LICHTGEDANKEN

The Research Magazine

13

EXCELLENCE »IMAGINAMICS« REACHES FINAL

AI IN PRACTICE A FINGER ON THE EARTH'S PULSE

CALENDAR MATHILDE VAERTING'S INAUGURAL LECTURE

FRIEDRICH-SCHILLER-
UNIVERSITÄT
JENA

OF MACHINES AND MEN

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Images labeled with this icon have been created by the AI tool Midjourney.

Learn and let learn

Over the last year, the topic of artificial intelligence has garnered serious attention. Generative AI tools, most notably ChatGPT, are now freely available online, with new tools released on an almost daily basis. On the other hand, there is growing concern about these increasingly powerful technologies. In 2023, prominent voices, including well-known AI experts, issued stern warnings about the risks involved and called for a moratorium—a pause in the training of AI systems. This is fuelled by a fear held by many people that self-learning, »intelligent« algorithms will become more than just useful tools. Instead, the undeniable superiority of AI models in many areas could eventually lead to us losing our ability to control them. Some have even put forward horror scenarios in which AI ushers in the end of humanity.

In this issue of LICHTGEDANKEN, we aim to outline what AI is and is not (yet) capable of doing. In our feature »Of machines and men«, AI experts Joachim Denzler (p. 12) and Clemens Beckstein (p. 14) provide an overview of the different forms of AI and explain how they work. They also discuss the limits of AI and demonstrate that artificial and human intelligence are not antithetical powers, competing for dominance: while the abilities of AI may challenge us, they also highlight where our own strengths lie. So, by combining self-learning systems with responsible application, we might even be able to produce an entirely new quality of »intelligence«.

AI tools and technologies are already applied in a variety of ways at the University of Jena. The feature in this issue of LICHTGEDANKEN presents a selection of AI-assisted projects, from climate research and historical science to chemistry and surgery (p. 22 ff.). Further interviews and articles detail the perspectives of a communication scientist (p. 36), a philosopher (p. 40) and a research team exploring legal issues (p. 38).

This issue of LICHTGEDANKEN also shines a spotlight on two female scientists whose impact extends far beyond the city of Jena: the educator Mathilde Vaerting, a pioneer of gender research who became the first full professor at a German university when she was appointed by the University of Jena 100 years ago (p. 41), and the jurist Anika Klafki, whose expertise was sought-after by media outlets during the COVID-19 pandemic and who has since become the youngest judge at the Thuringian Constitutional Court (p. 42).

I hope you enjoy reading this issue. As always, I would welcome any feedback, comments and critiques you have. You can contact me and the editorial team at: presse@uni-jena.de.

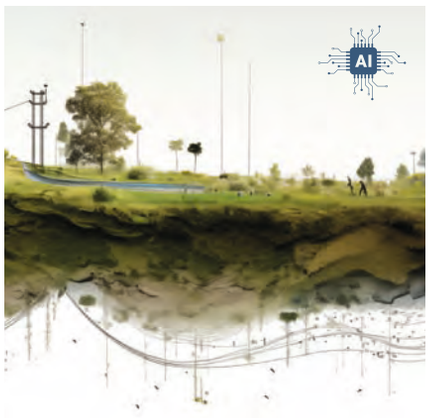
Jena, March 2024

ILLUSTRATION: MIDJOURNEY

FEATURE

Of machines and men

PHOTO: JENS MEYER



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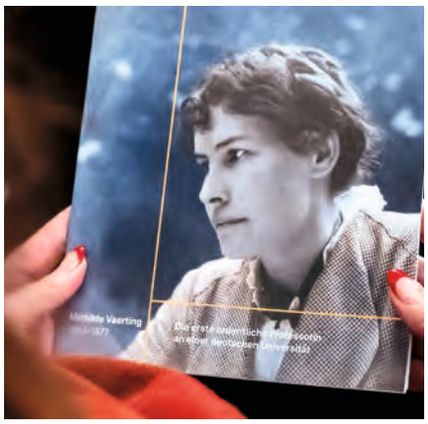

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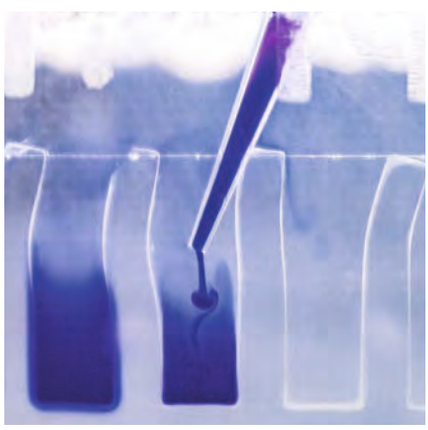


PHOTO: JENS MEYER

PHOTO: MARGAULT DEMASLE

The European Campus continues to grow

University of Jena awarded €2.3 million to fund further internationalization

The »EC2U« alliance connects the Universities of Jena, Coimbra (Portugal), Pavia (Italy), Poitiers (France), Salamanca (Spain), Turku (Finland), Linz (Austria), and Alexandru Ioan Cuza University of Iași (Romania). · Photo: Jens Meyer

Thanks to new funding, the University will be able to continue and expand its international activities over the next four years. In 2020, it joined the »European Campus of City-Universities« (EC2U). The EU has now agreed to support the alliance for a further four years through to October 2027 with a total of €14.4 million, of which €1.6 million has been allocated to Jena.

In an accompanying programme at national level, the German Academic Exchange Service (DAAD) is supporting the German universities selected by the EU. The University of Jena has again been successful in the fourth funding round, which began in early January 2024, and will receive €700,000 over the coming four years. AB

Screenshot from the film · Photo: Jens Meyer

Microverse film

The Cluster of Excellence »Balance of the Microverse« has developed a 360° film and made it available to planetariums worldwide. The film—entitled »Into the Microverse: Journey through the amazing world of microbes«—provides fascinating insights into this microscopic world.

This 15-minute film is available to download in English and German at: www.microverse-cluster.de/en/outreach.html. Nieber

Greek culture and language

Bessarion research centre established at the University of Jena

On 8 November, the Bessarion research centre was established with the aim of researching Greek culture and the diversity of the Greek language. Prof. Dr Thede Kahl, Professor of South Slavonic Studies, is working with Dr Sotirios Rousiakis and external collaborators to examine Greek dialects and aspects of Greek culture that have received little attention to date.

The research centre takes its name from Bessarion of Trebizond (born between 1399 and 1408; died 1472), a Byzantine humanist, theologian, church politician, diplomat and cardinal. Serving as Latin Patriarch of Constantinople in exile from 1463, Bessarion rendered great service to Greek culture and language, promoting their spread throughout Europe. »Greek has around ten dialects, some of which differ so significantly that they could almost be considered languages in their own right,« says Prof. Dr Thede Kahl. This is hardly surprising, he adds, given that Greek settlements have been spread far and wide throughout the Mediterranean since pre-Christian times.

