the fat storage organ, which is bright white in youth, but turns yellow with time,” Hanus notes.

As the royal pair nears the end of its reign, the colony can sense the change, triggering a struggle for power. Some immature termites (nymphs) begin transforming into secondary reproductives (becoming neotenic). They develop reproductive organs, mate, and the new queens start laying eggs. In some species, neotenic queens coexist with the original queen, but in most cases, the latter prevents competition from arising through its presence. Controlling the number of secondary reproductives is not just in the queen’s interest – the workers and soldiers also prefer a stable colony, as caring for too many royals is a burden.

A healthy, actively reproducing queen releases a pheromone that signals to the rest of the colony that everything is under control and that they do not need to waste energy on reproduction. And when the queen is missing, infertile, or dying, the absence of this primer pheromone alerts her daughters to the opportunity to transform into successors.

“Termite queen primer pheromones play a crucial role in termite society, yet scientists were unable to chemically identify them until quite recently. While honey bee queen pheromones were discovered as early as the 1960s, those of ants, wasps, and bumblebees were identified much later – likewise with termites,” Hanus says.

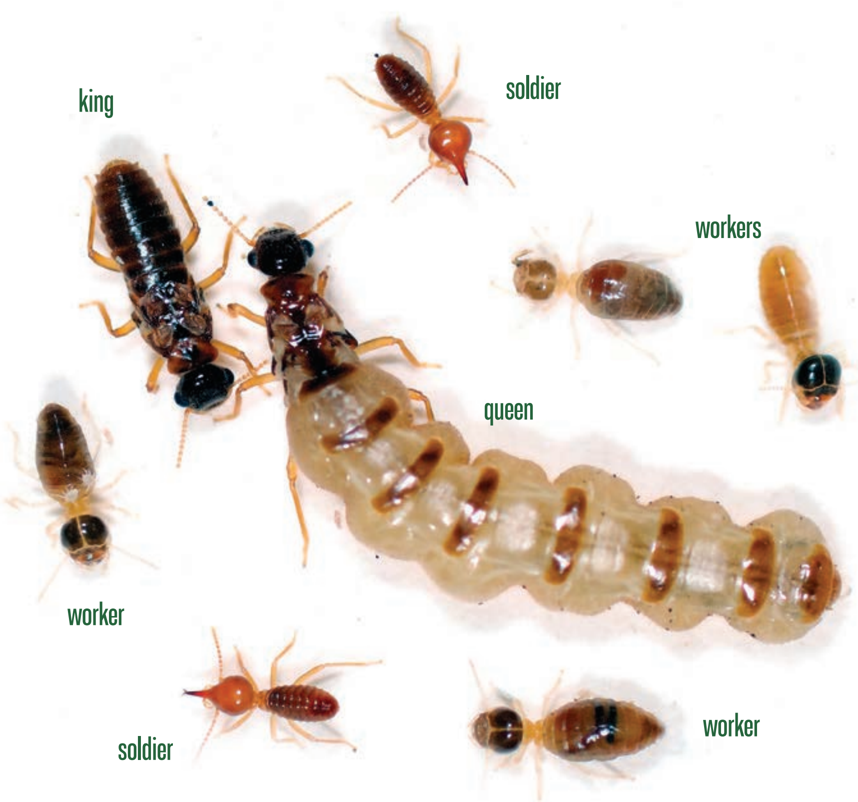
The first identification of a termite queen pheromone was published about fifteen years ago by Japanese researchers studying a species of lower termites. Around the same time, Hanus and his students also began working on the topic.

THE ROYAL PERFUME

Termites are classified into lower termites (fewer than a third of the 3,000 known species) and higher termites, which make up the majority. It was Czech scientists who finally managed to decipher the chemical nature of the primer pheromone in higher termites. In 2022, they

THE VARIETY OF LIFE IN A TERMITE MOUND

A single termite mound can house hundreds of thousands to millions of inhabitants. These include workers and soldiers of various ages and developmental stages and, of course, the reproductive royal pair. Members of each caste differ in appearance.



published a study in *Communications Biology* describing the substance secreted by the queen of the termite species *Embiratermes neotenicus*.

This species, which inhabits the tropical Amazon rainforest, has a unique system of replacement termite queens that functions somewhat differently from the one described earlier. In the early stages of the colony's life cycle, the founding queen is already substituted by a group of dozens to hundreds of replacement queens. These queens arise from unfertilized eggs through parthenogenesis – meaning they are essentially clones of their mother.

The female nymphs then wait patiently for the right time to replace the queen – i.e., for her death. Once they transform into queens, they form something like a harem, in which a single king mates with dozens to hundreds of small queens. This process produces workers and soldiers, as well as winged kings and queens that leave the nest to establish new colonies. Meanwhile, the queens in the harem occasionally lay unfertilized eggs, which develop into new clonal queens that replenish the harem.

The regulation of the number of replacement queens and the signal indicating the need to produce them is mediated precisely by the queen primer pheromone. Scientists identified it as a sesquiterpene compound, specifically (3R,6E)-nerolidol. "It's a fragrant terpene substance commonly found in perfumes. It's clear that termite queens must have a distinctive scent for their subjects. Of course, as humans, we can't detect it because it occurs in extremely low concentrations," Hanus notes.

The researchers managed to discover where and how the primer pheromone is produced. A single specialized enzyme is responsible for it, one that is highly active in the queen's skin but entirely absent in other members of the termite colony. The scientists also tested the pheromone's effects experimentally. They removed princesses (nymphs that have the potential to become replacement queens) from the colony and exposed them to the scent of the reigning queen's perfume. Its presence sent a clear message: do not attempt to transform into a queen. Conversely, when the scent was removed, the nymphs began to develop into replacement queens.

Additional experiments showed that the royal perfume works even from a distance. The princesses could sense it even when separated by a metal grid, and they responded precisely as dictated by the queen's chemical signal. One might be tempted to say termites have exceptionally sensitive noses – but in reality, their olfactory receptors are mainly located on their antennae.

FROM ANTENNAE TO EVOLUTION

In fact, antennae are an intriguing subject of study. The Prague-based scientists recently brought back a supply of termite antennae directly from the field in French Guiana. Although they have maintained viable colonies of multiple termite species in their Prague laboratory for decades, they need to travel to the tropics regularly to observe termites in their natural habitat and collect samples on-site for broader research insights.

Hanus most frequently – and most eagerly – returns to French Guiana. Not only does he speak fluent French, making it easy to communicate with locals, but the country is also an overseas region of France and thus part of the European Union. This means it operates under EU regulations, sparing researchers the bureaucratic hurdles they often face, for instance, in Africa.

The Czech researchers have established ties with the university campus in Kourou, which, incidentally, is also home to the spaceport from which European space missions are launched. "In Kourou, we have access to a small tropical field station where we've set up a lab with a microscope. Thanks to this local facility, we can prepare samples on-site just as we would in Prague. This is exactly how we prepped the antennae we are currently studying in our lab," the scientist explains.

And those antennae can reveal quite a lot – such as identifying candidate receptors for specific pheromones. In addition to the royal perfume that regulates reproduction in the termite colony, there are also pheromones for alarm, foraging, construction, trail-marking, and more. Each of these pheromones can be linked to the enzymes responsible for their production, as well as to the receptors in the antennae that allow termites to perceive them.

Each termite species has about fifty candidate receptor proteins. By tracing these proteins and their genes far back into evolutionary history, scientists can approximate when a particular protein and its corresponding gene first appeared. This, in turn, helps identify when specific types of communication evolved. "This opens up an opportunity to look at evolution – at how and when termites, who once barely communicated, developed into eusocial insects that use a rich chemical language," Hanus says, outlining the next direction of his research.

> In addition to many others, termites also use construction pheromones. These help them know when and where to add another level to the nest, how large the queen's chamber should be, and when to cap off the structure. Unlike the primer pheromone, the chemical composition of the construction pheromone has not yet been deciphered.

LOOKING AHEAD

At the same time, Hanus has other research aspirations. One of them is to decipher the chemical nature of the construction pheromone, which helps termites build their nests. Termites assemble these structures inch by inch, ›

FUN FACTS ABOUT TERMITES

In Czech, termites used to be called "všekazi" (literally "destroyers of all") because of their ability to consume books, wooden beams, or entire houses – a threat that still causes alarm in many parts of the world.

Termites were historically referred to in English as "white ants" – a name used by British colonists in tropical regions.

Many people think of termites as the tropical cousins of ants, which is a major misconception. Termites and ants are separated by millions of years of independent evolution.

To date, scientists have described around 3,000 termite species living in a wide range of habitats. While most termites live in the tropics near the equator, they can also be found in North America, around the Caspian Sea, the Balkans, and the Mediterranean.

The oldest known termite fossil dates back 130 million years, making termites one of the most ancient social organisms on Earth.

Lower termites build smaller nests and feed on dead wood, which they are able to digest thanks to symbiotic protozoa in their guts. The symbionts in higher termites are gut bacteria and fungi which the termites cultivate in their mounds.

A key factor in the evolutionary success of termites is their ability to digest cellulose – the structural component of plant cell walls. Although it is one of the most abundant organic materials on Earth, higher organisms cannot process it without microbial help.

row by row, precisely determining when to add another layer, seal a chamber, or create a ceiling. Chemical signals allow them to recognize that a certain section has been standing for a while and that it's time to shift construction in another direction. However, the chemical foundation of this signaling substance remains unknown.

Another unresolved topic is the remarkable longevity of termite kings and queens. The termite colonies in the Prague lab are still thriving. The oldest kings and queens are now twenty-three years old and in excellent health. Just last autumn, a student from the Prague team, Marie Pangrácová, successfully defended her doctoral thesis on this topic, and other research groups are continuing to investigate the termites' "elixir of youth," promising further fascinating discoveries.

A particularly intriguing question is what makes termites so evolutionarily successful. They have the ability to digest cellulose, aided by special gut bacteria and flagellates that they carefully cultivate. And Hanus's team has uncovered another key adaptation: termites can produce linoleic acid, one of the essential fatty acids. "Unlike most other animals, termites are not dependent on dietary intake of these substances, which has allowed them to become experts at consuming dead wood – and in doing so, they have essentially taken over the tropics," Hanus explains. Termites acquired this competitive advantage a very long time ago. The gene for the enzyme that enables them to synthesize linoleic acid was inherited from their ancestors approximately 160 million years ago.

Advances in genetic research now offer even deeper insights into insect evolution. In the case of termites, this means looking far back into the past. After all, they dominated terrestrial ecosystems long before the first bee and ant colonies appeared – and long before we humans arrived. Understanding the survival strategies of these insect Methuselahs is sure to be well worth the effort.

"The primer pheromone plays a crucial role in termite society, yet scientists were unable to chemically identify it until quite recently."

Robert Hanus

TERMITES WITH BLUE "BACKPACKS"

Some termite species defend their colonies by sending out kamikaze fighters with explosive payloads on their backs. These are not termite soldiers, but aging workers who are no longer as effective at foraging or nest-building as they once were. Over time, these workers accumulate a remarkable enzyme – laccase – in pouches on their backs. Due to copper ions in its structure, the protein has a bluish tint. The older the worker, the larger the blue crystals they carry. When the nest is threatened, the worker performs one final act of service: it ruptures the pouch, releasing a toxic substance that immobilizes and poisons the enemy. The self-sacrificing termite perishes alongside the intruder. The structure of this enzyme was recently revealed with the use of X-ray crystallography by Jana Škerlová and Pavlína Maloy Řezáčová from IOCB Prague.

A TERMITE MOUND FLATSHARE

In addition to the hundreds of thousands to millions of termites, termite "high-rises" are home to other creatures as well. Parasitic wasps, spiders, lizards – even parrots! – may take up residence in them. Although these tenants do not depend on termites for survival, many organisms have evolved to such a degree of dependency on termite mounds that they cannot survive without them. This includes certain rove beetles (family Staphylinidae), whose symbiotic relationship with termites is being researched by Aleš Buček from the Institute of Entomology at the Biology Centre of the CAS.

"Almost everywhere in the world where termites live, you'll find rove beetles living alongside them," Buček says. "The same parasitic strategy has evolved in different rove beetle and termite species independently across multiple locations." This phenomenon is known as convergent evolution, and it is one of Buček's interests to study the forms and processes of this evolution in parasitic rove beetles.

"Over millions of years, certain rove beetles have evolved to resemble termites, helping them blend in," the researcher explains. "Termites rely on their antennae to recognize others in the nest by touch." But visual mimicry is only one tactic. "Another is chemical disguise – the beetles need to have the same surface compounds, primarily hydrocarbons, as the termites do," Buček adds.

To investigate the co-evolution of rove beetles and termites, Buček uses genetic techniques – sequencing DNA to reconstruct family trees and evolutionary relationships between individual species. He compares beetles that have evolved to have a parasitic way of life with those that live independently of termites. He and his colleagues collect samples directly in the field in Africa, Asia, and South America.

"Sometimes it's harder than looking for a needle in a haystack – in a mound of a million termites, there may only be a handful of beetles," Buček says. He received a Junior Star grant from the Czech Science Foundation to support the project, enabling him to return to the Czech Republic after a long research stay in Japan to establish his own international team at the Biology Centre of the CAS. His research is not only uncovering the curious lives of rove beetles and termites, but is also addressing broader questions about evolution.

A termite of the genus *Hospitalitermes* (bottom) poses with a rove beetle of the genus *Hospitaliptochus*. The similarity in names is no coincidence – the beetle was named after its host, on which its survival depends (Malaysia, 2023).

Aleš Buček standing to the right of the mayor of the Cameroonian village Nguinda (in the green shirt). "This is a relatively rare photo – I usually spend most of my time analyzing genetic data on my computer or behind the camera lens," says the researcher, who involved much of the village in his fieldwork studying the diversity of termites and beetles.

UNWELCOME VISITOR FROM ASIA

It's slightly smaller than the native European hornet – but strikes fear into beekeepers across the continent. Meet the Asian hornet, a dangerous invasive species originally from Southeast Asia.

FROM CHINA TO CZECHIA

There are 13 known color morphs of the species. One of them – *Vespa velutina nigrithorax* – was introduced from China to other parts of the world in 2003 via the transport of goods and isolated cases of "stowaway" hornets. By the following year, it had reached Europe, and over the years it spread across the continent. In the Czech Republic, only a few individual specimens have ever been recorded, all of which were eradicated.

HOW MANY INDIVIDUALS INHABIT A NEST?

In Europe, usually **1,500** to **2,000**

HOW BIG ARE THE NESTS?

80 to **100** cm

HOW TO TELL THEM APART

The European hornet (*Vespa crabro*) is a native species in the Czech region. It's larger than the non-native Asian hornet and differs in coloration. It has a dark body with reddish-orange markings, a yellow-striped abdomen (the first segment can also be reddish-orange), and a head with a yellow face and reddish-orange temples. Its legs are almost entirely reddish-orange to brown. The Asian hornet is mostly black, including the thorax and legs, but has striking yellow segments on the tips of its feet (tarsi). The rear of its abdomen is marked with broad yellow to orange stripes.

HOW LONG DO WORKERS LIVE?

4 to **5** weeks

WHY IS THE ASIAN HORNET A PROBLEM?

The Asian hornet is a predator. Around human settlements especially, it often preys on the western honey bee (and other pollinators), jeopardizing not only beekeeping, but crop production as well. Naturally, it also puts pressure on native biodiversity by reducing populations of local species.

AVERAGE FLIGHT SPEED

5.5 km/h

HOW LONG DO QUEENS LIVE?

8 to **9** months

TEMPERATURE INSIDE THE NEST?

30 °C

THE THIRD HORNET OF THE OLD CONTINENT

Alongside the native European hornet and the invasive Asian hornet, Europe is home to another native species – the Oriental hornet (*Vespa orientalis*). "The focal point of its range lies in northeastern Africa and Central Asia, but it also extends into southeastern Europe. In recent years, it has been steadily spreading northward on its own. It now occurs across the entire Balkan Peninsula, as well as in Italy, southern Austria, and parts of Spain," says entomologist Michal Perlík from the Biology Centre of the CAS.

A CASE OF MISTAKEN IDENTITY

Southeast Asia is home to many hornet species, and the Asian hornet (*Vespa velutina*) is among the smallest. In fact, it's even preyed upon by other species – for instance, the Asian giant hornet (*Vespa mandarinia*), whose queens can grow to be over five centimeters long (see size comparison on the right). Confusion between the two species has spread among the public and in the media due to their similar names – however, the latter is not found in the Czech Republic.

HOW MANY EGGS DOES A QUEEN LAY?