Recording and preserving dialectal diversity

Kahl believes that greater appreciation of dialects and vernaculars is essential if the diversity of the Greek language is to be preserved. »We're interviewing speakers and archiving the recordings,« he explains. The project aims to preserve linguistic variants and make them accessible for others to discover. Another area of exploration for the new research centre is the history of Greek people in the Late Ottoman period in Asia Minor. sl

PHOTO: ANNA SCHROLL

Into the final round of the Excellence Competition

Project »Imaginamics. Practices and Dynamics of Social Imagination« at the University of Jena to be developed into a full application for a Cluster of Excellence by August 2024.

The University of Jena, with its new project and existing Cluster of Excellence, has reached the final round of the Excellence Competition, which supports cutting-edge research in Germany. The University submitted three new proposals for Clusters of Excellence, with the »Imaginamics« project now progressing to the full application phase.

In addition, »Balance of the Microverse«—a Jena-based Cluster of Excellence since 2019—can also apply for additional funding through the Excellence Strategy of the German federal and state governments. The deadline for submission of full applications is mid-August. Which large-scale research projects will be realized will be announced in May 2025.

Prof. Dr Johannes Grave is one of the spokespersons for the »Imaginamics« project«. ·Photo: Jens Meyer

Improving our understanding of social conflicts

Whether it's climate change, democracy or the pandemic, current debates often give the impression that people live in entirely different, almost irreconcilable worlds of imagination. These »social imaginations« vie for validity and dominance in highly dynamic processes.

These struggles for significance reveal the fundamentally open, negotiated and conflicted character of social coexistence. The project »Imaginamics. Practices and Dynamics of Social Imagination« now aims to investigate these struggles in detail. The project's name, »Imaginamics«—a portmanteau of »imagination« and »dynamics«—highlights the fluid, dynamic nature of these processes. In addition, there is always a practical side to these dynamics, namely that they are driven by social and political actors. With this in mind, the project not only looks at social imaginations themselves but also the practices of social imagining that produce them.

»We are delighted that the expert jury believes our project outline is pioneering and that we have particular strengths in this field of research. We will now dedicate ourselves to the challenge of refining our ideas in a full proposal. It's vital that we gain a better understanding of social imaginations and their unique dynamics, which is evidenced not least by the numerous discussions and demonstrations in recent weeks,« says art historian Prof. Dr Johannes Grave, who is a spokesperson of the »Imaginamics« project along with science historian Prof. Dr Christina Brandt and historian Prof. Dr Joachim von Puttkamer.

Cluster of Excellence »Balance of the Microverse« also reaches round two

Existing Clusters of Excellence are also directly eligible to submit full applications. The »Balance of the Microverse« Cluster of Excellence, which is being funded since 2019, will apply for additional funding. This large-scale research project is dedicated to examined microorganisms. It aims to research the dynamic balance of microbial communities, from the molecular level up to complex ecosystems. Building on the insights gained, new technologies are being developed to maintain or restore microbial balance. The current spokesperson of the Jena Cluster of Excellence is Prof. Dr Kirsten Küsel, Professor of Aquatic Geomicrobiology. AB

New University Council member

In November 2023, the Senate of the University of Jena appointed a new University Council. As a result, the council now has a new external member: Dr Bettina Böhm (photo), Secretary General of the Leibniz Association. Böhm, who holds a doctorate in Law, worked in the Legal Office at the University of Bielefeld and as a department head and permanent representative of the Chancellor at TU Dortmund University before becoming the first female Chancellor of the University of Münster in 2004. She was appointed Secretary General of the Leibniz Association in 2018. JK

PHOTO: LEIBNIZ-GEMEINSCHAFT

Animal welfare prize

Two scientists from Jena University Hospital received the Thuringia Animal Welfare Award in October 2023. In their work on infection research, Dr Lara Thieme and PD Dr Stefanie Deinhardt-Emmer develop and apply methods that reduce animal experimentation. While Thieme uses greater wax moth larvae to examine the efficacy of antibiotic combinations in combating bacterial infections, Deinhardt-Emmer is developing an infection model based on human lung tissue to research viral infections. The Thuringia Animal Welfare Award is presented each year by the Ministry of Labour, Social Affairs, Health, Women and Family. vdG

PHOTO: JENS MEYER

Germany's first political culture monitor

Following in the footsteps of a Thuringian study, a team of researchers from Jena, Halle and Mannheim have commenced pilot operation of a nationwide project based on public surveys—and revealed initial results.

Launched in 2023, the »Germany Monitor« (Deutschland-Monitor) aims to collect data and conduct comparative analyses on a regular basis to glean insights into short-term changes in social perspectives as well as the stability and changes in attitudes over time. Taking a Thuringia-focused study as a template, researchers hope that the results of this annual survey will offer information for politicians and the general public, while also providing a basis for scientific analysis and debate. This collaborative project is a joint endeavour between researchers in Jena, Halle (Saale) and Mannheim; in Jena it is based at the Institute of Political Science and the Centre for Research on Right-Wing Extremism, Civic Education and Social Integration (KomRex).

Differences between east and west are narrowing

One of the main findings from the first edition of the Germany Monitor, published at the end of January 2024, is that there is little difference in how people in eastern and western Germany assess their quality of life. The same is also true for people living in cities and in the countryside.
Key challenges in both urban and rural areas include the availability of affordable housing, the shortage of skilled workers and the widening disparity between the rich and the poor. In structurally weak rural regions—and especially in eastern Germany—respondents highlighted the exodus of young people as a particular challenge.

Housing and local environment influence political attitudes

Individual characteristics, as well as housing and the living environment, are decisive in the development of political attitudes. People in eastern Germany are twice as likely to feel left behind as those in western Germany. In addition, people in eastern Germany are more likely to report feeling that political actors show too little interest in their region and do too little to support its economic development. People in structurally weak areas in both eastern and western Germany report feeling left behind more often than those in structurally strong areas. PM

The end of neutrality?

Armed conflicts, climate change, displacement and migration—even after the end of the COVID-19 pandemic, our world continues to be marked by a wide variety of crises. Populists are taking advantage of the uncertainty, promising simple solutions that jeopardize social cohesion, or even democracy. In the search for direction and stability, universities are increasingly in the spotlight, challenged not only to communicate quickly and with scientific expertise, but also as organizations with a clear position.

COMMENTARY: KATJA BÄR

Katja Bär is CCO of the University of Jena and chair of the German Association of University Communications. · Photo: Jens Meyer

In recent years, the University of Jena has been called upon repeatedly to position itself publicly: after the invasion of Ukraine by Russian troops, after the violent death of 22-year-old Mahsa Amini in Iran, after the earthquakes in Turkey and Syria and, last but not least, after the revelations at the beginning of the year by the investigative journalism newsroom Correctiv.