Approximately
15,000 per year

Asian giant hornet
Vespa mandarinia
50 mm

European hornet
Vespa crabro
35 mm

Oriental hornet
Vespa orientalis
30 mm

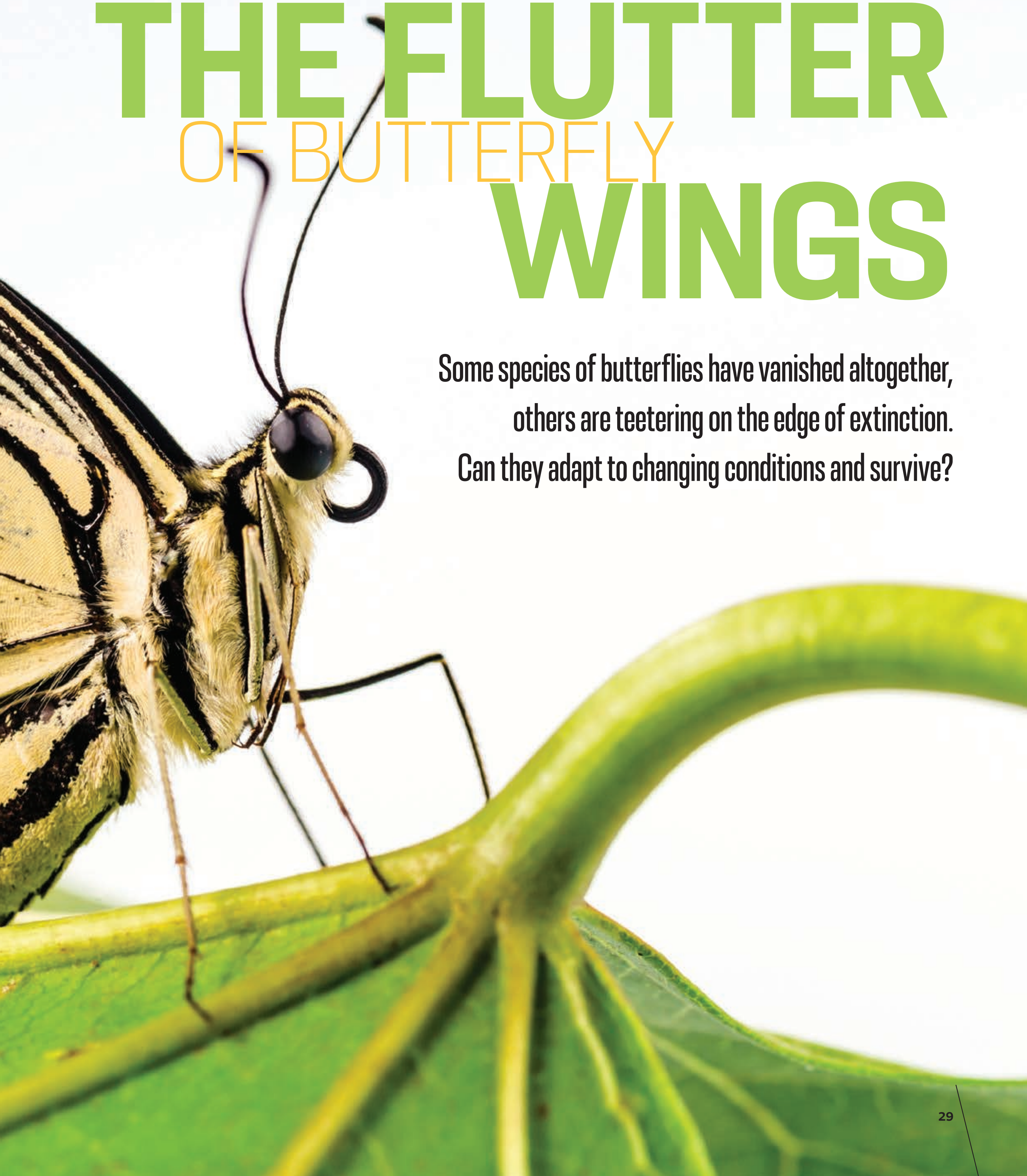
Asian hornet
Vespa velutina
25 mm

Common wasp
Vespula vulgaris
20 mm

Text: Markéta Wernerová \ Photo: Shutterstock (3), Jana Plavec (2), Wikimedia

THE FLUTTER OF BUTTERFLY WINGS

Some species of butterflies have vanished altogether, others are teetering on the edge of extinction. Can they adapt to changing conditions and survive?



Who doesn't love a good old love song? In one popular Czechoslovakian hit from the 1960s, the lyrics tell of a girl who catches a butterfly in a meadow – "because it has pale blue wings, we'll stay together, and slowly, it'll teach me how to kiss…" Bizarre much? Fun fact: in the original Czech version, the line was supposed to be "how to fly" (lítat), but somewhere between a phone call dictating the lyrics to the recording studio, a secretary's handwritten *t* was mistaken for a *b*, and "kiss" (líbat) ended up on the record instead. When the lyricist discovered the mix-up, he reportedly just shrugged and said, "Leave it in."

And so the butterfly – and learning how to kiss – remained, and the insect with the pale blue wings dominated Czech pop culture for a while. But let's set the music aside and look at butterflies through a scientific lens. What kind of winged bug might the singer have actually caught in the Czech countryside at the time? Perhaps one of the blues (subfamily Polyommatinae), of which several dozen species are found in the region. Some of these are now critically endangered and at serious risk of disappearing altogether.

Despite the name, not all of them are blue. The Idas blue (*Plebejus idas*), the Eastern short-tailed blue (*Cupido decolorata*), and the Mazarine blue (*Cyaniris semiargus*) do fit the bill – but only the males. In butterflies, coloration often varies between the sexes, with females tending to be less conspicuous.

Butterflies aren't the only creatures with this kind of sexual dimorphism. Many other animal species show differences in coloration between males and females. Still, butterflies are a particularly remarkable group of bugs. After beetles, they represent the second most diverse order of insects on the planet, with around 180,000 known species. They're also among the most important pollinators, second only to bees. And there's plenty more that makes them worthy of our attention.

RNDr. PÁVEL MATOS MARAVÍ, Ph.D.
BIOLOGY CENTRE OF THE CAS

Born in Lima, Peru, Pável Matos Maraví came to Europe in 2008 on a scholarship. He first studied in Finland, and in 2012 he began his PhD studies at the Biology Centre of the CAS, focusing on testing biogeographic hypotheses – for instance, why certain islands in Melanesia have higher ant diversity than others. He currently heads the Laboratory of Molecular Ecology and Phylogenetics at the Institute of Entomology, Biology Centre of the CAS. He is an expert in phylogenetic analyses, molecular methods in ecology, macroevolution, and biogeography. What he admires most about the Czech Republic is its breathtaking nature and beautiful national parks – places where one can escape everyday routine. In 2021, he received the Otto Wichterle Award from the CAS, which recognizes promising young researchers.

"Butterflies are among the most visually stunning animals. Their diversity in color, shape, and size often tells us captivating stories about their ecology and evolution," says Pável Matos Maraví from the Institute of Entomology at the Biology Centre of the Czech Academy of Sciences (CAS). His research allows him to appreciate not only their external beauty, but also to investigate how ecological interactions, genetic factors, and environmental conditions – like climate, temperature, humidity, and light – shape their remarkable diversity.

ANSWERS CODED IN THEIR GENES

The diversity of life in nature – biodiversity – is at the heart of this research. And since humans are the primary force threatening it, it's only fair that we should also be the ones trying to repay our debt to nature by finding ways to protect it. "The longer we delay restoring habitats and ecosystems, the greater the time, effort, and resources it will take to address the consequences of biodiversity loss. If we want to preserve nature's beauty and the benefits it provides for future generations, we have to act promptly and decisively," Matos Maraví emphasizes. So what approaches are scientists taking to protect biodiversity? How are they helping rare bugs survive so that future generations will also be able to catch – or better yet, simply admire – a butterfly with pale blue wings fluttering across a meadow?

One promising approach involves genomics. But why is this field – the study of organisms' genomes – important for insect conservation? "In the face of growing threats like climate change and habitat loss, genomics increases our capacity to address critical questions, such as which genetic variants a species needs in order to respond to environmental changes," Matos Maraví explains.

In conservation, bugs are an important indicator of ecosystem health and environmental change. Genomic data allows scientists to assess how processes like biotope management and habitat fragmentation – whether caused by natural forces or human activity – impact species' genetic diversity, gene flow (the transfer of genes between populations), population sizes, and adaptive potential.

Erebia butterflies don't dazzle with bright colors, but with the striking eyespots on their wings.

> "The greatest threats to ecosystems, species, and populations around the world stem from human activity over many generations. Biodiversity conservation therefore requires long-term commitment and international cooperation."
>
> *Pável Matos Maraví*

Genomics can also inform the protection of so-called umbrella species – species whose conservation indirectly benefits other organisms (both fauna and flora) that share their habitats, effectively "sheltering" the wellbeing of the broader ecosystem. As Matos Maraví explains, "To sustain threatened populations, it's sometimes necessary to translocate individuals of a particular species. ›

Genomic analyses can help us identify source populations that minimize the risk of introducing maladaptive genetic variation or of threatening unique genetic variants found in local populations."

For rare insect species, genomics is especially valuable for identifying losses in genetic diversity. For common species, it helps uncover the genetic basis of traits that allow them to thrive. Genes play a critical role in many aspects of survival, from disease and parasite resistance to tolerance of extreme environmental conditions or the ability to exploit new food sources – such as specific host plants. "We want to understand why some species are common while closely related species are rare," the entomologist adds. "This insight could help us design future conservation strategies, where genetic variants associated with traits that increase population fitness could be the key to sustaining certain endangered species."

MORE THAN MEETS THE EYE

Matos Maraví and his colleagues are also studying butterflies of the genus *Erebia*, commonly known as ringlets, though the term isn't used exclusively for this genus. This group includes more than 90 species in the Nymphalidae (brush-footed butterfly) family. They aren't exactly flashy – most are dark brown with orange, reddish-brown, or yellow spots or bands on their wings, each with a black dot or "eye" in the center. What they lack in glamor, they make up for in hardiness. Ringlets are well adapted to cold environments and are found in Central Asia, the Alps, and the Carpathians – along with a few species native to the Czech Republic.

In one study, the researchers examined how *Erebia* butterflies with a Holarctic distribution living in cold regions respond to their environment. They discovered that their responses are influenced by long-term adaptation to certain conditions, such as a specific climate. This adaptation – known as a climatic niche – tends to overlap in closely related species. In simplified terms, similar

"One of the perks of this job is the chance to travel for research to remote parts of the world – like the rainforests of Peru and Brazil, but also to beautiful places in the Czech Republic where endangered butterflies, such as the Alcon blue, still live."

Pável Matos Maraví

WHY DO BUTTERFLIES HAVE TAILS?

Our researchers traveled to the rainforests of South America to study skipper butterflies from the subfamily Eudaminae. These butterflies are especially notable for their hindwing tails. According to scientists, these "tails" serve several functions: they deflect attacks away from vital body parts and also act as a warning signal, saying "Don't eat me!" to would-be predators. These findings have raised new questions. Researchers are now examining how butterfly tails affect flight behavior. "In one study, we're quantifying the speed of tail evolution – since in many species, these wing structures evolved independently multiple times. This will help us understand how selective pressures acting at local and ecological scales influence species evolution over time," Matos Maraví explains.

DID YOU KNOW...?

Butterflies have taste sensors on the undersides of their feet.

The largest butterfly species in both Europe and the Czech Republic is the giant peacock moth (*Saturnia pyri*), with a wingspan of up to 16 centimeters.

Butterflies have been around since the time of the dinosaurs.

They are commonly classified into day-flying and night-flying species, though the latter are colloquially – and incorrectly – referred to as moths.

Adult butterflies have four wings, i.e., two pairs.

They inhabit all continents apart from Antarctica.

Adult butterflies typically only live a few weeks.

A butterfly's life cycle has four stages: egg, caterpillar, pupa, and adult.

Butterflies can see ultraviolet light but not red.

Most of a butterfly's head is taken up by compound eyes.

The scientific name for the order of butterflies – *Lepidoptera*, "winged insects," comes from the Greek λεπῐ́δος (*lepídos*), meaning "scale".

Telegonus fulgerator, a spread-wing skipper butterfly, can be found across the southern USA all the way to northern Argentina.

species usually have similar habitat requirements.

It turned out that, unlike their European counterparts, Central Asian *Erebia* butterfly species can survive in a wider range of conditions because the weather there is more variable than in Europe. According to the researchers, the differences between European and Asian *Erebia* butterflies are likely due to more pronounced seasonal contrasts in Asia, which have "forced" local species to adapt to greater changes. So, the environment butterflies live in shapes both their development and their adaptive abilities.

Let's stay with ringlets a bit longer. Another study looked at the impact of body size on thermoregulation in alpine *Erebia* species. Efficient thermoregulation is essential for animals living in fluctuating climatic and weather conditions. In a lab experiment using artificial light and heat sources, researchers used a thermal camera to measure how the butterflies' bodies warmed up.

They discovered that larger butterflies warm up more slowly than smaller ones, regardless of species. So, heating rate depends more on body size than on species identity. This finding will help us better understand how butterflies regulate temperature – how they adjust to thermal conditions in order to survive.

THE ENTOMOLOGIST'S FAVORITE

Matos Maraví's favorite butterfly is *Telegonus fulgerator*, a tropical American species from the family Hesperiidae (skippers). As the researcher puts it, this skipper butterfly's ecology and morphological traits are fascinating. "It's a stunning creature with dark brown wings marked by blue spots and white bands. Interestingly, many unrelated butterfly species share this same coloration. This points to a possible ecological benefit, such as signaling to predators that it's inedible."

Its caterpillars are just as remarkable. They show great variability in their choice of host plants and are brightly colored red and yellow – warning colors meant to deter predators. *Telegonus fulgerator* is a perfect example of how ecological interactions drive the evolution of phenotypes and spur the emergence of new species.

THE LITTLE THINGS

Why exactly do bugs fascinate Pável Matos Maraví? "In the words of famous American biologist and entomologist, E. O. Wilson, insects are the little things that run the world. In terms of species diversity, they outnumber all other animal groups. In nature, insects play vital ecological roles – pollination, for instance – and they're also an important food source for predators and parasites." In other words, they're excellent models for scientists seeking to understand how evolution drives speciation, adaptation, and functional diversity.

BUGS UP CLOSE

We come across them every day, yet we've never truly seen them – at least not like this. These strikingly detailed images of insect heads were captured using cutting-edge microscopes by scientists at the Biology Centre of the Czech Academy of Sciences in České Budějovice.

A JOURNEY INTO THE MICRO-WORLD OF INSECTS

The *Bugs Up Close* exhibition, on view in 2025 at the South Bohemian Museum in České Budějovice, took visitors on a journey through the evolution of insects – from representatives of the oldest groups whose ancestors date back to the Paleozoic era, to the most recently evolved forms. Captured with electron and optical microscopes, the images come from researchers at the Biology Centre of the CAS and reveal – in minute detail – creatures we all know, though never from so up close.

EUROPEAN MOLE CRICKET

Gryllotalpa gryllotalpa

With its stout, subterranean-adapted body, this insect is built for digging.
The European mole cricket uses its large, spade-like forelegs to tunnel through the soil. Preferring moist habitats such as gardens, fields, and meadows, it emerges above ground only during mating season in May and June, when it also takes to the air after dark. And it can even swim.
A predator by nature, the mole cricket feeds primarily on insects, segmented worms, and mollusks.

HEAD LOUSE

Pediculus humanus capitis

This tiny parasitic bug feeds exclusively on human blood. Although its bites can itch and cause irritation, it doesn't transmit disease. The much-dreaded head louse is a common occurrence across all socioeconomic groups, particularly among kids in schools and preschools. In recent years, global outbreaks have been on the rise, partly due to increasing resistance to common insecticides.

GREEN PEACH APHID

Myzus persicae

A small aphid and a serious pest of peach trees, this insect causes stunted growth, leaf deformation, and the dieback of various plant tissues. It reproduces rapidly – producing up to 80 offspring per week – and can change its form depending on environmental conditions. In case of stress or overpopulation, it develops wings, allowing it to migrate to new host plants.

SNAKEFLY

Dichrostigma flavipes

In the Czech Republic, *Dichrostigma flavipes* is found from lowlands to mid-altitudes. This species of snakefly inhabits open woodlands, clearings, scrubby hillsides, forest-steppe environments, roadside edges, and field margins. It lives on shrubs and tree branches, where it preys on small insects, especially aphids. Active mainly during the day, it's not a strong flyer, but moves nimbly from leaf to leaf.

GRAY'S LEAF INSECT

Phyllium bioculatum

This remarkable bug lives in tropical mountain forests of southern India and on islands such as Java, Borneo, Sumatra, Sri Lanka, Madagascar, and the Seychelles. It is a member of the order Phasmatodea and typically grows to 5–10 centimeters in length. Primarily herbivorous, Gray's leaf insect feeds on plants like mango, guava, and rambutan. Its flattened, irregularly shaped body, wings, and legs are nearly indistinguishable from leaves, making it a master of disguise.

BUFF-TAILED BUMBLEBEE

Bombus terrestris

One of the most widespread bumblebee species in Europe, the buff-tailed bumblebee excels at buzz pollination – a technique where wing vibrations dislodge pollen from flowers. It's especially effective for pollinating tomatoes and peppers, which is why commercial growers often use bumblebee colonies in greenhouses. Thanks to its long tongue, it can also reach nectar hidden deep in flowers.

EUROPEAN EARWIG

Forficula auricularia

Among the most misunderstood insects, the European earwig owes its common name to an old superstition that it crawls into people's ears while they're asleep – a myth dating back to the early Middle Ages. Although it has wings and can fly, the earwig spends most of its time crawling. Light-averse, it hides during the day to avoid sunlight. In colder seasons, it digs underground burrows where it overwinters.

Vladimíra Petráková

TINKERING WITH JEWELRY

Using gold and diamonds, she's working to refine optical microscopy and reveal hidden patterns in the nanoworld – while breaking Czech science stereotypes, such as women having to choose between children and a career.

Do you enjoy wearing gold jewelry?
I've got gold earrings and a wedding ring, but you wouldn't know it at first glance – they're made of white gold. I can't really wear other jewelry, since I'm allergic to certain metals.

What about a diamond necklace?
Still waiting for that one. *(laughter)*

Yet gold and diamonds are basically your daily bread...
They are, but I definitely don't come across jewelry at work. What fascinates me about gold and diamonds isn't their sparkle – it's how they behave when they're really, really small.

How small are we talking?
We're in the realm of the nanoscale – particles thousands of times thinner than a human hair, smaller than the wavelength of light. And in this tiny world, gold, diamonds, and other materials behave very differently to how they would in our everyday world.

In our world, we can usually recognize gold by its color – unless, of course, it's white gold, like your ring. Does gold look the same at the nanoscale?
Not at all! It can be blood red, but also blue, green, or purple. Its appearance depends on its size and shape – that determines which wavelength of light it interacts with the most. The most common shapes are spheres or rods, but there can also be triangles or even little stars.

So, no gold bars at the nanoscale. And I guess I shouldn't picture a nanodiamond as a tiny cut gem either?
Definitely not cut, but it basically is a miniature piece of diamond – extremely small crystals with irregular shapes. Nanodiamonds can also come in different colors: pink, blue, yellow – it all depends on the defects inside them. Blue ones, for instance, have boron atoms in their lattice; yellow ones contain nitrogen. Pink or purple diamonds also contain nitrogen, but it's paired with a vacancy – a missing carbon atom in the lattice. That particular defect, known as a nitrogen–vacancy center, has incredibly interesting properties that change depending on external environment.

> "Gold and diamonds fascinate me. In the nanoworld, they behave very differently to how they would in our everyday world."
> Vladimíra Petráková

You've been working with nanodiamonds since your doctoral studies. What drew you to them?
It kind of started off by chance. I had my daughter when I was twenty, and in my fifth year of university, I was looking for a job I could combine with taking care of her. I found out that doing a PhD would give me a fair amount of flexibility. That's how I first started researching the biomedical potential of nanodiamonds – and I really got into it.

We'll definitely get to the topic of combining family life and science later. But first – how exactly can nanodiamonds be useful in medicine?
Nanodiamonds can serve as drug delivery vehicles for targeted therapies. They're non-toxic, you can attach biomolecules to their surface, and they can enter cells. You can also create nitrogen–vacancy centers in them, which fluoresce. These then act as luminescent centers that don't flicker and are incredibly stable. This makes it possible to track the nanodiamonds' movement through cells.

Nowadays, your main focus is on gold nanoparticles. But you haven't completely left diamonds behind, have you?
I have not. We're still working with them, just in a different way. In one of our projects, we needed to find molecules that fluoresce in a very specific way – and nitrogen–vacancy centers turned out to be a perfect match. We want to use them to study how gold nanoparticles influence the fluorescence of nearby molecules.

Wait – are we talking about gold or diamonds here?
Both, actually. We place a gold nanoparticle next to a nanodiamond and observe how the gold affects the diamond's glow. We jokingly describe ourselves as "nanojewelers." *(smiling)*

So tell us, what's a tiny piece of gold good for, really?
Gold has some truly fascinating properties, especially related to how it interacts with light. It can amplify the optical response of molecules, help manipulate light, and even change the light's color or direction. Sometimes I compare it to a kind of "nanomagnifying glass" that enlarges a molecule's image from the inside – so when we look at it under a microscope, we're actually seeing an already magnified version. That allows us to observe finer details.

Gold is a symbol of wealth and luxury. Is its nano form valuable too, or just regular lab material?
The value of gold nanoparticles lies more in the time and energy we put into working with them. They're not actually that expensive. I can even give you a vial of nano-gold if you'd like. *(laughter)*

A vial? So it's a liquid?
Gold nanoparticles are solid crystals, but so small that when suspended in a solution, they stay evenly dispersed and be-

Assoc. Prof. Ing. VLADIMÍRA PETRÁKOVÁ, Ph.D.

J. HEYROVSKÝ INSTITUTE OF PHYSICAL CHEMISTRY OF THE CAS

She studied biomedical engineering at the Czech Technical University in Prague. During her PhD, which she completed in part at the Institute of Physics of the CAS, she researched luminescent centers in diamonds. Between 2016 and 2019, she worked at the Free University of Berlin, where she began focusing more on gold nanoparticles. Her goal is to describe what happens when gold nanoparticles interact with light, and how this could be used to enhance optical microscopy. In 2021, Petráková received a Junior Star grant from the Czech Science Foundation, followed by the Lumina Quaeruntur Award from the Czech Academy of Sciences in 2022. She is also a co-founder of Czexpats in Science, a platform connecting Czech researchers abroad and advocating for the positive transformation of the Czech scientific system.

come part of the fluid. It's called a colloidal suspension. Think along the lines of milk – that's fat droplets in water. In the lab, we work with both gold and diamond nanoparticles in solutions.

You said gold nanoparticles are unique in how they interact with light. So what exactly happens when they "meet"?
Gold is a metal, so its lattice contains free electrons. When light passes near a gold nanoparticle, all those electrons start to oscillate in sync – and they actually extend slightly beyond the particle. This creates a dense cloud of electrons around the surface, known as a surface plasmon. The electrons oscillate at the frequency of light, so in a way, they mimic it.

And what does a plasmon do?
It acts as an amplifier. It focuses the energy of the incoming light into a tiny region near the surface of the nanoparticle. That, in turn, affects the light that's passing through, and that's why gold nanoparticles appear so intensely colored to us.

I guess these effects don't happen at larger scales, do they?
That's right. In a large piece of gold, the electrons won't form that oscillating cloud. These effects only occur at the nanoscale, where the particles are smaller than the wavelength of light.

So gold nanoparticles act like miniature floodlights that help us see more clearly what's happening in a sample?
That's one way of putting it! But it only happens very close to the nanoparticle's surface. Other fascinating effects occur in that ›

space that we don't fully understand yet. A few years ago, for instance, we noticed that we saw a molecule that was close to a gold particle somewhere else to where it actually was. It was a bit like a mirage – when you think you see something in one place that is somewhere else entirely.

The nanoworld clearly isn't boring. But can this "mirage effect" be put to any use?

That's exactly what we're trying to figure out. We're experimenting with this seeming motion of molecules – trying to learn how to control and use it as a more precise kind of nanomagnifying glass. It could help us determine what's really happening inside the sample we're observing. More detailed information on the structure and motion of molecules could make it easier to understand enzymatic reactions or DNA processes that can lead to cell damage. So there is potential for medical applications – and possibly even completely different areas, like energy research.

That's a field quite distant from medicine. How can gold nanoparticles be useful there?

True, the applications are different, but the basic principles of how materials interact with light are the same. In some types of solar cells, for instance, nanomaterials are arranged close together, and it's important to understand what affects how efficiently they interact with light. By grasping these fundamental principles, we can ultimately help improve solar cell performance.

Do people often ask you what your research is actually good for?

All the time. And I find it a bit tricky to answer, because what we're doing is looking at basic principles. I compare it to exploring an unknown rainforest. You're venturing into a place no one's ever been to before. It's important to keep your eyes open and try to understand and describe how this new world works. But at the same time, it's good to think about how the findings could be useful. We're not building new microscopes or solar panels ourselves, but even in our research we develop things that can be used in practice – for instance, we've created our own computer algorithms that others in different fields might find useful.

Speaking of exploring new worlds – you spent some time living and doing research in Germany. What did that experience give you?

It was amazing in every way. It totally changed how I think about science – I felt freer, somehow. Like I had more time and energy to ask big, bold scientific questions. In the Czech Repub-

MOTHER OF FOUR

Doing top-level research at an international standard while raising four children? For Vlaďka Petráková – who radiates boundless energy in person – it's perfectly normal. Her daughter was born when she was twenty, and the family later grew with three sons, now aged thirteen, eleven, and five. Whether the kids will follow in her footsteps remains to be seen: "It's that age-old story – no one's a prophet in their own land. What Mom does isn't as cool as what other people do. My eldest is in her first year of university studying IT. The one most interested in science might be my youngest. He got a science kit with test tubes for Christmas and was absolutely blown away," the researcher says.

"In Germany, being a scientist and mom of four was never an issue. Coming back to Czechia was a real shock."

Vladimíra Petráková

lic, I've always felt more overwhelmed and distracted. Maybe it's because Germans are better organized – they plan more, so they're not constantly getting thrown off by unexpected stuff.

Can you give an example?

Sometimes I get an email asking me to take care of a task right away or within a few days – to my liking, that kind of thing happens here too often. In Germany, everything tends to be well planned in advance, and when something urgent does come up, people give you enough time to deal with it. To me, the Czech system feels a bit too spontaneous and chaotic – and I think that can lead to a kind of passivity, where people mainly just react to requests instead of taking the initiative. Since I came back from Germany, I keep bumping into this and have to really push to carve out time for deep thinking and creativity.

But carving out time for yourself isn't where it ends – you've got ambitions to change Czech science. What's your approach?

By drawing inspiration from abroad. I want to tap into the potential of the Czech scientific diaspora. In 2018, I co-founded a platform called *Czexpats in Science* with two friends – we were classmates at CTU. Our organization gives researchers abroad a chance to share their experience and help improve the research environment back home. A lot of them would love to come back, but certain things are holding them back.

Do you have a sense of how many people we're talking about and what kinds of obstacles they're facing?

We estimate there are several thousand Czech scientists working abroad. Many of them we know are eager to stay in touch with institutions here and would like to return. They want to contribute to their fields, and personal reasons also play a role in their motivation to come back. When we asked them about the main obstacles, they pointed to a lack of transparency in hiring, salaries, and career advancement – and also academic inbreeding, meaning jobs and leadership positions going to a narrow pool of in-house graduates. We've mapped all of this in a report we published earlier this year.

That's the one called "Who Are the Czech Scientists Living Abroad? An Analysis of the Czech Scientific Diaspora and Its Relationship to Science in the Czech Republic". It's a fascinating read. What was the goal of the report?

To show how the Czech research environment is perceived from the outside, and to pinpoint areas that need improvement. I'm really pleased it has now been published. We collected data via online surveys as well as in-depth interviews. At the time of the survey, respondents were working in thirty countries around the world – three-quarters in STEM fields, and one-quarter in the social sciences and humanities.

One of the biggest issues raised – particularly by women, but also by men – was the attitude of Czech society toward women. What's been your experience?

That issue hits very close to home. In Germany, I never once had a problem being a researcher and a mother of four. Kids there are seen as a natural part of life – and that includes your career. The institutions are set up and prepared for it. It's a completely different story in the Czech Republic. It's really about the overall social climate.

What do you mean by that?

Let me give you an example. I had my daughter in my first year of university. I wasn't eligible for maternity leave, there were no social stipends, and nursery school only started at age three. I really had to fight hard just to stay in university as well as making sure my daughter was taken care of. When I tried to raise awareness about these issues, people saw me as whiny and weak. And my whole identity in other people's eyes changed. Suddenly no one was asking me what I was passionate about or what I wanted to do after university. I was "the mom," and everyone seemed to know exactly how I was supposed to feel, what I should be doing, and what should matter to me. That kind of environment leads many women to stay at home with their kids or settle for part-time jobs instead of going after ambitious goals – like leading their own research group.

So what needs to change for Czech science to be more open and inclusive?

A good first step is simply to acknowledge the problem and give it a name. Then you need to adjust grants and institutional policies to take life events, like having children, into account. Some institutions and grant agencies are already doing this, but the Czech research system as a whole is fragmented and lacks coordination. Through our Czexpats platform, we're highlighting these issues. Over the past few years, we've professionalized – we now have our first employees and a clear vision with a plan to make it happen.

> "My daughter was born when I was twenty. Later, a PhD gave me some flexibility to balance work and childcare."
>
> *Vladimíra Petráková*

What's the plan, and how is it going so far?

We want Czech science to be global, open, and ambitious. We believe Czech universities belong in the world's top 100 – and we want to help get them there. A major milestone is the ›

report I mentioned earlier – it clearly identifies the key problems and proposes ways to address them. Another part of our work involves engaging with policymakers who can influence science policy. But we also believe strongly in grassroots efforts – supporting the scientists themselves. Together with Charles University, we launched a platform where heads of research groups can meet and share experiences. We call it the PI Forum – short for "Principal Investigator." They can learn from each other how to lead teams, motivate coworkers, and pass on what they've learned, including insights from abroad.

You really lit up when you talk about Czexpats. That kind of excitement reminds me of researchers telling me stories about fieldwork in rainforests. Do you ever get opportunities in your research work to do something like that?
Though I did compare my research to exploring a rainforest, I'll admit – it's not quite *that* adventurous. *(laughter)* But I do find it really fulfilling. I love the variety of it, which allows for a lot of creativity. I have a dynamic research group, with its members always coming up with new ideas. We're all different, so I'm constantly learning.

What's your secret for building a strong team across various disciplines and cultures?
I try to keep this in mind right from the selection stage – it makes everything easier later on. We have chemists, material scientists, biophysicists – people from Germany, the UK, and Nigeria. Communication is key, and it's important to really understand each other. Non-work activities help, too. Last year we all went on a group bike trip to Lidice. I wanted my team to connect with a piece of Czech history.

"We estimate that there are several thousand Czech researchers abroad. Many want to stay in touch with Czech research institutions – and even return home."
Vladimíra Petráková

That's a pretty intense start. The story of Lidice, destroyed and massacred by the Nazis, is deeply tragic.
All the more reason to commemorate it. I'm from Kladno, and the grammar school I attended was where the women of Lidice were held and separated from their children. It's something that stayed with me, and I wanted to share that part of myself – and of our local history – with my team. The landscape around Lidice is actually very peaceful and delicate, so it made for a striking contrast with the place's tragic past. And here's a fun detail – for our colleague from Nigeria, it was a total first. He'd only sat on a bike a few times before, and this was his very first trip like that.

You ride a bike often and with joy. But as far as I know, there's no direct bike path from Kladno to Prague, so do you take a different form of transport to get to the lab?
Unfortunately, there's no cycle path, but I still ride my bike to work – though not every day. Sometimes it's pretty rough. Even though I choose smaller roads, they still have traffic. I love cycling and see it not just as a great way to commute but also as a perfect means of transport for longer distances on our family vacations.

Where do you and your family go cycling? And is my image correct of a peloton of bikes loaded with gear, sleeping bags, and a tent?
There's quite a few of us, that's true, but we're no racers. We like to enjoy the ride through the countryside. Our favorite destination is France, which has great cycle routes and campsites. We've ridden along the Atlantic coast from Brittany to Bordeaux, and we've crisscrossed Provence and Alsace. We'd also like to visit northern Europe, but the weather there makes it a bit more challenging.

Travelling with kids comes with its own challenges. Any adventurous stories to share?
It used to be a lot about trivialities – like figuring out where to go potty – but these days it's more about motivating the kids to push through exhaustion, get up that hill, and enjoy that sense of victory. The memory that stands out most is our very first cycling trip ten years ago. We were in France and it rained the entire time. Everything was drenched – even the tent was waterlogged – and the final straw was when our son marched straight into a lake wearing his last pair of dry pants. I can still picture the moment the water started pouring over the tops of his wellies. At that point all I wanted to do was cry. But he loved it, and now it's one of our fondest memories. *(laughter)*

Exploring the nanoworld must be intense work, so I can see why cycling would be a great way to clear your head. How else do you relax?
I quite enjoy running, too. I have a dream of doing this race in New Zealand that goes all the way across the island from one coast to the other. It's a mix of running, biking, and kayaking. When I turned thirty, I told myself I'd do it at forty. Well, I'm turning forty this year, and I'm definitely not ready yet. I'll have to step up my game. *(laughter)* Maybe next year. For now, it's still up in the air.

Speaking of skies – this January, your team published a paper in *Nature Communications* that surprisingly connects with stars a little, doesn't it?
Yes. We use fluorescence to visualize molecules, so what we see under the microscope resembles a starry sky: a black background

with lots of glowing dots. We took inspiration from a technique used in astronomy and adapted it to help identify molecules in microscopic images.