»Sind sie zu bunt, bist du zu braun«

The phenomenon is not new in communication science. »Haltungskommunikation« (positioning communication) is the name given to the strategy used by companies, brands or managers to position themselves on social, ethical or political issues. Fisherman's Friend set an example for tolerance and diversity in Germany as early as 2015 with its campaign featuring the slogan »Sind sie zu bunt, bist du zu braun« (»If they're too colourful, you're too brown«, which can be interpreted as »If they're too diverse, you're too racist«). From the Berlin public transport company BVG to drinks manufacturers such as Fritz Cola and supermarket chains such as Edeka, companies are increasingly seeing this positioning communication as part of their corporate strategy. A growing number of consumers not only expect quality from brands, but also a contribution to social or ecological goals. Encouraged to shoulder social responsibility, not only management but also employees are speaking out as »corporate influencers« on corporate values such as sustainability and diversity in line with their mission statement.

In contrast, universities have long chosen to remain without a mission statement and the political communication of researchers reflects their individual views, due to their academic freedom. »Isn't the very premise unrealistic that an unwieldy entity such as the modern university system has to be permeated and sustained by the common way of thinking of its members?« asked Jürgen Habermas in 1986 on the occasion of the 600th anniversary of the University of Heidelberg [1]. The historical »idea of the university« remained as much a blank space as a position in the mission statements that emerged in past years via the circuitous route of »New Public Management«.

»Hippie-like«: the mission statement

However, the University of Jena's mission statement stands out. The University has explicitly formulated its responsibility to get involved in public debates when its principles are attacked. Even though the Frankfurter Allgemeine Zeitung newspaper mocked the University's aspirations and values as »hippiesque« [2], they define a new idea of the university, which sees itself as a place of freedom, diversity, inclusion and tolerance, and takes political action in defence of its principles [3]. In the participatory process of developing the mission statement, it was decided to cite racist discrimination as an example where the University must position itself.

The Senate and Executive Board of the University of Jena were not alone in deciding to take part in initiatives supporting cosmopolitanism, such as »weltoffenes Thüringen« (open-minded Thuringia) or #Zusammenland (#Togetherland). Universities elsewhere are also championing the values of this new political university. University managements in Germany and Austria are calling for demonstrations in their cities and speaking out against xenophobia. At the University of Jena, management can be sure that their University does not confuse the party-political neutrality of the public institution with political abstinence.

University Communications and Marketing, which defends the values of the University and the free and democratic basic order on a daily basis in social media, can also refer to the mission statement. Nevertheless, the University's stance must be found anew each time it positions itself. This sometimes requires the broadest possible dialogue, which rules out overly rapid responses in the case of complex issues. Furthermore, the mission statement does not confer a general political mandate. Instead, political speech and action must remain related to the University. One thing is clear: not only is it impossible for you not to communicate, but you cannot be without a position. Silence is also a position and needs to be carefully considered. ■

[1] Zeitschrift für Pädagogik 32 (1986) 5, S. 704
[2] FAZ, https://www.faz.net/-in9-ajgmh
[3] DUZ Wissenschaft & Management 07/2021

Illustration of an artificial neural network using a generative AI tool (see p. 16) . · Illustration: Midjourney

FEATURE

Of machines and men

How artificial intelligence is transforming our lives

It began with a handful of people and their dream of developing machines that are our equals—that think like us, make decisions like us, and have the ability to learn from experience. Since the first basic learning computing machinery of the past century, enormous advances in artificial intelligence (AI) algorithms have seen this technology gain a foothold in almost every area of our lives. This is particularly true in the world of science. Academics in almost every discipline now use AI applications in both teaching and research. In this feature, we present the work of research teams at the University of Jena that are training and applying AI tools—and tackling the questions raised by these technologies that have long gone unanswered. These include the availability of data and energy resources, legal and ethical aspects of their use and, of course, how much influence we should allow AI to exert on our lives.

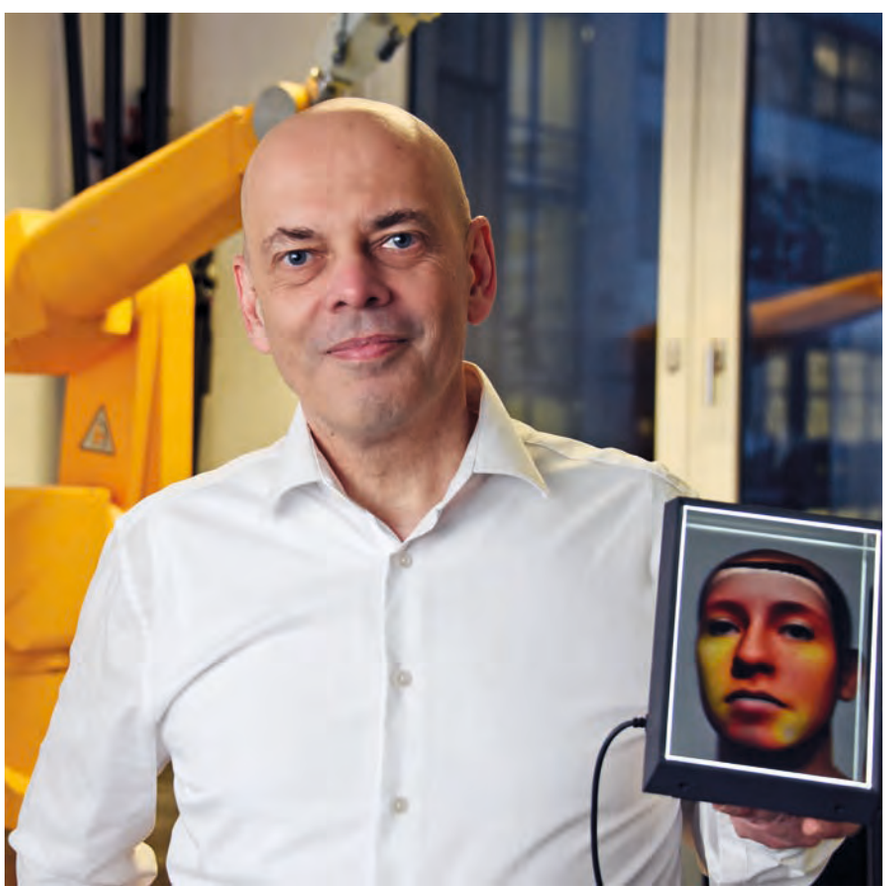
The dream of the human machine

Artificial intelligence, usually referred to simply as AI, is the topic on everyone's lips. Growing numbers of people are now aware of AI, certainly since generative AI tools like ChatGPT were made available for anyone to use. Nevertheless, AI has long been integrated in many everyday applications, from voice assistants to image recognition tools to apps that offer book and film recommendations tailored to your personal tastes. But just how »intelligent« is AI? What is it capable of? And what is—as of yet—beyond its abilities? We explored these issues in an interview with computer scientist and AI development expert Prof. Dr Joachim Denzler.