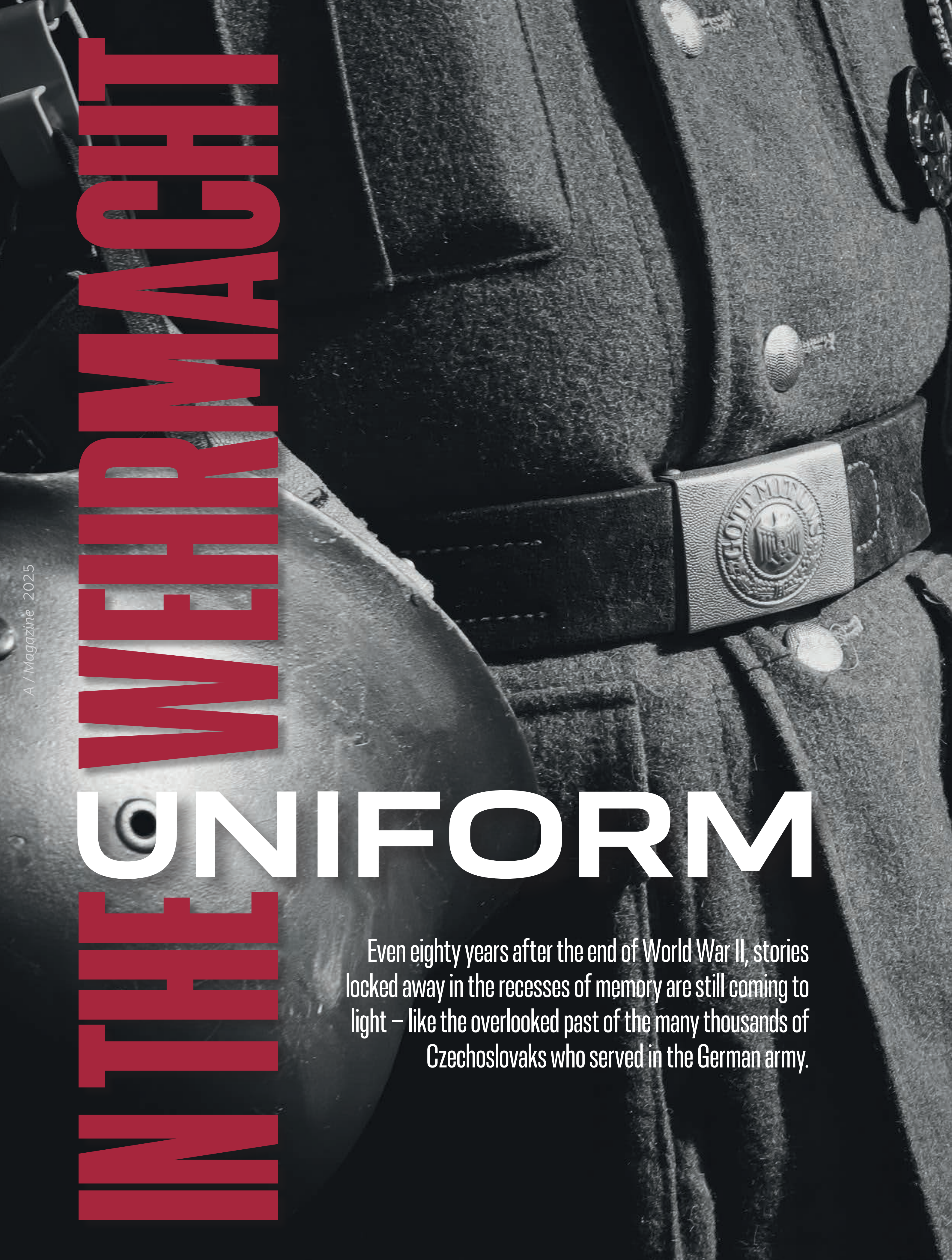
How did you come up with that idea?
This method has long been used in astronomy and radar systems, but oddly enough, not in microscopy. The idea came from my colleague Miroslav Hekrdla, who used to work in radar research. I think it's a brilliant example of how ideas from one field can spur advances in another. There truly is strength in diversity.

That diversity seems to run through your entire scientific path. Which field would you say you actually belong to – physical chemistry, biophysics, materials engineering?
Originally, at the Czech Technical University in Prague, I studied biomedical engineering, which deals with hospital technologies, ultrasounds, MRI, and so on. It gave me a solid grounding across disciplines – I learned physics, chemistry, electronics, signal processing, as well as biology and the basics of medical subjects. Our whole team is interdisciplinary, which allows us to approach our research from unconventional perspectives.

So that's why you see potential in gold and diamond nanoparticles that might not be obvious at first glance…
There's still a lot to uncover – the nanoscale world is largely unknown, like those metaphorical jungles we talked about earlier.

SUPERGLASSES THAT ZOOM IN REALLY CLOSE

For a long time, it was considered a given in the scientific world that optical microscopes had a hard limit due to the physical properties of light (the so-called Abbe diffraction limit). These barriers were only broken through recently. In 2014, the Nobel Prize in Chemistry was awarded to Americans Eric Betzig and William E. Moerner and German scientist Stefan W. Hell for discoveries that led to the development of super-resolution optical microscopy. We covered the evolution of these new microscopy techniques in the 2024 English issue of *A / Magazine*, in a special feature on light.



IN THE WEHRMACHT UNIFORM

Even eighty years after the end of World War II, stories locked away in the recesses of memory are still coming to light – like the overlooked past of the many thousands of Czechoslovaks who served in the German army.

> Refusing to sign the Volksliste meant risking reprisals – at worst, even imprisonment in a concentration camp.

Otmar Malíř was fifteen when Polish forces occupied his native region of Těšín Silesia in 1938, and sixteen when the Germans took over the same territory in 1939. The Silesian region around the towns of Těšín (Cieszyn, Teschen), Jablunkov, and what is now Havířov historically developed at the intersection of Polish, Czech, and German cultures. It belonged to Czechoslovakia during the years between the two world wars, yet its inhabitants maintained a distinct identity that defied traditional notions of nationality. Most locals spoke (and some still speak) "po naszymu [our way]," a dialect that sounds like a blend of Polish and Czech.

When Nazi Germany invaded Poland in 1939, it seized control of the Silesian Voivodeship, which included the Těšín Silesia region. As in other annexed Polish territories, the Nazis introduced the so-called Deutsche Volksliste – a register of inhabitants deemed suitable for Germanization. Refusing to sign could result in harsh reprisals, including imprisonment in a concentration camp. Signing the Volksliste conferred certain rights – graded by category – such as permission to remain in one's homeland and keep a job, property, or land. The flip side was the obligation for men to enlist in the German army.

The aforementioned Otmar Malíř received his call-up papers for the Wehrmacht in September 1942. After the war, he recalled planning to desert the German army from the start and join the Allies. He got his chance soon enough – while serving in the Afrika Korps, the Wehrmacht force fighting in North Africa, he was captured by the British in May 1943. Together with several friends from Těšín Silesia, he plucked up the courage to approach the guards and declare that they were not Germans and wanted to switch sides.

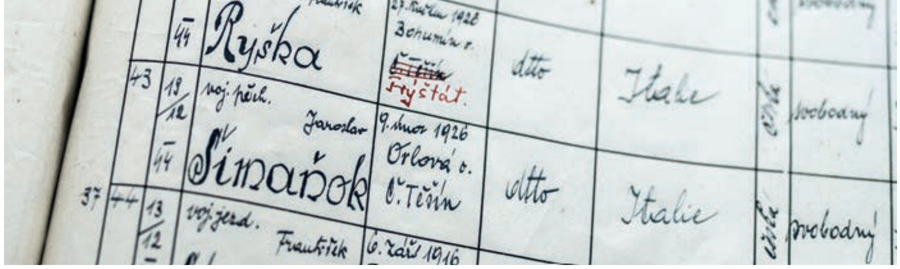
"Without a doubt, one of the first people to break the long silence surrounding the participation of Czechoslovaks in the Wehrmacht was Otmar Malíř. He was a patriot who had already stood up for the Czech cause during the Polish occupation, deserted the Wehrmacht at the first opportunity, and joined the Czechoslovak army in exile," says military historian Zdenko Maršálek from the Institute of Contemporary History of the Czech Academy of Sciences (CAS).

MURKY STATISTICS

The story of Malíř may be the first to have been recorded, but it's far from typical. "You can't generalize. There were so many individual fates, and each one was completely different. Not every Czechoslovak who served in the Wehrmacht joined the Czechoslovak forces after being captured. Most spent the entire war in a German uniform," the historian adds.

Statistics do little to clarify the situation. Precise figures on how many Czechoslovak citizens were drafted into the Wehrmacht simply don't exist – we only have estimates. It's clear, though, that by far the greatest number of conscripts came from among Czechoslovak Germans, be they from the annexed Sudetenland or the Protectorate. The total may have reached as many as three-quarters of a million people. After the war, the vast majority of them were expelled to Germany.

The picture is different, however, for Těšín Silesia, where roughly 23,000 men were gradually conscripted, and for the Hlučín (Hultschin) Region, which saw about 13,000 locals join the Wehrmacht. Both regions were returned to Czechoslovakia after the war and remain part of the Czech Republic today. Most local residents were not expelled because they were not ethnic Germans. This left thousands of men with wartime experience on the German side living in ›



Draft records of soldiers joining the Czechoslovak army-in-exile reveal that a large number of them had previously served in the Wehrmacht. The documents are held at the Central Military Archive in Prague.

PRUSSIAN HLUČÍN REGION

Franz Kalwar, a 23-year-old from Darkovice near Hlučín, was working in an iron ore mine in the German town of Eiserfeld when the war broke out. Not long afterward, he was called up from nearby Siegen. He served with the infantry in several locations, including Finland, where he took part in Operation Arctic Fox – part of the German assault on the Soviet Union. Franz was wounded there, and – as his family later recalled – was lucky to encounter a doctor he knew from before, who issued him a certificate stating that he was unfit for further military service.

By July 1942, Franz was back in the mines of Eiserfeld. He made it back to his home village of Darkovice several months after the war ended. His story is one of around 11,000 more or less documented accounts of men from Hlučín who fought in the Wehrmacht, preserved in the online database of the Hultschiner Soldaten project.

The Hlučín Region – bounded roughly by the cities of Opava, Ostrava, and Bohumín – has a different history from neighboring Těšín Silesia. For nearly two centuries, from 1742 to 1920, it was part of Prussia. The local Slavic population retained close ties to German language and culture even during the interwar period. To this day, the villages in the region are dominated by churches built in the typical Prussian style of bare brickwork, and the locals are still known in surrounding areas as *Prajzáci*, derived from *Preußen* (Prussians).

There are some in the Hlučín Region who even welcomed the German arrival in 1939 with enthusiasm. But soon enough, even those who didn't share their neighbors' joy were forced to enlist in the Wehrmacht. Of the 13,000 local men who served, roughly one in five never returned.

TURNCOATS

For Wehrmacht soldiers who ended up in the Czechoslovak army in exile, the path typically led through Allied captivity – whether they actively defected across the front or simply allowed themselves to be captured. Over the course of the war, around 250 men from the Hlučín Region and more than 2,000 from Těšín Silesia swapped the German uniform for a Czechoslovak one.

Strikingly, more than 61 percent of all former Wehrmacht troops who were assigned during the war to Czechoslovak units in the West came from just two small districts – 786 men from the Český Těšín District and 1,009 from the Fryštát District.

Historian Zdenko Maršálek came across the fates of these men in the German uniform while examining archival records related to the Czechoslovak armies in exile in the West. "We were compiling a database of all members of the Czechoslovak forces in exile, and it was a genuine shock to us once we realized how many of them had served in the Wehrmacht prior to joining the Czechoslovak units," he says.

This is also because the subject had been taboo for fifty or sixty years after the war – it wasn't taught in schools, and no systematic research had been done. It's worth noting that this wasn't just a Czech phenomenon. "We see similar stories in many European countries that bordered Germany and experienced occupation and the annexation of parts of their territory into the Reich," Maršálek points out.

Forced conscription was a shared fate in regions like Alsace and Lorraine in France, Carniola in Slovenia, Upper Silesia in Poland, or the area around Eupen and Malmedy in Belgium. In all these regions, historians and journalists only began tackling the topic many decades after the guns had fallen silent.

BREAKING DOWN BLACK-AND-WHITE NOTIONS

"We tend to see World War II in fixed images that we consider unquestionable and reflective of reality. But more and more, it turns out it's not that simple," Maršálek stresses. The phenomenon of

Interested in learning more?
Visit the website *Czechs in the Wehrmacht* or the website of the Hlučín Region Museum.

AUTHOR'S NOTE

He was sixteen when he was drafted. My grandfather, Gustav Heczko, was one of those whose life was shaped by the forces of history more than he would have liked. That's why the subject of this article hits far closer to home than any other. Reading through the few testimonies I found from the men of Český Těšín, I was deeply affected. "There were piles of winter coats covered in blood. They must have been uniforms from dead soldiers. We had to put them on quickly. We were just kids. Nothing fit, everything was too big. I got a pair of boots that were about to fall apart," recalls František Bocek from Bukovec near Jablunkov in the Paměť národa (Memory of Nations) project, describing his induction into the German army in 1944. The same birth year, same draft year, and practically the same hometown as my grandfather. Did they know each other? Did they endure the same horrors? I can no longer ask my grandfather. By the time he started opening up about his wartime experience, I didn't record or write anything down. Back then I was too shy to ask if I could. My grandmother's older brother also served in a German uniform – but he never made it back home to Karviná. My father doesn't recall his parents ever speaking about the past; they lived in the present. Just like in many other families with similar fates, the war story in ours remained a taboo.

non-German soldiers serving in the Wehrmacht reveals just how much our perception of the past can be shaped artificially.

That this chapter of history is only now coming to light is, in a way, understandable. After the war, there was a need to rebuild faith in the future, and the focus was mainly on stories of heroism and brave, direct resistance to Nazism. The fact that hundreds of thousands of citizens from Allied countries fought on the enemy's side didn't fit that narrative. "If there had only been a few, they might have been dismissed as contemptible collaborators. But the number of people who served in the Nazi forces was relatively high across all Allied countries," the historian adds.

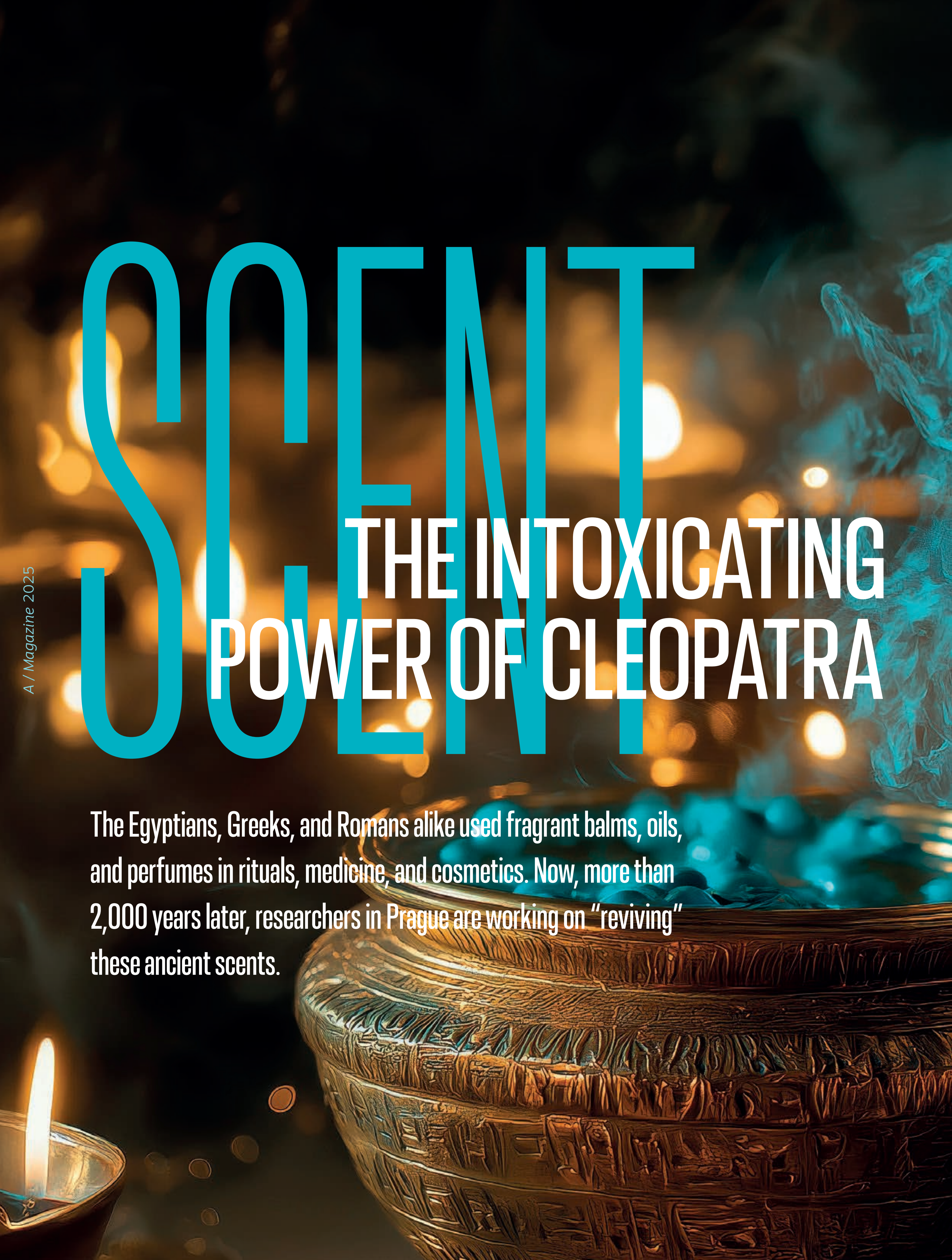
These former Wehrmacht soldiers returned home without fanfare. Their future was uncertain. In most areas, including Těšín Silesia and the Hlučín Region, a kind of unwritten social contract was eventually reached between the state and its citizens: the regime granted them a general pardon and left them in peace, and in return, they "forgot" their past and refrained from speaking about it publicly.

Today's renewed focus on the topic is a generational matter. Grandchildren, now grown up, are asking questions about the fate of their grandfathers who had served in the Wehrmacht. Their own parents, however, often know very little about it. Until the fall of the Iron Curtain in 1989 – and even for several years after – it was a locked room no one dared open. Although in the regions affected, practically every family had been touched by the experience, it was rarely spoken of.