INTERVIEW: UTE SCHÖNFELDER

What exactly does AI mean?
The term »artificial intelligence« is already quite old. It was coined in the 1950s and originally referred to the notion of developing machines that could act like humans, with the same capabilities as humans. As we know, such machines still do not exist. What's more, they are unlikely to exist any time soon.

Despite this, we find ourselves talking about AI more than ever.
Yes, but we use the term to refer to something else. Based on the original idea of emulating humans, researchers in the 1960s began recreating the basic structures of the human brain, creating artificial neural networks. While this approach yielded considerable progress—in pattern recognition and machine learning, for example—it did not come close to genuine AI.
We now have so-called »deep neural networks« that perform »deep learning« (see p. 16) and are very powerful. These networks have now become synonymous with AI in common parlance.



Prof. Dr Joachim Denzler is a specialist in computer vision and has co-developed an AI that automatically detects people's emotional facial expressions (small image). · Photo: Anne Günther

But are these networks »genuine« AI?
No; that's why we refer to them as »weak AI«. In truth, this term covers all currently available AI tools and technologies, from statistical data analysis, machine learning and deep learning to autonomous vehicles and voice assistants. These are all machines designed to perform defined tasks and which are only suitable for these tasks. Nowadays, we're able to integrate increasing numbers of tasks into these systems, and their processes run very swiftly and efficiently, which can create the illusion of real intelligence. Ultimately, however, we are still working in the field of machine learning and, therefore, remain in the field of weak AI.

What would »strong AI« look like? And when will we be able to use it?
In contrast to the weak AI tools I've described, which are used for specific tasks, strong AI is universally applicable. It can solve almost any problem at least as well as a human could. This

means it can act independently, flexibly, and proactively. However, we will likely have to wait some time yet before we have this »strong AI«.

How are researchers trying to make this a reality?

One current avenue of exploration is the development of AI models trained with very different modalities. Just as we humans have different sensory organs that »feed« our brain with different stimuli, we are now attempting to train AI with different text, image and sensor data to convey increasingly complex »knowledge«. However, strong AI would require the machine to be able to acquire knowledge independently before transferring that knowledge and applying it to other areas.

Such models would bring about significant advances. But does this represent the step to strong AI? I don't think so.

To what extent to do you engage with AI in your own work?

My team and I develop our own artificial neural networks. One topic we're working on at present is known as causal inference. In other words, we're trying to teach the machines the principle of cause and effect.

So, instead of merely identifying statistical relationships in datasets, AI should determine the cause of the correlation between them. For example, there is a correlation between ice cream sales and the use of air-conditioning systems. The underlying cause is the outdoor temperature.

How are you proceeding here?

To begin with, it looks exactly like AI has functioned to date: we train AI models with known principles of cause and effect from different areas of application. We use hybrid modelling approaches like this in our work at the ELLIS Unit (see p. 18).

Later on, however, the machines should be able to distinguish between correlation and causation themselves. As humans, we usually determine this by intervening in a system. If, for example, I want to know whether it's warm in my office because I've turned the heating up or because the sun is shining through the window, I can find out by switching off the heating and checking whether the room temperature changes. Alternatively, I can pull down the blind and see what happens. In order to teach neural networks to understand cause and effect, we use time-series data, such as water levels in rivers (see p. 28). These levels depend on the water levels in tributaries, among other factors. We try to train the model to understand this relationship by changing the time series. This way, the model learns whether one variable influences another.

What do you consider to be the challenges and limitations in the use of AI?

In addition to technological implementation, which I mentioned earlier, I think the vast energy requirements of these systems pose a further challenge. The current computing paradigm, in which systems have to become bigger in order to become more powerful, means that their energy consumption is rising immeasurably. Given the finite resources at our disposal and the challenge of climate change, this is a problem we absolutely must solve.

The ethical issues of AI are an additional aspect. Current AI models are already so complex that no human can fully understand them. This raises the issue of the credibility of the results produced by an AI model and how we should deal with them, in a medical setting, for example, in relation to diagnoses and possible treatment options. AI, however, has also already been applied in some legal proceedings. In the USA, AI models have been used to assess the likelihood that criminals will re-offend. People are assessed differently depending on their ethnicity—and such cases are incredibly delicate from an ethical perspective.

Is there anything you think AI will never be able to do?

I'd rather not make any predictions about that. If you'd asked me that ten years ago, I wouldn't even have thought it was possible to achieve what is already possible today. I don't think we can even imagine the developments that will emerge in the years ahead. That's why I'm very cautious when making predictions like that.

What AI tool or AI-based technology do you personally hope to see?

In truth, I'd like to see what AI was originally meant to be: a sort of personal assistant, a machine that can help me with all my day-to-day tasks. That would be useful. ■

»Sapere aude!«

The current hype surrounding AI tools such as ChatGPT can easily obscure that AI already has a long history. Not only in science but also in business, medicine, administration, and, last but not least, in most people's everyday lives, AI technologies have already become firmly established. In this interview, Prof. Dr Clemens Beckstein explains what characterizes generative AI tools such as ChatGPT and why they rely primarily on human intelligence. The computer scientist also reveals what Immanuel Kant can teach us about handling AI.

INTERVIEW: UTE SCHÖNFELDER

You're a Professor of Practical Computer Science with further specialization in artificial intelligence. How would you define the term »intelligence« for your specialist field?
As a computer scientist, the idea of trying to define »intelligence« would never cross my mind. But I nevertheless believe that the term »artificial intelligence« can be meaningfully used as a synonym for digitalizing areas in society, business, culture, and science that previously operated without computer support and that are so complex that they are assigned the attribute »intelligent«. According to this »definition«, AI is an ascriptive term: its meaning changes in line with the progress we are making in constructing digital, programmable systems. What was called AI 20 or 30 years ago, such as voice assistants and robots, differs from what we call AI today. In this sense, AI is a moving target.

What type of AI does your work focus on?
For the most part, it is classical, symbolic AI (see p. 16), such as symbolic knowledge representation and processing, intelligent computer support of the scientific research processes, and algorithmic network analysis, but also research on foundational and philosophical aspects of AI. Currently, my team and I are focusing on using AI technologies to digitally model the research process in the humanities. For this purpose, we collaborate with partners from the humanities through a cross-faculty research team called MEPHisto (Digital Models, Explanations and Processes in the Historical Sciences) (see p. 22).

How do AI tools like ChatGPT actually work?
There are now very many very different AI systems, and they all work differently. ChatGPT is a specific software tool that associates texts, a so-called generative pre-trained transformer (GPT). Grossly simplified, such a transformer is nothing but a gigantic, algorithmically compressed association table consisting of two columns of text. One column lists all conceivable questions, or »prompts«, while the other lists the most suitable responses for those prompts. A huge amount of publicly available digital texts is processed to create this table. For a conversation with ChatGPT, this model computes the probability with which any theoretically possible word should be the next or final word uttered by ChatGPT in this conversation. This statistical model is called a large language model (LLM) or a generative pre-trained transformer (GPT).