Otmar Malíř was one of the few who wrote down their personal memories. Others buried the past deep within themselves and had no desire to revisit it. Many untapped sources can still be found in archives across Europe. And perhaps additional compelling testimonies will surface within families too – now, after so many decades, the right time may finally have come. Maybe somewhere in your attic or cellar, there too is an unexpected relic from a grandfather, great-grandfather, or distant relative who had once served in the German army. •

Mgr. et Mgr. ZDENKO MARŠÁLEK, Ph.D.
INSTITUTE OF CONTEMPORARY HISTORY OF THE CAS

His parents, both mathematicians, had hoped he would become a statistician or economist. But Zdeno Maršálek was always drawn more to words and images than to numbers. After a brief career as an art teacher, he studied history following the Velvet Revolution in 1989. He worked at the History Institute of the Army of the Czech Republic and the Central Military Archive in Prague; since 2006, he has been a research fellow at the Institute of Contemporary History of the CAS. He is the author of the book *"Česká", nebo "československá" armáda? Národnostní složení československých vojenských jednotek v zahraničí v letech 1939–1945* (A "Czech" or "Czechoslovak" Army? The Ethnic and Nationality Composition of the Czechoslovak Military Units-in-Exile in 1939–1945) and co-author of *Dunkerque 1944–1945*. His forthcoming book *V uniformě nepřítele. Čechoslováci a služba ve wehrmachtu* (In the Enemy's Uniform: Czechoslovaks and Conscription in the Wehrmacht) is due out later in 2025.



SCENT
THE INTOXICATING POWER OF CLEOPATRA

The Egyptians, Greeks, and Romans alike used fragrant balms, oils, and perfumes in rituals, medicine, and cosmetics. Now, more than 2,000 years later, researchers in Prague are working on “reviving” these ancient scents.

Text: Leona Matušková \ Photo: Midjourney (2), Institute of Philosophy of the CAS (5), Jana Plavec (6), Shutterstock

Tapputi-Belatekallim is the first known perfumer on record. She lived in Mesopotamia in the second millennium BCE and is sometimes described as the world's first known chemist.

The legendary beauty of Queen Cleopatra was said to have been enhanced by a captivating, all-encompassing fragrance of myrrh, cinnamon, and other exotic substances. She made sure her first meeting with the Roman general Marc Antony would be unforgettable. Cleopatra wanted to make an impression – after all, she needed him as an ally to help her hold on to her faltering rule over Egypt.

Cleopatra VII, the last Egyptian monarch of the Macedonian Ptolemaic dynasty, was renowned for her interest in perfumes and scented balms. She likely used them not only for adornment, but also to support her health and guard against disease. In fact, she has even been credited with writing a treatise on fragrant ointments – a text later referenced by the Roman physician Galen.

The queen, who took her own life in 30 BCE, was far from unique in her love of fragrances. She was part of an ancient Egyptian tradition, going back hundreds or even thousands of years, of using aromatic substances – primarily for ritualistic and religious purposes, but also for medical and cosmetic ones.

So what made Egyptian scents so special? Why did ancient philosophers study them, and how did they later influence alchemy and the natural sciences? How can we make sense of ancient recipes preserved in hieroglyphs or in Greek and Roman texts? And is it possible to recreate contemporary versions of legendary ancient perfumes using nothing but incomplete or fragmentary historical formulas?

These questions are being explored by the interdisciplinary team led by Sean Coughlin from the Institute of Philosophy of the CAS. Since 2021, the Canadian researcher has been developing the *Alchemies of Scent* project, supported by the JUNIOR STAR program of the Czech Science Foundation.

A scene of perfume production from the tomb of Petosiris in Tuna el-Gebel

CLEARING THE AIR

Sean Coughlin's journey into the world of scents began while studying the history of ancient philosophy and medicine at McGill University in Montreal. In antiquity, the preparation of medicines and healing remedies was closely linked to aromatic essences and the production of tinctures and ointments. Ancient physicians believed that diseases were caused, among other things, by impure air (the word "malaria," for instance, comes from the Latin *mal aria* for "bad air"). To recover from or ward off illness, they recommended exposure to pleasant aromas.

When, for example, a highly contagious epidemic of unknown origin swept through Rome in the latter half of the second century CE, the imperial physicians sent Emperor Commodus to a countryside palace surrounded by fragrant laurel groves on the Tyrrhenian coast. According to the medical advice of the time, air infused with laurel was thought to offer strong protection against infection. The Greeks and Romans attributed almost magical powers to this aromatic plant – laurel wreaths were given to victors in athletic competitions, and the plant was even recommended as protection from lightning.

Whether the treatment was effective or not, Commodus survived the epidemic – though today, we might attribute his survival more to isolation than to aromatherapy. In any case, the emperor – best known to modern audiences as the villain of the Hollywood blockbuster

"In the Ptolemaic era, Egyptian perfumes were a symbol of luxury. The Greeks and Romans adored them, considered them highly fashionable, and wanted to smell like Egyptians."

Sean Coughlin

Gladiator – lived another twelve years before being killed by his enemies.

Unlike the instructions given to the emperor, ordinary Romans received far less effective advice during this epidemic. To protect themselves from the contagious disease, they were told to anoint themselves with perfumed oils, burn fragrant incense, and stuff their nostrils and ears with aromatic spices. According to the historian Herodian, as many as 2,000 Romans were dying each day from the illness.

SCENTS AS A SOCIAL MARKER

Fragrance played a crucial role in ancient societies – even in everyday social interactions. One's scent could indicate social status; wealthier individuals could afford frequent baths, visits to public bathhouses, and luxurious perfumes, while the poor relied on simpler, more affordable fragrances – or none at all.

The importance of perfumes is also reflected in ancient Greek literature. Comedies often featured men adorned with fashionable Egyptian fragrances or depicted young men loitering in the streets of Athens near perfume shops. Even the philosopher Plato mentions perfumes and their role in an ideal society in his *Republic*.

But what is it about scents that makes them so influential? Biologists might discuss olfactory communication signals, pheromones, receptors, and neurons. Chemists will talk about volatile compound molecules and the reactions between different substances. But how does a philosopher approach scent? And what fascinates them about it?

"For me, scent raises fundamental philosophical problems," Coughlin says. "How can we perceive something that no longer exists, like incense after it has burned away, and yet fail to perceive what is still present once we've grown used to it? These are familiar experiences, but they unsettle our everyday ideas about perception and our access to reality."

There are many unknowns to uncover. How did people produce perfumes ›

SEAN COUGHLIN, Ph.D.
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Sean Coughlin studied ancient philosophy at McGill University in Montreal and Western University in Ontario. Between his studies, he worked for a year as a cook to better understand culinary metaphors in Aristotle's biology. Coughlin completed research fellowships at the Hebrew University of Jerusalem and Humboldt University in Berlin. He contributed to the reconstruction of Queen Cleopatra's perfume, which was presented at the *Queens of Egypt* exhibition at the National Geographic Museum in Washington, D.C. Since 2021, he has been the principal investigator of the *Alchemies of Scent* project, funded by the Czech Science Foundation under the JUNIOR STAR program. Coughlin is working on the project with the Chemistry of Natural Products research group at the Institute of Organic Chemistry and Biochemistry of the CAS.

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before the distillation method was developed in the ninth century? Who was involved in making them? And how did advancements in perfume-making techniques contribute to the development of the natural sciences, particularly chemistry?

THE ALCHEMY OF SCENT

"At the start of the process, you have ordinary olive oil, and at the end, you have a liquid that smells like roses or lilies. Transforming oils into fragrant substances is, in a way, a form of alchemy," Coughlin explains, referring to the name of his research project, *Alchemies of Scent*.

The researcher, who previously worked at Humboldt University in Berlin, appreciates the opportunity to pursue his work in Prague. "The alchemists at the court of Emperor Rudolf II were searching for the elixir of life. In a way, you could say we're doing something quite similar – trying to revive long-lost methods of producing fragrant essences," he adds.

But why do we speak of "lost methods" when written records of them have survived? It's because many of the ancient texts contain words that, after so many centuries, are no longer understood. The terminology varies from author to author, and the instructions often fail to include the full, precise procedure.

It's a lot like trying to follow a great-grandmother's recipe. An experienced cook likely wouldn't have written down every detail because the process was second nature. But if we can no longer call her for advice, we'll never recreate the dish exactly – we'll have to improvise.

This analogy with cooking is no coincidence. As a student, Coughlin felt that merely reading ancient texts wasn't enough to truly understand them. To do so, he believed, one had to "get their hands dirty" and try every process out in practice. That's why he took a year off from his studies to work as a cook. And this experience turned out to be pivotal for his academic journey.

"In antiquity, floral perfumes were typically favored by men, who liked the smell of lilies and roses, while women tended to wear heavier, resinous perfumes with the scent of myrrh and cinnamon."

Sean Coughlin

IN SEARCH OF LOST TIME

Exploring the world from different angles has proven invaluable. Perhaps that's why Coughlin designed his "perfume project" with an interdisciplinary approach in mind. Understanding the ancient techniques of perfume production and their sociocultural context thus involves a team of experts across disciplines – Egyptology, chemistry, botany, archaeology, and even IT. Their focus is on a specific period between the fourth and first centuries BCE, framed by Alexander the Great's conquest of Egypt in 332 BCE and the death of the last Ptolemaic queen, Cleopatra VII, in 30 BCE.

This was a time of intense cultural exchange. Both Greeks and Romans admired Egyptian expertise in perfumery, healing ointments, and fragrant oils. Much of the Mediterranean world was connected, with languages, influences, and traditions intermingling. The powerful Greek and rising Roman civilizations were deeply fascinated by the cultural wealth of ancient Egypt and sought to emulate it. Thanks to the writings of ancient scholars, much of this Nile kingdom's heritage has survived – including perfume recipes.

In addition to Greek and Roman texts, a handful of original Egyptian sources also exist, though they are challenging to interpret. "Most of the ancient Egyptian


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WALLS FULL OF PERFUME RECIPES

Ancient Egyptian recipes for perfumes survive as inscriptions on the walls of Ptolemaic temples (e.g., in Edfu and Athribis).

1 – The entrance to the "laboratory" of the Edfu temple

2 – A scene of offering *antu* (myrrh or another aromatic resin) from the Edfu temple

3 – A list of resins and aromatic woods

4 – A list of aromatic resins and a tree relief (Athribis temple)

recipes for what we might call 'perfume' survive as inscriptions on the walls of Ptolemaic temples. If we exclude medical texts, which have their own specific context, there are very few similar examples on papyri or other materials," says Diana Míčková from the Institute of Philosophy of the CAS and the Czech Institute of Egyptology at the Faculty of Arts, Charles University.

The most interesting research for the project is centered on the Temple of Edfu. One of its halls – known as the "laboratory" – is decorated with reliefs and texts depicting the offering of fragrances to the gods, ritual scenes with annotations, recipes, and an extensive list of various resins and aromatic woods.

The actual recipes inscribed on the walls are often complex. "Producing such a 'perfume' could take several years and involved many ingredients and steps. For instance, the recipe for an Egyptian 'oil' called *medjet* begins by describing how to raise and then slaughter a bull, whose fat was to be used after a year to form the base of the product," Míčková explains.

In the Ptolemaic era, Egyptian perfumes were a symbol of luxury. "The Greeks and Romans adored them, considered them highly fashionable, and wanted to smell like Egyptians," Coughlin notes. Producing Egyptian perfumes was likely expensive, ›

> "We often don't know exactly which plants, minerals, or resins the Egyptians used – only their Egyptian names. In some cases, we know what they were used for, but not which plant or substance they refer to."
>
> *Diana Míčková*

THE SCENT OF CHRISTMAS

Cinnamon, cloves, star anise, vanilla, fresh pine needles, and roasted apples… The smells of Christmas can induce feelings of togetherness, calm, and peace (once the frantic baking and preparations are over). In ancient Egypt and Greece, however, these aromas carried a very different meaning. "The Mendesian perfume had a strong scent of myrrh and cinnamon. Today, it might remind us of holiday cookies or gingerbread – but in antiquity, it was a sexy, provocative fragrance," Sean Coughlin says. The raw materials used for perfumes were exotic, expensive commodities imported from afar. So when the Gospel of Matthew claims that the Three Wise Men brought myrrh and frankincense to the infant Jesus, these were indeed precious gifts. But if we're imagining biblical Bethlehem filled with the scent of cinnamon and vanilla, we're likely far from the truth. It probably smelled more of goats, sheep, donkeys, and unwashed people. Reality is sometimes grittier – and more pungent – than the idealized picture.

Mgr. DIANA MÍČKOVÁ, Ph.D.
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Diana Míčková studied Egyptology at the Faculty of Arts, Charles University in Prague. She currently works in the Department for the Study of Ancient and Medieval Thought at the Institute of Philosophy of the CAS and at the Czech Institute of Egyptology at the Faculty of Arts, Charles University. She regularly takes part in archaeological expeditions in Abusir. Her research focuses on translating and analyzing religious texts. Míčková teaches Egyptian language and literature, and publishes studies on religious texts, magic and rituals, Egyptian literature, and the ancient art of memory. Together with Dorotea Wollnerová, she co-authored the book *Poslyš vyprávění z časů tvých otců* (Hearken to Stories from the Time of Your Ancestors), which consists of tales from ancient Egyptian literature.

as many ingredients had to be imported from both near and distant lands.

The Mendesian perfume, a blend of myrrh, cinnamon, and other ingredients, was no exception. This was the ancient equivalent of Chanel No. 5, with which Cleopatra probably captivated Marc Antony.

EGYPTIAN CHANEL NO. 5

The Mendesian perfume takes its name from the city of Mendes, located in the Nile Delta. Thanks to its strategic location, Mendes had access to exotic spices and resins brought by traders from distant lands. The Egyptian city is explicitly mentioned in ancient Greek and Roman texts in connection with perfumery, and its fragrance-making history is further confirmed by modern archaeological research at Tell Timai, which partially overlaps with the ruins of Mendes.

A team led by Robert J. Littman from the University of Hawaiʻi and Jay Silverstein from Nottingham Trent University uncovered objects at the site that may have been part of a perfume factory. Among the finds were kiln remains that were 1.3 to 1.7 meters in diameter – possibly used to produce perfume bottles – along with silver jewelry and Ptolemaic coins dating from 110 to 61 BCE.

Coughlin established contact with these archaeologists while working in Berlin. Together with Dora Goldsmith, he embarked on the first experimental replication of the Mendesian perfume. The resulting perfume was unveiled in 2019 at the *Queens of Egypt* exhibition at the National Geographic Museum in Washington, D.C.

In his current *Alchemies of Scent* project, Coughlin aims to revive the production of five fragrances: in addition to the Mendesian perfume, these include the Metopion and susinum perfumes, the myrrh-based oil *stakte*, and a smoked oil that is to be created using a technique resembling distillation.

AN ADVENTUROUS JOURNEY

The ultimate goal of the researchers isn't, of course, to become perfumers or to bring back ancient recipes to today's fragrance market, but rather to understand the processes and connections behind the production of ancient perfumes. In addition to studying Greek and Roman philosophical and literary texts and ancient Egyptian inscriptions, uncovering the chemistry behind the recipes has also proven to be crucial.

"For me as a chemist, this project is truly a dream come true. I absolutely love the whole adventure of trying to recreate an ancient perfume," says Laura Juliana Prieto Pabón, a PhD student originally from Colombia, involved in the Chemistry of Natural Products group at the Institute of Organic Chemistry and Biochemistry of the CAS.

In organic chemistry, the goal is usually straightforward – the synthesis of a particular molecule. "But when you're trying to replicate an ancient perfume recipe, you don't know what the final result should look like. In fact, you have no idea what it actually smelled like to people back then. So you go through the process and try to understand what's happening from a chemical point of view," the young scientist explains.

Take the Mendesian perfume, for instance – one of the trickiest parts turned out to be the mysterious oil called *balaninon*. It may have been made from the moringa tree, which grows in areas that are now the Sinai Peninsula, Syria, or Israel. But we can't be sure. Not only do we not know exactly what the substance was, the method of preparing the oil for use in perfumery is also unknown – it likely differed from processes used for other purposes. The Greek philosopher Theophrastus (372–287 BCE) suggested heating the oil for ten days and nights to help it better absorb the scents of resins – but this instruction doesn't appear in other ancient texts.

With the Mendesian (as with any ancient perfume), many uncertainties remain. One of its main ingredients was supposedly myrrh. But which kind? Myrrh is an oleo-gum resin that can come from the sap of various tree species. In ancient times, it was imported to Egypt from what is now Ethiopia and Somalia, from Palestine, and from the Arabian Peninsula – and each time it came from a slightly different tree species.

Cleopatra's perfume was also said to have smelled of cinnamon. But we have no idea whether it was a variety from India or China, or a local cultivar that resembled cinnamon in scent and taste but came from a different plant altogether. ›

The *Alchemies of Scent* project also includes public workshops where participants can create a perfume based on ancient recipes – such as Metopion (1). Guided by Egyptologist Diana Míčková and chemist Laura Juliana Prieto Pabón, visitors at the Week of the Czech Academy of Sciences festival in 2024 (2) had the chance to try it out for themselves. Key ingredients in Metopion include myrrh, calamus, cardamom, bitter almonds, wine, and honey (3).