So, how intelligent is ChatGPT?
Only as intelligent as the humans who develop, fine-tune, and use the model. In and of itself, ChatGPT is not intelligent at all. It does not have a mind or even a memory of its own and cannot learn anything autonomously. But ChatGPT does possess a great deal of human intelligence: the digitalized, written cultural heritage of humankind, as well as vast quantities of data that people have scraped and filtered from the internet and every other digitally available source to construct and fine-tune the language model of ChatGPT. Human intelligence can also be found in the underlying technology and in the public institutions that work hard to ensure a socially compatible alignment and responsible use of ChatGPT by establishing ethical and political frameworks.
It is only through people that ChatGPT becomes what it is: an exceptionally literate, extremely easy-to-train »stochastic parrot« that can speak with polish—but does not really understand what is being said.

Computer scientist Prof. Dr Clemens Beckstein works on symbolic AI, but also on foundational and philosophical aspects of AI. · Photo: Anne Günther

Nevertheless, ChatGPT in particular has advanced leaps and bounds in the last year. How would you assess its progress to date?

The reason for the progress achieved recently, especially with respect to generative AIs, is not so much technological breakthroughs but rather scaling phenomena. The progress is mainly due to a huge increase in resources used to train these systems: ever larger and better optimized artificial neural networks and ever more powerful hardware for their simulation, together with a gigantic volume of data from almost all areas of our life, which are primarily collected by the four big players: Microsoft, OpenAI, Meta and Google. Exactly how long this scaling will continue to produce significant improvements in AI systems remains to be seen.

How reliable is the output from ChatGPT and the like?

At the moment, it actually isn't that reliable. As I've outlined, the output from ChatGPT is nothing more than statistically founded statements. Its hit ratio is currently around 80%. That isn't going to change significantly because, like all machine-trained systems, ChatGPT still only has incomplete knowledge of the »right« output and the »right« behaviour. Everything depends on the data used to train it. Another issue is that its output cannot be explained or validated and often enough contains prejudices and biases.

The problem here is not only that the model lacks the technical ability to distinguish between »right« and »wrong« behaviour but also that these categories are socially negotiated and often ambiguous. Strictly speaking, Microsoft, OpenAI, Meta, and Google currently decide what is »right« and what is »wrong« because they control the data used to train foundation models like ChatGPT and set the standards for fine-tuning which is supposed to eliminate prejudices and biases.

Where do you think regulation is needed in relation to AI?

It's the same for AI as for dogs: whether big or small, aggressive or toothless, the biggest risk with dogs is at the other end of the lead: the human controlling them. That is to say we as a society are responsible for ensuring that AI is used responsibly and accountably in politics and business, and by each and every individual.

I am, therefore, rather disappointed by the current European proposal on AI regulation because it omits a lot of things. It is not the technology that is being regulated, but the application of AI. It is obviously a good thing that mass biometric surveillance or »social scoring« are to be prohibited. But there has actually been consensus on these issues for a long time. What I think is missing from the current draft law, however, is clear regulation of the foundation models themselves, in particular transparency regarding the data used.

Is there also a need for development on the part of users?

In my opinion, this area has the greatest need for development—at least if we do not want an unconsidered use of AI to unintentionally (but culpably) reverse humanity's emergence from its self-inflicted immaturity, mindlessly reversing more than 200 years of enlightenment!

This is not about having to acquire or develop new skills. Instead, we simply can remember the advice of the great Enlightenment philosopher Immanuel Kant, who wrote: »Sapere aude! Have the courage to use your own understanding!« This is something we should do consistently, despite ChatGPT and the like. ■

What's everyone talking about?

A brief guide to AI terminology

Artificial neural networks (ANN)

Artificial neural networks are computer models inspired by the processes of biological neural networks. They are made up of numerous interconnected nodes (»neurons«) that independently perform calculations depending on certain parameters, sharing their results via the connections between them. These computational networks are thereby able to learn to recognize patterns and relationships in data. This means that a learning process based on suitable »training data« can systematically configure and optimize the network parameters for a given task. ANNs are primarily used in situations beyond the limitations of symbolic AI approaches, such as image analysis, voice recognition, forecasting models and automated decision-making.

Generative AI

This term covers a range of ML models that generate new content, such as text, images, audio and video. These models are trained using large volumes of suitable data and »learn« to mimic content based on these templates. Generative AI models include ChatGPT and Midjourney, which we have also tapped to generate images in this issue.

Deep learning

Deep learning describes the process of training extensive, complex ANN architectures (known as »deep artificial neural networks«), which are comprised of multiple layers of »neurons«. Their hierarchical structure enables them to solve highly complex tasks. Another significant difference from conventional ANNs is that deep ANNs are capable of automatically identifying and extracting complex patterns in data in order to model a problem (known as »representation learning«).

Symbolic AI

Symbolic AI (also known as »classical AI«) represents knowledge about a given domain propositionally, i.e. as a collection of statements that apply to that domain. These statements are depicted by means of meaningful symbol structures and supplemented with computational rules that allow a computer to solve problems similarly to humans in clearly structured, precisely described domains. Their applications include »expert systems« used by doctors to assist with diagnosis. Symbolic AI reaches its limits in areas that lack a propositional description and for which people can struggle or fail to accurately verbalize their problem-solving methods. It is therefore often supplemented by approaches such as machine learning.

Machine learning (ML)

In machine learning processes, an algorithm repeatedly performs a defined task and thereby learns to perform it independently. Instead of following a programmed solution path, data-driven, mathematical optimization procedures enable ML systems to adapt to a defined objective—a process referred to as »training«.

Foundation models

These models are artificial neural networks that have been pre-trained for a general task with extensive, diverse datasets using ML techniques. They can then be optimized for specific applications and tasks with the help of specialized datasets (known as »finetuning«).

Large language models (LLM)

ChatGPT is one example of this type of autoregressive language model, which is trained exclusively on text data. These models harness deep learning algorithms for word prediction in order to process, understand and generate natural language. When presented with a given »prompt«, the LLM generates subsequent words as text output. Given the complexity of the architecture of LLMs and the volume of texts that are used to train them, their text output often appears very plausible to people—though its content is frequently inaccurate.

In a joint research project, the Palaeontology and Micropalaeontology research group at the University of Jena and a team at the University of Hong Kong are exploring ways to identify, count and measure tiny ostracods (sometimes known as »seed shrimps«) using AI. In an initial study, the team examined the pictured ostracod fauna from Lake Stechlin in Brandenburg. Ostracods are a highly diverse group of microscopic crustaceans that appear in all kinds of waters. Their calcite shells are preserved in the sediment over long periods. They therefore make excellent bioindicators and, as fossils, can be used to reconstruct environmental and climatic conditions. · Image: Ella Quante

Combating the climate crisis with AI

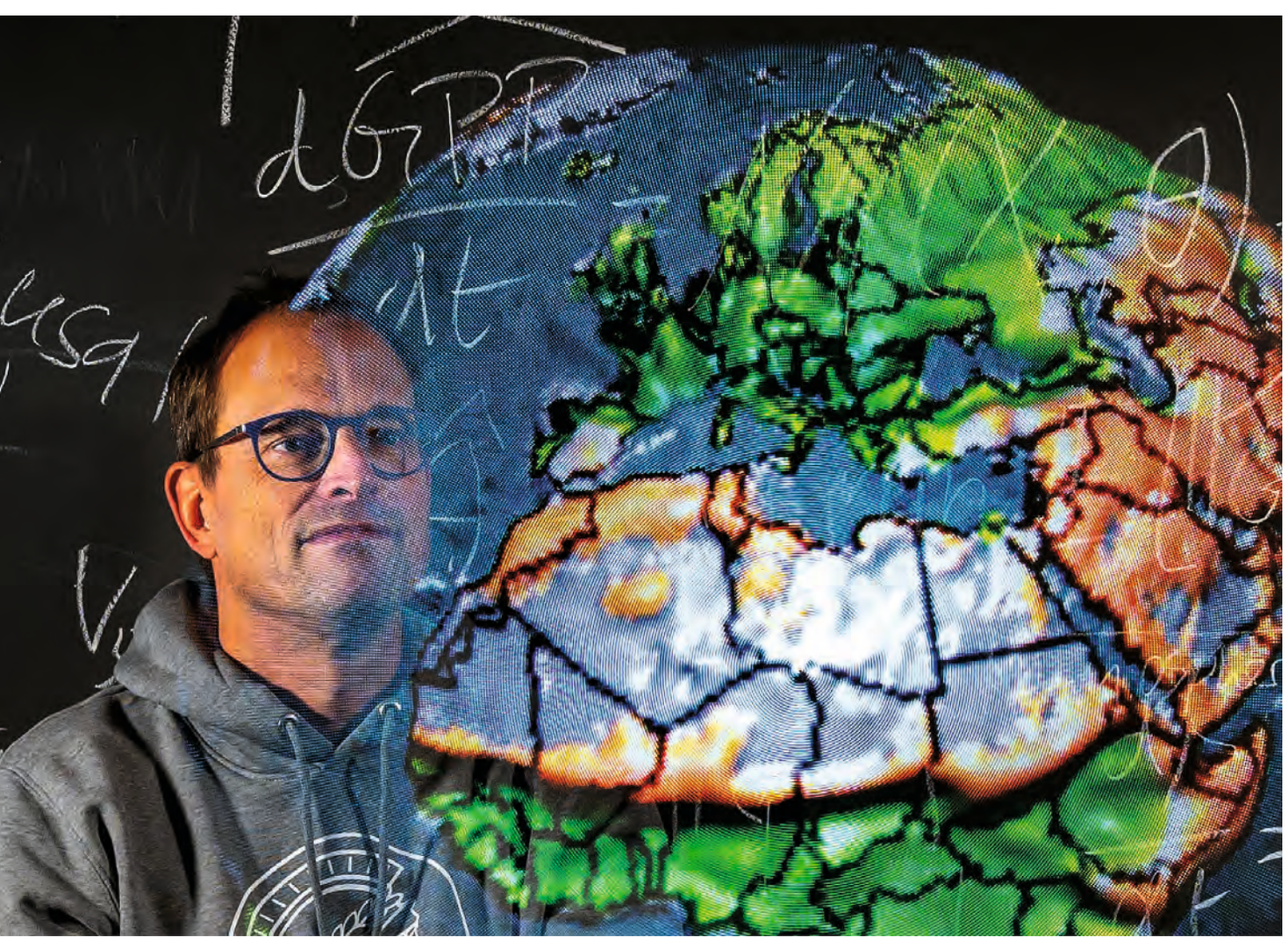
At the ELLIS Unit Jena, under the leadership of Prof. Dr Markus Reichstein and his colleague Prof. Dr Joachim Denzler, researchers are striving to predict the impact of extreme weather events with the help of AI. This should make it possible to provide advance warning to the people likely to be affected.

BY MARCO KÖRNER

Protecting people against extreme weather events and their consequences in good time requires precise forecasts. A research team led by Markus Reichstein is examining how to develop artificial intelligence (AI) tools to adapt to these effects of climate change. Reichstein is Professor of Global Geoecology at the University of Jena, director of the Max Planck Institute for Biogeochemistry and one of two directors of the ELLIS Unit Jena.

ELLIS—which stands for »European Laboratory for Learning and Intelligent Systems«—is a pan-European excellence network specializing in AI. Three research institutions—the University of Jena, the Max Planck Institute for Biogeochemistry and the Institute of Data Science at the German Aerospace Center (DLR)—joined the ELLIS Unit

Prof. Dr Markus Reichstein and his team use AI methods to accurately forecast future weather events from historical climate data. · Photo: Jens Meyer



Jena in 2021. »When it comes to the climate crisis, there are two aspects to consider: climate change mitigation and climate change adaptation,« explains Prof. Reichstein. There is already a genuine need to adapt to climate change, he emphasizes, pointing to the increase in extreme weather events as a clear indication.

A game-changer in weather forecasting

Reichstein believes that AI can be a game-changer. »Certain situations like fires and local flooding are so complex that we can't easily predict them with physical models. However, we can forecast them with AI,« he explains. »AI methods like machine learning can identify patterns in historical climate data—from satellite images to temperature measurements—and estimate future weather events with greater accuracy. Plus, we now have the advantage of vast amounts of data.« By way of example, Reichstein points to satellite data, which records parameters such as vegetation, temperature, moisture levels and much more over years and decades in some regions. »We are using this to train an AI model and tell it, for example, what a given landscape looks like. We can then use this AI to help us forecast whether and where flooding, droughts and fires might occur when subject to different weather conditions.«

The fact that the impacts of climate change differ significantly from region to region plays an important role in the ELLIS Unit's research. »Regional variations are decisive to understanding how different ecosystems and geographical areas react to changes in the climate,« says Reichstein. He offers an example to illustrate his point: »A few months before the huge downpours in Germany's Ahr Valley in July 2021, similarly heavy rain had fallen in the Uckermark, an area in northern Germany. On that occasion, however, the impact was relatively small. This was due to the sandy soil and the gentle terrain, so the water was able to flow away at a fairly relaxed rate.«

This example, he explains, shows how a few factors can determine whether or not disaster strikes. »This is also where conventional physical models reach their limits because, ultimately, they have to identify and consider every single factor at play.« By contrast, AI models identify patterns without having to determine the specific factors that cause them. Not only does this often provide more precise results, it also saves computing power and, as a result, both time and energy.