THOUSANDS OF LILIES

Seeing gardeners tending to trees and other plants at the Prague Botanical Garden in Troja is nothing out of the ordinary. But in October 2024, a passerby might have been surprised to see just who was poking around in the flowerbeds. Wielding gardening gloves and spades was a group made up of philosophers, chemists, Egyptologists, and other experts who, on a normal work day, have little to do with digging in the dirt. This unlikely team showed up to plant more than a thousand lily bulbs, which will be used to make susinum, one of the most iconic perfumes of antiquity.

If all goes to plan, several thousand lilies will flower from the bulbs. According to a recipe recorded by the Greek physician Dioscorides (40–90 CE), one needs to process a thousand lily flowers a day for three days to make a single liter of susinum (three thousand flowers per liter total).

"This shows just how costly perfume production likely was. If the Egyptians wanted to make a hundred liters of susinum perfume, they needed huge lily plantations, which would've been tended by a lot of slaves. It was a massive operation," Coughlin explains.

The team won't be making that much perfume, of course. But they do intend to follow all the instructions and methods that can be gleaned from the preserved recipes. So far, they've tested only a small sample batch of susinum. This year, working with thousands of flowers ought to be a far greater adventure.

Just like with the previous Mendesian and Metopion perfumes, the researchers will once again invite the public to join their experiments. The project includes workshops where participants can try their hand at ancient perfume-making techniques.

THE SECRET OF CLEOPATRA'S PERFUME

Today, the Mendesian perfume can be partially reconstructed thanks to a handful of preserved recipes. One was recorded by the Roman scholar Pliny the Elder (23–79 CE) in his *Naturalis Historia* (*Natural History*). The Greek physician and botanist Dioscorides (40–90 CE), who worked in Rome, described the procedure in his pharmacopeia *De Materia Medica*. A perfume with nearly identical ingredients but a different name – *megaleion* – was mentioned even earlier by the Greek philosopher Theophrastus (372–287 BCE).

The processing of lilies is expected to yield a pleasant, fresh floral scent – one that modern fragrance wearers might well enjoy. But would Cleopatra have liked it?

Surprisingly, probably not. Just like fashion, fragrance preferences are shaped by cultural trends. "Texts suggest that in antiquity, floral perfumes were typically favored by men, who liked the smell of lilies and roses, while women tended to wear heavier, resinous perfumes with the scent of myrrh and cinnamon," Coughlin explains.

UNCOVERING EGYPT'S SECRETS

The *Alchemies of Scent* project offers a unique perspective on the history of the ancient world and sheds light on previously unknown details about ancient Egypt. Egyptologist Diana Míčková particularly values the interdisciplinarity of the research, which has opened up entirely new perspectives for her. At times,

> "For me as a chemist, this project is truly a dream come true. I absolutely love the whole adventure of trying to recreate an ancient perfume."
>
> *Laura Juliana Prieto Pabón*

SCENTED RITUALS

The perfumes and fragrances referenced in inscriptions on the walls of ancient Egyptian temples were primarily used in ritual contexts – for instance, to anoint statues of gods. They also played a key role in funerary rites. A deceased person's body needed to be treated with fragrant oils to make it smell divine in the literal sense, ensuring that the gods would accept the person into their realm. The importance of scent carried over into Christianity as well. The characteristic smell of a church comes from burning frankincense, which has been used in Christian liturgy since at least the second century CE. During baptisms, confirmations, and ordinations, *chrism* – a mixture of olive oil and aromatic resin – is used.

for instance, she encounters references to plants in the temple wall inscriptions that cannot be identified without deeper knowledge of botany and chemistry.

Even when working with colleagues, reading Ptolemaic texts remains immensely challenging. In their own time, they were already written in what was effectively a dead language. "The everyday Egyptian language looked different and used different scripts, while Greek – and later Latin – served as the common language of communication in Egypt. Only a select group of priests who worked with old texts could read hieroglyphs," Míčková explains.

These priests even developed a special hieroglyphic system known as the Ptolemaic script. It relied heavily on wordplay, pictorial riddles, acronyms, and other linguistic tricks. Those who created the system were constantly inventing new signs – while Old Egyptian had around 750 characters, Ptolemaic script boasted thousands.

This makes translation extremely demanding and time-consuming – and many texts remain untranslated. "Sometimes we understand the language but struggle to grasp the meaning. But it also gives us a fascinating opportunity to get a glimpse into the minds of the ancient Egyptians – to learn how they saw the world, what their scientific knowledge and technical methods looked like, and how these were preserved and passed on for centuries, eventually influencing the Greek and Roman societies," Míčková adds.

And to some extent, our modern civilization still draws from them. The influence of a world more than 2,000 years removed from our own is still tangible – even in the perfume and aromatherapy industries. Just take note of how many contemporary products, with all kinds of ingredients, bear names that reference the Orient, ancient Egypt, or Queen Cleopatra herself. •

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Laura Pabón studied organic chemistry at the National University of Colombia in Bogotá and perfume chemistry at Université Côte d'Azur in France. She is currently pursuing a PhD at the Institute of Organic Chemistry and Biochemistry of the CAS in the Chemistry of Natural Products group. Her research focuses on organic chemistry and fragrance analysis. Within the *Alchemies of Scent* project, Pabón is responsible for its chemical component and also actively participates in public workshops on ancient perfume-making.

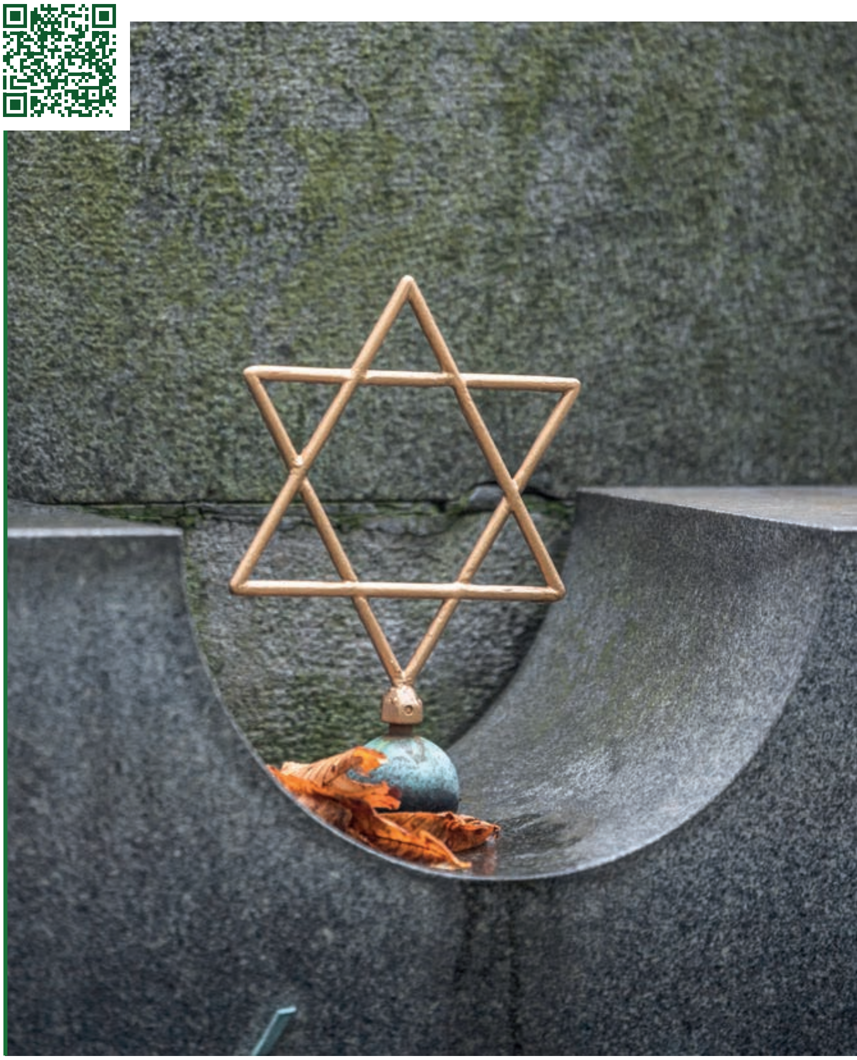
FOSSILIZED MEMORIES

A / Magazine 2025

Text: Leona Matušková \ Photo: Jana Plavec

CEMETERY RESTORATION

Nearly four hundred cemeteries, thousands of tombstones, and centuries of remembrance. Jewish identity shaped the history of the Czech lands and was an integral part of our society until the tragedy of the Holocaust. The majority of Czech Jews did not survive World War II, and Jewish communities fell apart, with no one left to tend to the memory of their ancestors. Many (especially) rural graveyards fell into disrepair and disappeared, though larger and eminent cemeteries faced similar ruin as well. In the Czech Republic, their gradual restoration only became possible after the fall of communism. Despite proper documentation being key to the care of Jewish cemeteries, out of 370 sites across the country, only about half have been partially documented. The Matana company, affiliated with the Jewish Community of Prague, focuses on documenting and restoring Jewish heritage, with the Institute of Art History of the CAS conducting research in this field.



A TOUCH OF PREHISTORY

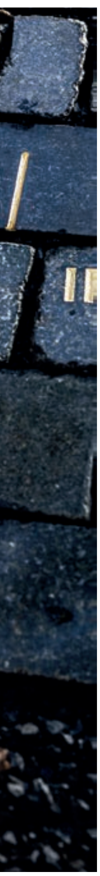
In the shadow of the looming Žižkov Television Tower lies one of Prague's oldest surviving Jewish cemeteries. Nearly 38,000 people were laid to rest here, yet fewer than three thousand gravestones (*matzevot*) or their fragments remain today. The cemetery was originally founded as a plague burial ground, with the oldest discovered gravestone dating back to 1679. But the story tied to this site reaches much further – back into prehistory. Some *matzevot* were carved from Slivenec marble and other similar stones marked by the presence of fossilized creatures. A keen-eyed visitor may spot crinoids, cephalopods, or even bits of trilobites in the tombstones. One such fossil, remarkably well preserved, is shown in the photo above by Pavel Veselý from the Jewish Community of Prague.

THE LANGUAGE OF SYMBOLS

Jewish gravestones are rich in visual symbolism. The lion motif, for instance, is linked with the biblical tribe of Judah and, by extension, with the Jewish people as a whole. The lion sculpture (left) can be found in the Old Jewish Cemetery in Josefov where it adorns the tomb of Hendl Bashevi, who died in 1628. She was the second wife of the influential financier and merchant Jacob Bashevi, ennobled by Emperor Rudolf II. The lion clutches her husband's noble coat of arms in her paws. A weeping willow (*alon bachut*), a symbol of sorrow and mourning, appears on the gravestone on the bottom left photo. The cluster of grapes (bottom right photo) stands for abundance and blessing, but also for spiritual growth in communion with God, renewal of life, and hope. And that simple string tied to the *matzevah* on the bottom left of the page opposite? It is no modern symbol at all, but a purely practical marker identifying graves slated for restoration.

AN OPEN-AIR GALLERY

The New Jewish Cemetery in Olšany has been in use since 1890, and many of its gravestones and tombs were designed by prominent architects and artists. The photo on the bottom left shows the Elbogen family tomb, created by Jan Kotěra. Visitors can also admire works by Josef Fanta and Jan Štursa, as well as contemporary artists such as Jaroslav Róna. In 2001, a symbolic tomb was unveiled in the newer section of the cemetery (photo below), holding remains transferred from the destroyed medieval Jewish cemetery on today's Vladislavova Street, near the Quadrio shopping center. Another striking modern monument is the memorial by Jaroslav and Lucie Róna, composed of 200 paving stones from Wenceslas Square. Toward the end of the communist era, these paving stones were made in part from old Jewish gravestones. The memorial, pictured on the bottom right, can be seen in person at the old Žižkov cemetery in today's Fibichova Street by the Žižkov Television Tower.



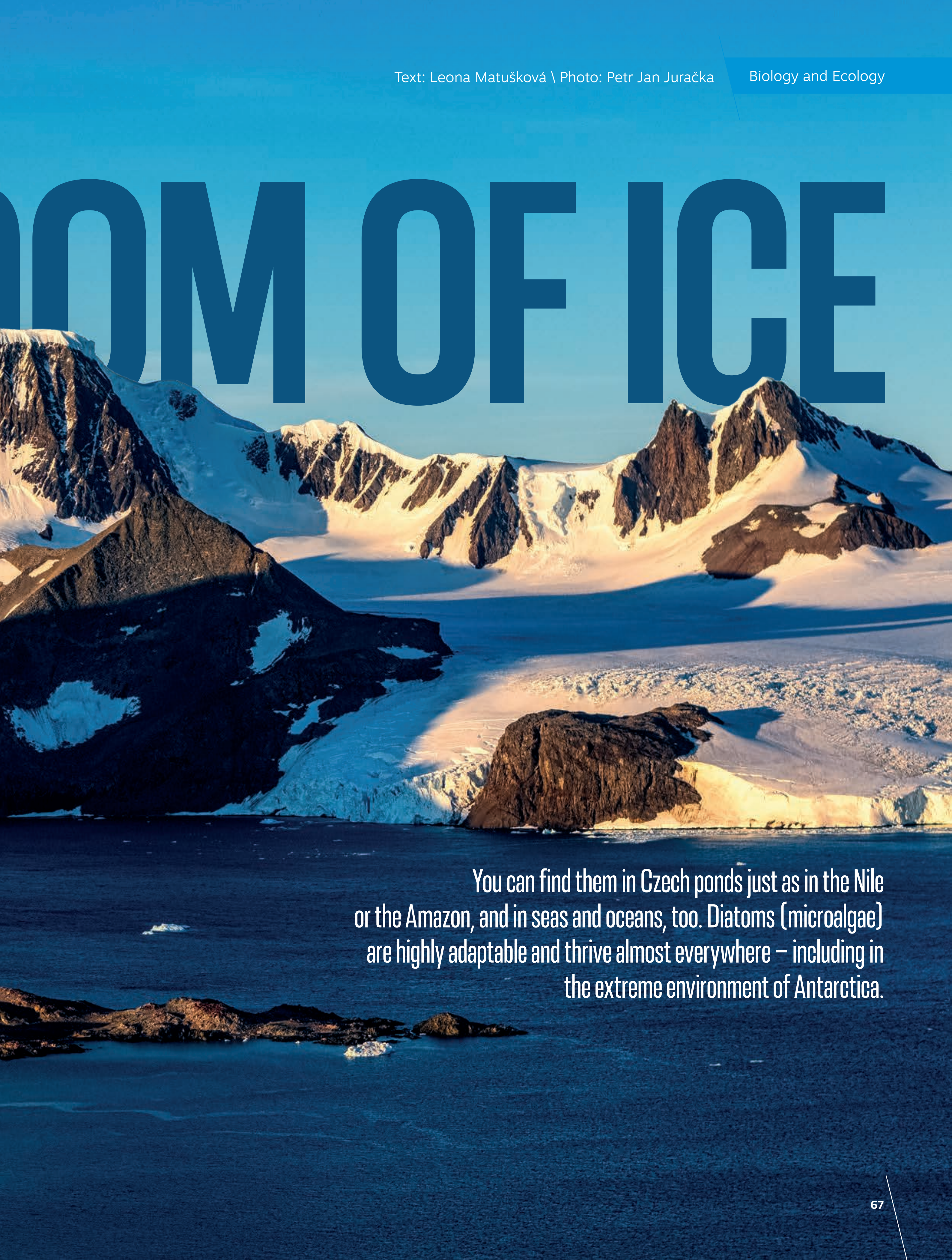
NOTABLE BURIALS

Many prominent and celebrated figures have been laid to rest at the Olšany Cemetery. Visitors can seek out the graves of writers Ota Pavel (1930–1973), Arnošt Lustig (1926–2011), and Jiří Orten (1919–1941), as well as film director Jiří Weiss (1913–2004) and singer Yvonne Přenosilová (1947–2023). The most visited site of all, however, is the final resting place of Prague's German-language writer Franz Kafka (1883–1924). His grave is surrounded by hundreds of small stones inscribed with messages such as "I love you, Franz" or "Grazie Franz Kafka." Beneath some of them lie entire letters and petitionary notes (kvitel in Hebrew) – bottom right. Among the many gravestones are, of course, those belonging to figures important to Prague's Jewish community itself. The photo above, for instance, shows the gravestone of David Tezner, chairman of the Vinohrady Synagogue and a respected member of the Jewish burial society.

BEAUTIES FROM THE KINGD

Text: Leona Matušková \ Photo: Petr Jan Juračka

OM OF ICE



You can find them in Czech ponds just as in the Nile or the Amazon, and in seas and oceans, too. Diatoms (microalgae) are highly adaptable and thrive almost everywhere – including in the extreme environment of Antarctica.

Snow-white ice floes dot the surface of the sea and look like scattered building blocks from above. The sun is shining, and the sky is a brilliant blue. It's January 2025, high summer in Antarctica, with long polar daylight and temperatures hovering around zero. Ideal conditions for landing near the research base bearing the optimistic name Esperanza (Hope), located at the northern tip of the Antarctic Peninsula, not far from a huge penguin colony.