»We start by training the AI with remote sensing data, for all of Africa, for example. Then, if we want to see whether there is a risk of crop failure in Rwanda, the AI can take a closer look at Rwanda. In addition to this data, we provide local information such as the latest weather reports, forecasts for the coming days and current vegetation levels,« he explains. »In this manner, we can look at any weather situation around the globe and model the impacts that could occur, such as droughts in East Africa or forest fires like those we recently saw in Canada.«

Reichstein is well aware that remote sensing data has its limits. »We can use microwave data to determine whether or not the surface of the soil is moist. However, this doesn't allow us to draw any conclusions about deeper layers.«

It is also essential that forecast climate data and risks are communicated appropriately so that the people affected can take action to protect themselves. »Communicating the results and, if necessary, the warnings and recommendations for action to those affected is probably the primary task,« adds Reichstein. This can be seen, he says, in the challenge of making complex data such as elevated river levels and their potential consequences comprehensible to a wide audience, from the residents affected to the relevant authorities.

Communicating complex climate data—by way of AI

AI also has a role to play in this regard. »We have the ability to make forecasts and depict different scenarios very vividly,« explains Reichstein. »For example, just as AI is used to generate artificial images, we can use AI along with Google Maps or OpenStreetMap to show what flooding in a given city might look like in an actual, real life scenario.« This illustration demonstrates that a one-metre change in the level of a river can determine whether a given house will be flooded or not. »With AI, we can vividly depict who exactly is at risk of such events and also the degree to which their house might be flooded,« he explains.

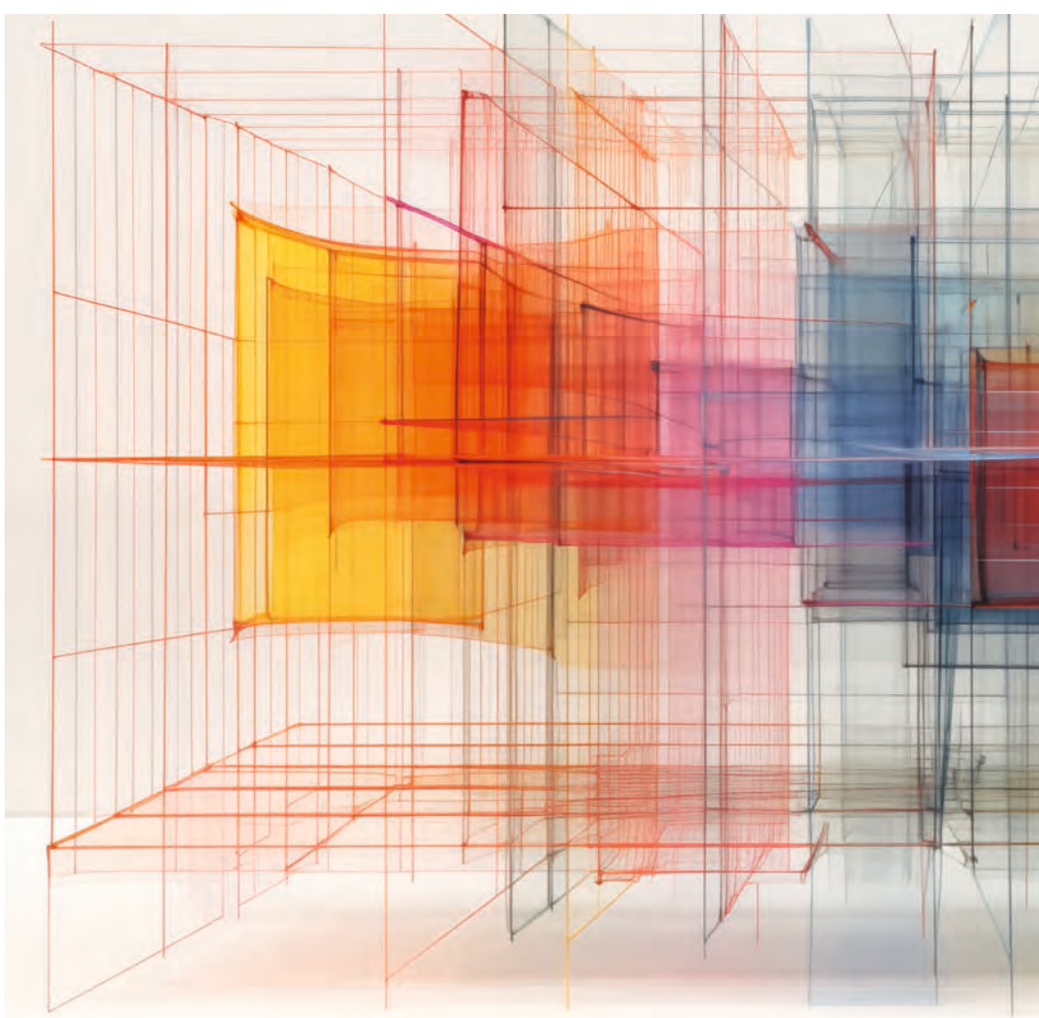
With this in mind, Prof. Reichstein believes that communicating the potential impacts of upcoming weather events to the people likely to be affected is also part of climate resilience. »It's precisely because we want people to prepare for specific events that I believe communicating research results is an essential aspect of climate science.« ■

In the engine room

The impressive world of AI applications functions only because it is supported by a broad technological basis. Research in this field is considerably more abstract but all the more important. Scientists at the Institute of Computer Science, for instance, are optimizing nothing less than the cognitive process of artificial intelligence.

BY SEBASTIAN HOLLSTEIN

When people talk about artificial intelligence, they are usually referring to the fascinating possibilities for seemingly countless applications. The practical use of AI, however, is merely the tip of a technological iceberg. Hidden beneath the surface are vastly greater layers of infrastructure—from fundamental AI models to software and hardware. Funded by the Carl Zeiss Foundation, the »Interactive Inference« Research Training Group at the Institute of Computer Science trains the next generation of experts for this »AI engine room«, where there is a massive shortage of skilled professionals. »The technological foundation of artificial intelligence receives far too little attention in the public discourse, even though this is where the most value is generated,« says Prof. Dr Joachim Giesen from the Research Training Group. »Both the fundamental AI models as well as the software and hardware are mostly not from Europe.« It is therefore vital, he argues, that young computer scientists here learn to understand, analyse, and develop AI infrastructure.



The researchers in Jena are focusing on what is, in simple terms, the cognitive process of AI: inference. When users send a request to ChatGPT, for example, inference software generates the desired response—in this case, a piece of text. This inference software has been taught using vast amounts of data in a process known as training. Just as it can take some time for humans to learn something, AI training can be a prolonged process, several months in the case of large AI models. However, answers to an inference query should be available much faster—ideally in just a few milliseconds. To answer queries from millions of users at this speed, significant computing power is needed, which consumes a lot of energy and causes correspondingly high costs and CO_2 emissions.