"The weather really played into our hands this time. But it must be said that every trip to Antarctica is extraordinary. The landscape there just sweeps you away. The vastness, the silence, the pristine wilderness – everything there takes on a life of its own," recalls polar ecologist Kateřina Kopalová over coffee in Prague. A researcher at the Institute of Botany of the Czech Academy of Sciences (CAS) and the Faculty of Science at Charles University, Kopalová has already visited the southernmost continent five times. But in many respects, this year's expedition was exceptional.

Until now, the ecologist had always stayed on the surrounding islands. This year, for the very first time, she set foot directly on the Antarctic mainland. Unlike previous expeditions, she was not the only Czech in the Argentinian team and, for the first time in the southern land of ice and snow, she also played the viola. But let's start at the beginning – Kopalová's scientific journey was anything but straightforward.

FROM SETBACKS TO SUCCESS

As often happens in science, Kopalová stumbled onto her research topic – Antarctic diatoms – practically by accident. She had wanted to work on something related to water; during her undergraduate studies, she was tempted by research of lakes in the Pyrenees, for example. But around twenty years ago, the first samples from Antarctica arrived at the Department of Ecology where she was studying.

At that time, preparations were in full swing for building the Czech research station on James Ross Island, and

Want to learn more about polar ecologist Kateřina Kopalová's journey to Antarctica? To see how you can prepare for an expedition, how to get from Prague all the way to the southernmost continent, and what it's like to work in the realm of penguins, sea lions, and humpback whales? Check out the video series by science communicator Petr Jan Juračka on YouTube.

> Antarctica is, on average, the coldest, windiest, and driest of all continents. It is sometimes called the world's largest desert.

the number of Czech scientists there was growing. They were exploring sites where virtually no one had done research before, and they were bringing back unique samples to be studied in Prague.

"I thought to myself: I don't know anything about diatoms, but Antarctica sounds amazing. So I said yes to the offer. I grabbed the first European atlas of algae I could find and started identifying Antarctic samples under the microscope," Kopalová says with a laugh today. "Of course, at the beginning I misidentified almost all of them. It was like trying to recognize birds in Africa using a Czech ornithological handbook."

These early setbacks only spurred her onward. At an international conference, Belgian diatom specialist Bart Van de Vijver noticed the young student's enthusiasm and offered Kopalová an opportunity to work together. She left to Belgium for a research fellowship and later spent part of her doctoral studies at the University of Antwerp.

Together with her Belgian supervisor and other colleagues, she began systematically analyzing available algal samples and set out herself to collect more in Antarctica. Altogether they described dozens of new species. The result was a completely new identification atlas of freshwater diatoms for the Antarctic Peninsula and nearby islands, published in 2016.

JEWEL-LIKE GLAMOR

Diatoms are fascinating microorganisms. They can photosynthesize, they live in the waters of almost every environment on Earth, and they are capable of adapting to extreme conditions. They form the foundation of freshwater and marine food chains and are also used, for instance, in routine water-quality monitoring and forensic analysis. While diatoms in other regions, including Central Europe, have been fairly well studied, Antarctic diatoms have until recently received far less attention.

As Kopalová explains, diatoms are basically tiny plants encased in intricate glass (silicate) shells of every imaginable geometric shape and pattern. Under an electron microscope, you can distinguish the fine ornamentation on their silica frustules. "I find it incredible that something so minuscule can be so perfectly crafted. They're simply beautiful," the ecologist says.

Her favorite is the genus *Luticola*, an exceptionally species-rich group of diatoms. They can be found in lakes, wetlands, moss, and damp soils, and they are among the most diverse diatom genera in Antarctica.

Another of Kopalová's favorites is *Microcostatus naumannii* (Hustedt) Lange-Bertalot. "I love the way it looks, even though it's not a particularly rare species. You can recognize it under the microscope right away, unlike many other Antarctic diatoms," the researcher says.

INTO THE FIELD

Kopalová collected her first research samples in 2011. Since 2007, James Ross Island has hosted the J.G. Mendel Czech Antarctic Station, operated by Masaryk University in Brno, but the biologist headed instead to another part of the island, independent of the Czech base. Thanks to a joint project with the Argentine Antarctic Institute, she began working with Argentine scientists, who, given their country's geographic position, have the closest access to Antarctica. That very first expedition, however, proved to be a serious trial: practically everything that could possibly go wrong, did.

The weather was relentlessly against them, and the aircraft broke down, so the originally planned six-week trip stretched to almost three months. "We ended up spending Christmas and New Year in Antarctica. To make matters worse, I didn't speak any Spanish at the time, and the Argentinians weren't fluent in English, so communication was tricky. And I was the only woman there among about a hundred soldiers," Kopalová notes with a laugh.

Unpredictability is characteristic of fieldwork in Antarctica. Nothing can be taken for granted – the climate can foil even the best-laid plans. But once you come to terms with this, you can enjoy the journey to the fullest. Alongside her rough first experience, the polar ecologist has a trove of amazing memories and powerful encounters – with both breathtaking nature and the people she has met there.

DIATOMS ARE NO WHALES

Today, Kopalová is at home in Antarctica and even acts as a guide for fellow scientists and adventurers. Such as this past January, when she brought along photographer and science communicator Petr Jan Juračka, whom she has known since their first year at university. A passionate traveler, Juračka once mentioned to her he had visited every continent except Antarctica. So she arranged with her Argentine colleagues to bring him along this time, to document their local research and share it with the public. ›

> "As a microbiologist, I'm usually knee-deep somewhere in the mud, looking for diatoms. They're beautiful in their own way, but it's thrilling to get the chance to watch penguins, sea lions, and humpback whales in their natural habitat."
>
> *Kateřina Kopalová*

What for her has become almost routine, Juračka experienced with the wide-eyed wonder of a child. He photographed and filmed everything that caught his attention. Thanks to his perseverance – waiting for the perfect shot even to the point of nearly freezing – he returned from Antarctica with stunning images and videos of penguins, seals, sea lions, giant kelp, and cormorants.

"As a microbiologist, I'm usually knee-deep somewhere in the mud, but when I get the chance to watch penguins and sea lions in their natural habitat, I'm thrilled. The absolute highlight, though, was Petr's drone footage of humpback whales – I had never seen whales so beautifully before," Kopalová notes, praising her friend's work.

Diatoms are no whales or penguins, but for the polar ecologist, they are an endlessly fascinating subject of research. From the start, she has approached diatoms from two angles: first, identifying and classifying Antarctic species and mapping their distribution (taxonomy and biogeography), and second, studying them ecologically as model organisms within the ecosystem.

TEST TUBES IN THE FRIDGE

On her trips to Antarctica, Kopalová tries to cover as many locations as possible, which is why she always sets out for a different area. She has explored ponds and streams on Seymour and James Ross Islands and in the South Shetlands. Only this year did she finally make it to the mainland itself – specifically, the northern tip of the Antarctic Peninsula. She collects samples either on her own or together with other scientists from various disciplines. Some focus on the geological bedrock, others on the chemical and physical properties of lakes or on climate conditions.

Diatoms generally live in lake sediments and can be found on stones, in sand, and in mud; some species thrive in damp moss or on wet rock faces. They also occur in cryoconite holes – i.e., little glacier depressions filled with dust. The best time for collecting samples in Antarctica is during the austral summer, which usually corresponds to January and February. Temperatures hover around 0 °C, and if the icy wind isn't blowing, conditions allow you to move about fairly comfortably.

In the field, Kopalová places samples of diatoms taken from sand, mud, or moss into test tubes, and from a single Antarctic expedition she usually brings home around three hundred of them, stored in camping coolers. Back in Prague, this is followed by months and years of painstaking study.

For three hundred years, scientists have identified diatoms mainly by the appearance of their silica shells. Microscopy remains the cornerstone of this research, but molecular methods are playing an ever more important role. "There's a lot of cryptic diversity among diatoms. That

Mgr. KATEŘINA KOPALOVÁ, Ph.D.
INSTITUTE OF BOTANY OF THE CAS

The decision whether to become a professional violist or a scientist was settled by Kateřina Kopalová's first Antarctic expedition during her doctoral studies at the University of Antwerp in Belgium. The musician path may have fallen by the wayside, but Kopalová hasn't abandoned her viola. In her spare time, she plays in the Malá Strana Chamber Orchestra and has performed in orchestras in Belgium and during her postdoctoral stay at the University of Colorado Boulder. Her professional passion lies with diatoms – microscopic algae with silica shells that occur in countless geometric shapes. In 2022, she co-founded the research group DiCE (Diatoms in Cryospheric Ecosystems) at the Department of Ecology, Faculty of Science (Charles University). She is the recipient of the Charles University Bolzano Award, and in 2024, Kopalová also won the prestigious L'Oréal–UNESCO For Women in Science award.

HOW A DIATOM GETS ITS NAME

Together with colleagues, Kateřina Kopalová has identified and described dozens of new Antarctic diatom species. Among them is *Luticola katkae*, inspired by the researcher's own first name. "We don't name diatoms after ourselves. Usually, it's a way for someone to thank you, recognize your work, or simply make you happy," the ecologist explains. The first name is the genus – in this case, *Luticola*. The second name is the species, given in Latin or a Latinized form with an ending that matches grammatical gender: *-ii* for masculine and *-ae* for feminine (so, for instance, *Luticola evkae*, after Kateřina's friend Eva). A species name can also reflect geography, as in *Luticola austroatlantica*, which points to the alga's occurrence in the South Atlantic. Or it can be descriptive, as in *Mayamaea curvata* – where *curva* in Latin means curved, referring to its shape.

> "Antarctica is extraordinary and just sweeps you away – the vastness, the silence, the pristine wilderness. Everything there takes on a life of its own."
>
> *Kateřina Kopalová*

means they may look identical at first glance, and even at the microscopic scale we can't tell the difference, but DNA sequencing reveals they're actually different species," the biologist explains. As a result, algal checklists are constantly being revised and refined, while a digital molecular library of algae species is being built at the same time.

MELTING GLACIERS AND THE FUTURE

For polar ecologists, diatoms are an ideal model organism, and Antarctica an ideal model ecosystem. Its advantage lies in its simplicity – very little can survive in such extreme conditions. Life is found there mainly in the form of microorganisms; mammals and birds only make use of the land temporarily, mostly during breeding season.

Because of the relative simplicity of environmental conditions, the consequences of climate change – especially the effects of global warming – can be observed in Antarctica almost in real time. For instance, in 2021, meteorologists recorded temperatures of over 18 °C at the Esperanza Base, whereas the average summer temperatures there usually range from −2 to +5 °C.

Rising temperatures affect ice shelves (floating slabs of ice), which break up under melting temperatures and in turn destabilize the continental glaciers behind them. The first colonizers of the newly ice-free ground are microorganisms, including diatoms. Studying in detail how they spread makes it possible to better understand the colonization of new soils – both in Antarctica and more generally in warming environments alike.

Scientists can thus model how climate change will shape not only Antarctica, but also, for instance, Europe. In a few decades, it is expected that all Alpine glaciers will melt, creating new expanses of ice-free land. Thanks to this research, we can already anticipate which microorganisms will colonize them and how the associated changes in hydrological conditions will transform the environment.

STRINGS IN THE WIND

Whereas Kopalová's first Antarctic expedition fourteen years ago didn't go entirely according to plan, this year, it was a success beyond expectations. She returned to Prague with nearly thirty kilograms of samples for her team to study in the coming years, while Juračka brought back home gigabytes of unique photos and video footage.

Their joint journey resulted in a series of documentary vlogs on YouTube, several popular science articles, and a lecture tour of Czech cinemas and cultural centers, bringing audiences both the beauty of Antarctica and the behind-the-scenes reality of conducting research in extreme conditions.

This latest expedition differed from the earlier ones in one other way, too. Packing for the Antarctic terrain is always demanding, and you only bring what is absolutely essential to stay warm and collect your samples in peace. This time, however, Kopalová decided to take something you wouldn't expect to find in the backpack of a polar ecologist – a viola, her lifelong companion, which almost led her to an alternate career path.

Bringing it along was a slightly mad idea, but it fit perfectly with the spirit of an extraordinary expedition. It allowed the researcher to combine her two passions – music and Antarctica – and tuxedoed penguins got the rare chance to sway to the sounds of Antonín Dvořák. "It was a challenge to tune the viola in the cold, and after a while my fingers were freezing, but otherwise, I enjoyed it immensely. The most beautiful moment came when we held the instrument in the wind, which began producing its own sounds against the strings. Once again it became clear that Antarctica lives a life all its own," Kopalová recalls with a laugh. •

More about the DiCE – Diatoms in Cryospheric Ecosystems research group:

Text: Viktor Černoch \ Photo: Shutterstock (3), Jana Plavec (7)

THE RUSTING HUMAN BODY

In orthopedics, bones sometimes have to be stabilized using metal screws, plates, or wires, which are later surgically removed. But what if these materials simply dissolved in the body instead?

Rust is boat cancer. / I'm sorry. When I was a kid, I lost a bike to that. – This line from the cult sitcom *Friends* serves as an apt introduction to the topic at hand. Corrosion can strike fear into the hearts of car owners, cyclists, and those with tin roof cottages alike. Metals exposed to harsh weather conditions quite literally fall apart. The human body is an even more challenging environment – with fluids flowing constantly, the body is relatively warm and teeming with ions and a variety of chemical compounds with differing affinities, charges, and reactivities.

It took years of research to develop the perfect metal compositions for medical use – metals that wouldn't release harmful substances into the body and would remain safe for human use. Today, such implants are commonly utilized. However, having mastered alloys that can withstand the body's demanding conditions, scientists and medical professionals are now pursuing the opposite goal: finding metallic materials that degrade within the body instead. The rationale? Practicality.

In some cases, doctors implant metal orthopedic components into the body only temporarily, which later have to be removed under general anesthesia – for instance, in cases of comminuted or complicated fractures. And what if the tissue not only needs to heal but also grow? In children, fixed metal implants can interfere with bone growth, potentially causing deformities. Here's where biodegradable metals come into play – materials strong enough to stabilize a bone but capable of breaking down in the body over time, eliminating the need for a second surgery.

Absorbable screws, plates, and splints could also be used beyond orthopedics – biodegradable stents could find applications in cardiology, for instance. And the potential doesn't stop there, given that 80% of all implants used in medicine are made of metals. Biodegradable materials could offer many advantages, but several obstacles still prevent their practical use. "Above all, they must be non-toxic and safe for the human body," explains Jan Pinc from the Institute of Physics of the CAS, who is working on developing such materials.

> "We work with domestic companies on implant production and submit projects together. A company won't invest money on its own when development is just starting and the outcome is uncertain."
>
> *Jan Pinc*

METALS WITH ISSUES

Magnesium, iron, and zinc appear to be the most promising candidates for biodegradable metals, but each has its drawbacks. Magnesium releases hydrogen gas as it degrades, leading to gas accumulation in the body (hydrogen molecules are very small). "It likely settles in fatty tissue, but no one knows for sure – it is still the subject of research," Pinc says.

This isn't magnesium's only problem. It also degrades far too quickly. A standard orthopedic implant needs to last two to six months in the body, but magnesium breaks down well before that. At the other extreme is iron, which degrades far too slowly, and, under certain circumstances, its byproducts can harm the body.

Zinc currently seems to have the most favorable profile. It degrades at an ideal rate (about 0.3 millimeters per year), and its degradation products are non-toxic. On paper, zinc is a strong candidate, but it's not without issues. It falls short in terms of mechanical properties. To function, a component must retain sufficient strength even as it degrades to continue supporting, for example, a fractured bone.

A CNC device used for manufacturing small implants.

This is where alloys come in. Zinc serves as the base material, with other metals added to it. The specific combinations and proportions of these additives need to be tested to determine what the resulting alloy can withstand and how it will behave in the body.

TESTING, TESTING... AND MORE TESTING

The development of biodegradable metals is still in its infancy and will require extensive research and testing. Factors such as temperature play a significant role. Lab tests performed under standard conditions can yield misleading results because they don't replicate the

BIOREACTOR AND NEW ZEALAND RABBITS

Testing on living organisms is mandatory for the approval of any material or implant. "As part of one project, we conducted tests on rabbit models. A special New Zealand breed must be used, and only males, so that the results aren't influenced by female hormones. The entire process is enormously expensive, and as soon as you slap a 'scientific' label on something, the price quadruples," describes Jan Pinc, reflecting on the costs of purchasing mammals for testing. For ethical and practical reasons, he focused on developing his own bioreactor to at least partially replace in vivo testing.

body's environment, which operates at 37 °C. "For some metals, this doesn't matter much. However, we've found that temperature significantly affects the mechanical properties of zinc," explains Pinc, who focuses on testing potential future implants.

Conventional tests using cell cultures are designed for metals that are not meant to degrade in the body, such as titanium screws or joint replacements, and aren't suitable for biodegradable metals. Before these materials can be used in practice, they must also undergo in vivo testing in living organisms – a process that is both time-consuming and expensive.

It would be advantageous if lab tests could replicate the conditions that implants will face in the body as closely as possible. "That is why my goal is to develop a bioreactor that simulates conditions like fluid flow, oxygen levels, and body temperature. These factors are usually neglected in lab tests – for example, corrosion testing is often done by simply immersing the material in liquid, which is quite different from the actual conditions the material will encounter in the human body," Pinc explains.

To complicate matters further, the conditions in the body are not constant – they can vary. For instance, pH levels: these metals are stable at a pH of around seven. However, if the body is fighting inflammation – a common occurrence with injuries – the pH in the affected area drops. This introduces yet another variable that can influence how a biodegradable metal component behaves.

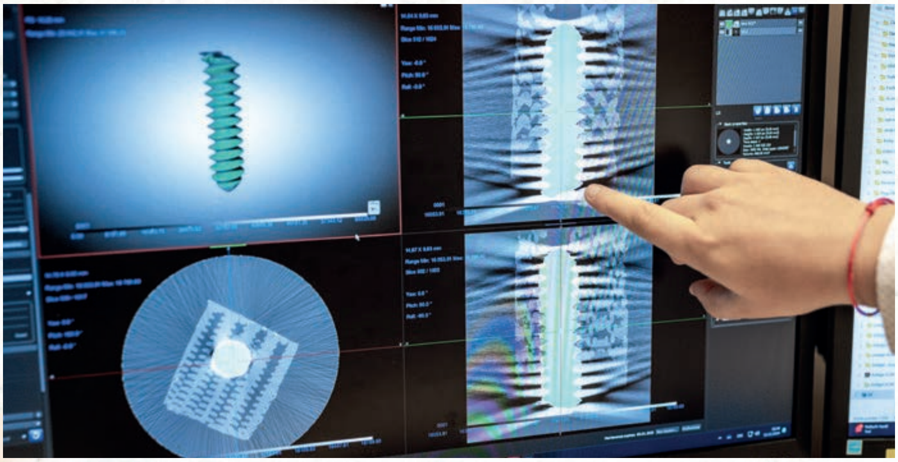
PAST AND FUTURE CHALLENGES

It's evident that metals face a harsh environment inside the human body, and scientists face a tough challenge as well. Pure metals are practically unusable for these purposes due to the reasons already mentioned – there are simply too many drawbacks. Instead, scientists are working with alloys. Essentially, another metal is incorporated into the base metal. This creates what are known as "phases" in the material – miniscule grains of another metal embedded in ›

Ing. JAN PINC, Ph.D.
INSTITUTE OF PHYSICS OF THE CAS

Jan Pinc studied biomaterials and metallurgy at the University of Chemistry and Technology in Prague (VŠCHT). He worked at the Czech Technical University (ČVUT) and since 2018 has been a researcher at the Institute of Physics of the CAS in the Department of Functional Materials. Pinc specializes in biodegradable zinc-based materials. His goal is to minimize animal testing, utilize AI in development, foster collaboration with international partners and domestic manufacturers of metallic implants, and promote interdisciplinary knowledge-sharing in the field of implantology. Pinc described the degradation mechanism of Zn-Mg alloys in a study published in *Bioactive Materials*. In 2024, he received the Otto Wichterle Award of the CAS for young talented scientists.

> “Besides research issues, we have to deal with a lot of red tape. For final applications as well as in vivo tests, you need another worker tackling the regulations alone.”
>
> *Jan Pinc*



A damaged screw analyzed using X-ray microtomography.

the matrix of the base metal – in this case, zinc. In one section, there might be more magnesium atoms than elsewhere. Different parts can even behave differently in the body, such as degrading at varying rates. It’s a bit like Swiss cheese – or a three-dimensional spider web.

To modify the material’s properties, processes like extrusion are used. In this process, the metal is forced through a kind of press, similar to a pasta maker. The resulting “spaghetti” has a more homogeneous structure than the original alloy. At the same time, this method can alter the material’s mechanical properties. The processing reduces the size of the grains and arranges them in a specific orientation within the structure. As a result, the material can have mechanical properties and exhibit different strengths depending on whether pressure is applied from below or from the side. “This is a very advantageous property, for example, when using an orthopedic plate in the leg, where forces act on the component to varied degrees in each direction,” Pinc adds.

The properties of the material – such as its degradation rate – can also be adjusted using special coatings. Researchers at the Institute of Physics of the CAS are planning to work with colleagues from the Institute of Rock Structure and Mechanics of the CAS and the Department of Materials at the Faculty of Nuclear Sciences and Physical Engineering of the Czech Technical University in Prague to coat components with specific polymer layers. They are also planning to launch a European project in collaboration with researchers from France in 2025.

For specialized applications, the surface of the metal can even be bombarded with nitrogen ions, which integrate into the material’s surface. This creates enormous internal pressures and forms tiny pores in areas where the nitrogen impacts. “We are capable of creating highly porous, nanometer-thick layers that are also uniform, and we’re considering their use as drug carriers,” Pinc explains. This is still a preliminary idea that he hopes to develop with colleagues from the Czech Technical University and Slovakia.

There are even ideas involving 3D printing. And that’s without mentioning the sterilization of these components, which is no simple feat either. It’s fair to say that scientists face more than enough challenges in this field.

FUTURE PROSPECTS

Jan Pinc now has access to a new powder metallurgy laboratory, where precise mixtures of metallic powders can be prepared for the desired alloys. The material is created through sintering, using extremely high currents. One advantage of this process is that the resulting material is relatively porous. It can even be used to create lightweight “scaffolds” for additional fillings. However, every version of the material must not only fulfill its intended purpose but also function as an integrated whole.

Scientists at the Institute of Physics of the CAS are tackling the problem holistically, studying not just isolated traits of the material but designing entire functional systems that would work effectively in the body. For instance, they have developed an orthopedic plate – a small flat piece with special screws.

“We want to test it in terms of anisotropic mechanical properties – that is, how it handles mechanical stress from different directions. And we don’t just want to test each part individually but as an integrated system. In connection

> “For clinical application, the key priority is the long-term stability of mechanical properties, along with the capacity to fine-tune material properties precisely for each intended use.”
>
> *Jan Pinc*

with this, it's also necessary to determine the degradation behavior under the same conditions, because this brings up a host of additional issues," Pinc explains.

One of these issues could be the connection between the plate and the screw head. A tiny gap – no more than 10 µm – will inevitably form between them, where the exchange of ions with the surrounding environment will be limited. In such areas, the local environment could become more aggressive. This might lead to the screw head degrading too quickly and falling off. Naturally, the entire plate system would then become nonfunctional.

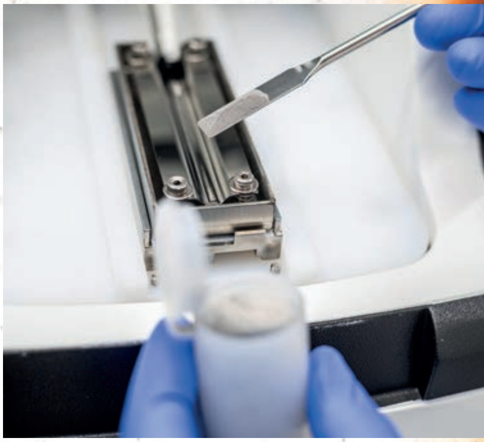
The screw itself also poses a challenge. With a titanium screw, the surgeon can apply significant force. Zinc, however, is more brittle and could break. The material must therefore be designed to withstand the necessary handling.

This requires an interdisciplinary and comprehensive approach to problem-solving. Experts in metals, other materials (polymers, ceramics), chemists, biologists, and medical professionals are all needed. But one day, we may very well see biodegradable metallic zinc-based implants used in the human body for orthopedic applications. And for that purpose, we might finally make peace with rust.

"With advances in artificial intelligence, I believe we'll reach a point where the material selection process, which we currently base on our experience, will be significantly accelerated. Then we'll be able to predict the properties of individual alloys or materials – or even the components themselves – before we manufacture them," Pinc envisions, optimistic about the future.

TWENTY-FIRST-CENTURY WIREWORKING

At the Institute of Physics of the CAS, researchers can produce special wires made from biodegradable alloys, with a thickness of just 300 microns. They are currently working on coating these wires with polymer layers. Such wires could then be used in specific applications. "For instance, if you suffered a complicated fracture in the middle joint of your finger, two holes would be drilled and the bones tied together with wire. Similarly, during heart surgeries, the opened rib cage would later be tied back together with wire," Jan Pinc explains.



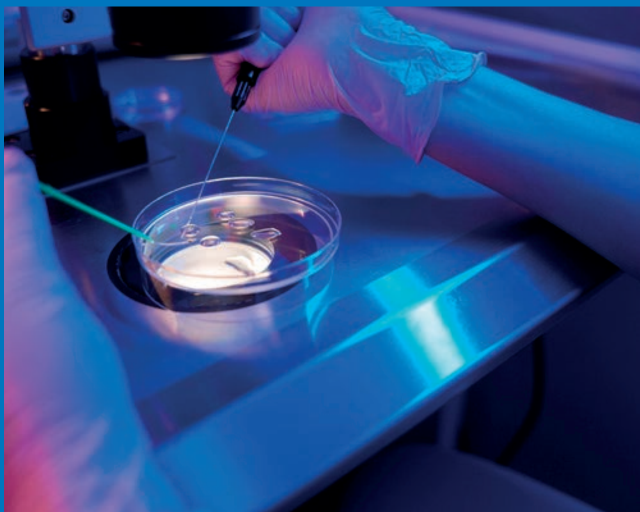
RUST IN THE BODY

Metals inside the body don't rust like iron railings outside on the street. Instead, they break down – or more accurately, dissolve. At points of contact with albumin, amino acids, or inorganic compounds, the metal begins to dissolve into the surrounding environment as ions. "These ions interact with others, and a very thin layer of phosphates starts to form on the surface. For zinc, at least, these aren't harmful to the body. This creates a kind of barrier that slightly reduces the corrosion rate. In most cases, much more complex compounds form. What's crucial is that they aren't toxic to the body," Jan Pinc explains.

RADOMÍR PÁNEK TAKES THE HELM OF THE ACADEMY

Since 24 March 2025, the Czech Academy of Sciences (CAS) has been headed by Radomír Pánek from the Institute of Plasma Physics of the CAS, succeeding Eva Zažímalová after eight years. The election of the new CAS President for the 2025–2029 term was the main agenda of the 64th session of the Academy Assembly, held on 10 December 2024 at the National House Vinohrady in Prague. In the first round of the secret ballot, among five contenders, Pánek received 128 out of 242 votes. “It would make sense for me to speak about my experience and qualities that I would apply in the role of President. However, I primarily want to emphasize that since deciding to run, I have spoken with many of you and taken away one important impression – we are all united by our shared interest in a strong and confident Academy,” Pánek said in his speech. His nomination was reviewed by the government and he was appointed to his role by the President of the Czech Republic.

Prepared by: Jana Bečvářová
Photo: Jana Plavec (4), Stanislava Kyselová, Vojtěch Cimpl, Institute of Experimental Botany of the CAS, HiLASE, ERC, ESA, Shutterstock (2)



LAUNCH OF FIVE NEW CAS STRATEGY AV21 PROGRAMS

The CAS Strategy AV21 platform, whose motto is "Top research in the public interest," tackles complex issues that require broad-based interdisciplinary research, both basic and applied. Its vision is realized through fifteen programs coordinated by CAS institutes together with universities, state institutions, and industry partners. This year, five new research programs have been launched – The Power of Objects: Materiality Between Past and Future; AI: Artificial Intelligence for Science and Society; Sustainable Food Production and Consumption; Future of Assisted Reproduction; and Epicenters of Civilization: Intelligent Households, Technology, and Society.

FOUR ERC GRANTS TO SUPPORT UNIQUE CAS PROJECTS

Developing new enzymes, pushing the limits of optics, investigating Roma wartime experiences, or "thieving" marine algae. Four projects by CAS researchers have secured ERC Consolidator Grants, each worth €2 million. The five-year funding will support the research of Karel Žídek (Institute of Plasma Physics of the CAS), Tomáš Pluskal (Institute of Organic Chemistry and Biochemistry of the CAS), Martin Fotta (Institute of Ethnology of the CAS), and Elisabeth Hehenberger (Biology Centre of the CAS). Five projects from Charles University and Masaryk University also succeeded – an exceptional achievement for Czech science.

TOP SCIENTIFIC HONORS FOR THE JUNGWIRTH BROTHERS

One's research focus is salt water and ions, the other's is antiferromagnetic spintronics – and both have recently been recognized for their life's work. In January 2025, physical chemist Pavel Jungwirth from the Institute of Organic Chemistry and Biochemistry of the CAS received the Neuron Award, while two months earlier, his brother Tomáš Jungwirth from the Institute of Physics of the CAS was recognized by the Česká hlava (Czech Head) National Government Award. Both researchers were also awarded ERC grants in 2023 – Tomáš Jungwirth being the first Czech scientist ever to receive a second ERC Advanced Grant.

NEW CENTER FOR ELECTRON MICROSCOPY OPENS IN BRNO

A third of the world's electron microscopes are made in Brno, Czech Republic. The tradition, dating back to the 1950s, continues today with the new Center for Electron Microscopy, opened on 12 May 2025 by the Institute of Physics of Materials of the CAS. The facility houses five specialized rooms designed to meet the stringent environmental requirements of two transmission (TEM) and three scanning electron microscopes (STEM) – i.e., minimizing vibration, electromagnetic interference, and temperature drift – all conditions necessary for accurate atomic-scale imaging in TEM/STEM, according to Stanislava Fintová, head of the Electron Microscopy Group.

PRAK BRINGS 13 PROJECTS CLOSER TO APPLICATION

What connects solar panels of the future, biosensors, and market research in materials diagnostics? All are among the projects supported by the Application Development and Commercialization Program (PRAK), which the CAS Technology Transfer Office uses to help researchers bring their ideas into practice – one path being the creation and support of spin-off companies. In the fifth year of the PRAK program, 21 teams applied, with 13 of these receiving a total of CZK 5.8 million in funding. The CAS has thus become the first Czech research organization to systematically support research making its way into practical application.

CZECH PLANT GENETICIST TAKES ON PRESTIGIOUS ROLE

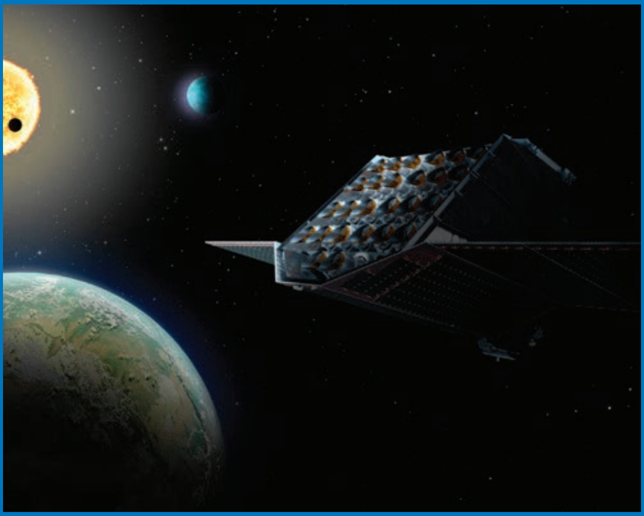
As of 2025, David Kopecký from the Institute of Experimental Botany of the CAS holds a top leadership position at the European Association for Research on Plant Breeding (EUCARPIA) – the first Czech scientist ever to do so. EUCARPIA brings together around one thousand scientists and breeders worldwide. Its mission is to advance the breeding of more resilient crops and foster scientific and technical cooperation in this field. "Today, it's crucial to breed crops that can better cope with climate change without lowering yields," says Kopecký, whose research focuses mainly on interspecific hybrids of grasses and cereals.

TWENTY-FIVE YOUNG TALENTS RECEIVE THE OTTO WICHTERLE AWARD

Gravitational waves, metal alloys, cancer treatment, transmission of skin diseases from guinea pigs to children, or the role of artificial intelligence in education. The range of topics researched by the 2025 recipients of the Otto Wichterle Award, bestowed by the CAS, is remarkably broad. The award, named after the world-renowned chemist, inventor of soft contact lenses, and first post-1989 President of the Czechoslovak Academy of Sciences, is intended to encourage exceptional early-career researchers under 35. This year's 25 laureates received their awards from CAS President Radomír Pánek on 11 June 2025 at Villa Lanna in Prague. "Talented young scientists need stronger support at the start of their careers. Today, many of those honored with the Otto Wichterle Award a decade ago are now leaders in their fields. This year's laureates, too, are the future of Czech science," Pánek said at the ceremony. The award comes with CZK 330,000 in funding spread over three years. To date, about 540 researchers have received the accolade.

PLATO SPACE MISSION WITH CZECH PARTICIPATION NEARING READINESS

Are there planetary systems like ours out there? And how are they evolving? The European Space Agency's PLATO mission, scheduled for launch at the end of 2026, aims to find the answers. Its main goal will be to search for Earth-like planets around stars similar to the Sun. In June 2025, the mission team reached an important milestone: they managed to install all 26 cameras, including their electronics, on the satellite's body, leaving only the solar panels to be fitted. The Astronomical Institute of the CAS has contributed to the mission with sophisticated hardware and software, and Czech scientists will also be involved in interpreting the data.



LASER-PRO AIMS TO RESHAPE THE HIGH-TECH SECTOR

Lasers – the supertools of the 21st century – are advancing fields from engineering and healthcare to aviation. Now, 18 institutions and companies from the Czech Republic, Lithuania, and Ukraine have joined forces in the ambitious Laser-Pro project. Its goal is to transform Europe's high-tech industrial landscape and strengthen Europe's role as a global leader in photonics and laser technologies. "Combining interdisciplinarity with the commercialization of innovations will allow us to create a European center of laser excellence based in Czech Republic and Lithuania," said Tomáš Mocek, head of the HiLASE Centre, which hosted the consortium's meeting.

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