The Jena researchers see a promising method for making inference more efficient in optimizing so-called tensor calculations, which can be used to map out many problems and are therefore frequently used in AI infrastructure. »A tensor is a mathematical concept that

Prof. Dr Joachim Giesen (left) and Prof. Dr Alexander Breuer (right) conduct research in the »Interactive Inference« Research Training Group.· Photo: Anne Günther

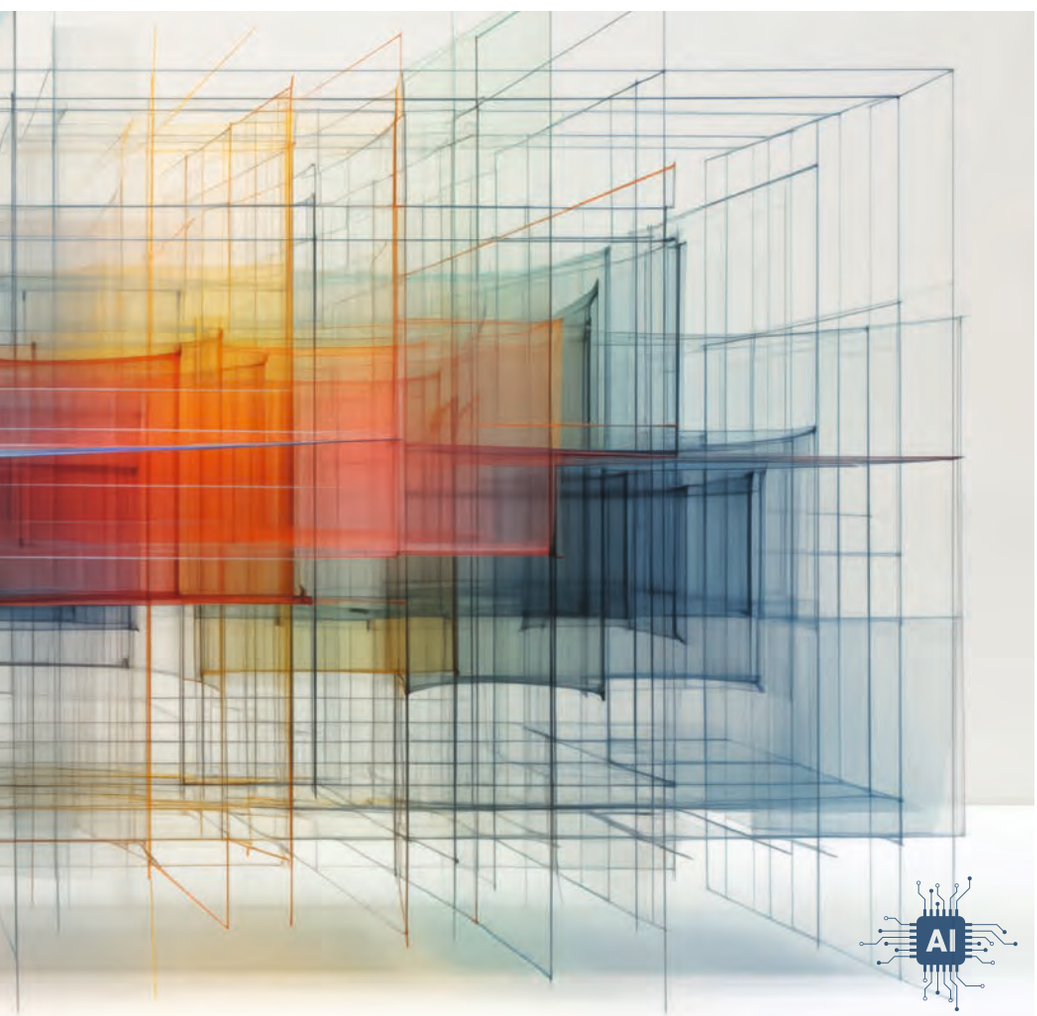


Illustration of a higher order tensor. · Illustration: Midjourney

allows us to depict complex data in an organized way,« explains Prof. Dr Alexander Breuer from the Research Training Group.

»If a data point consists of several numbers—for example, a wind direction—then this data point is called a vector. If we need several vectors to store data, we get a matrix, a two-dimensional grid. And, if several matrices are used, this is referred to as a higher-order tensor with more than two dimensions.« This structured representation of data offers many possibilities for accelerating computing processes. »If, for example, many numbers within the tensors are zeros, many calculations on the tensors also result in zero—this can be taken into account in advance to avoid unnecessary computations,« adds Giesen.

Efficient calculation of probabilities

The experts in Jena are researching these and other methods to increase efficiency to accelerate inference queries, for example, on probabilistic AI models. These are models in which probabilities play a major role and which are used in fields such as logistics. AI, for example, can compute how likely it is that passengers will need a ride at a certain location at a certain time, taking account of the regular traffic volume or potential roadworks. »We expect that such applications will become increasingly important in the future and are therefore focusing on the development of the underlying AI infrastructure,« says Joachim Giesen.

In the years ahead, AI will become an integral part of just about every area of our lives. This makes it even more important that infrastructural issues receive more attention. »The computing effort involved in both training AI models and inference is already massive and will continue to increase,« says Breuer. »While hardware performance is also increasing, its programming will no longer be as straightforward.« Excellent training for early-career computer scientists is therefore essential. ■

Big data of the late Middle Ages

MEPHisto (»Models, Explanations and Processes in the Historical Sciences«) is an interdisciplinary research group consisting of researchers from the Professorship of Practical Computer Science II (Artificial Intelligence) and the Professorship of Medieval History. Its mission is to investigate and develop digital techniques and tools to support historical research. In a current project, the team led by Prof. Dr Clemens Beckstein and Prof. Dr Robert Gramsch-Stehfest focuses on the digital indexing of what are known as »regesta«. These short, semi-structured texts summarize the content of historical sources in condensed form.

Specifically, this involves sources from the Vatican Archive. »The Roman Curia began to comprehensively document and archive its administrative records in the High Middle Ages. The result is a vast amount of written tradition unlike anything else for the Middle Ages,« says Robert Gramsch-Stehfest. However, the thousands of handwritten tomes in the Vatican are almost entirely inaccessible for a systematic investigation.

Researchers identified this issue over 130 years ago and began to transfer the extensive documentation into semi-structured form. Initiated in 1892, the »Repertorium Germanicum« (RG) project summarizes documents from the Vatican Archives which relate to Germany in a shorthand system. It is »a sort of Latin stenography,« as Clemens Beckstein describes it. To date, the ten volumes of the RG list tens of thousands of clergy members and scholars from 1378 to 1484 and report on the events involving them. However, these summaries are still unsuitable for a comprehensive, computer-aided evaluation.

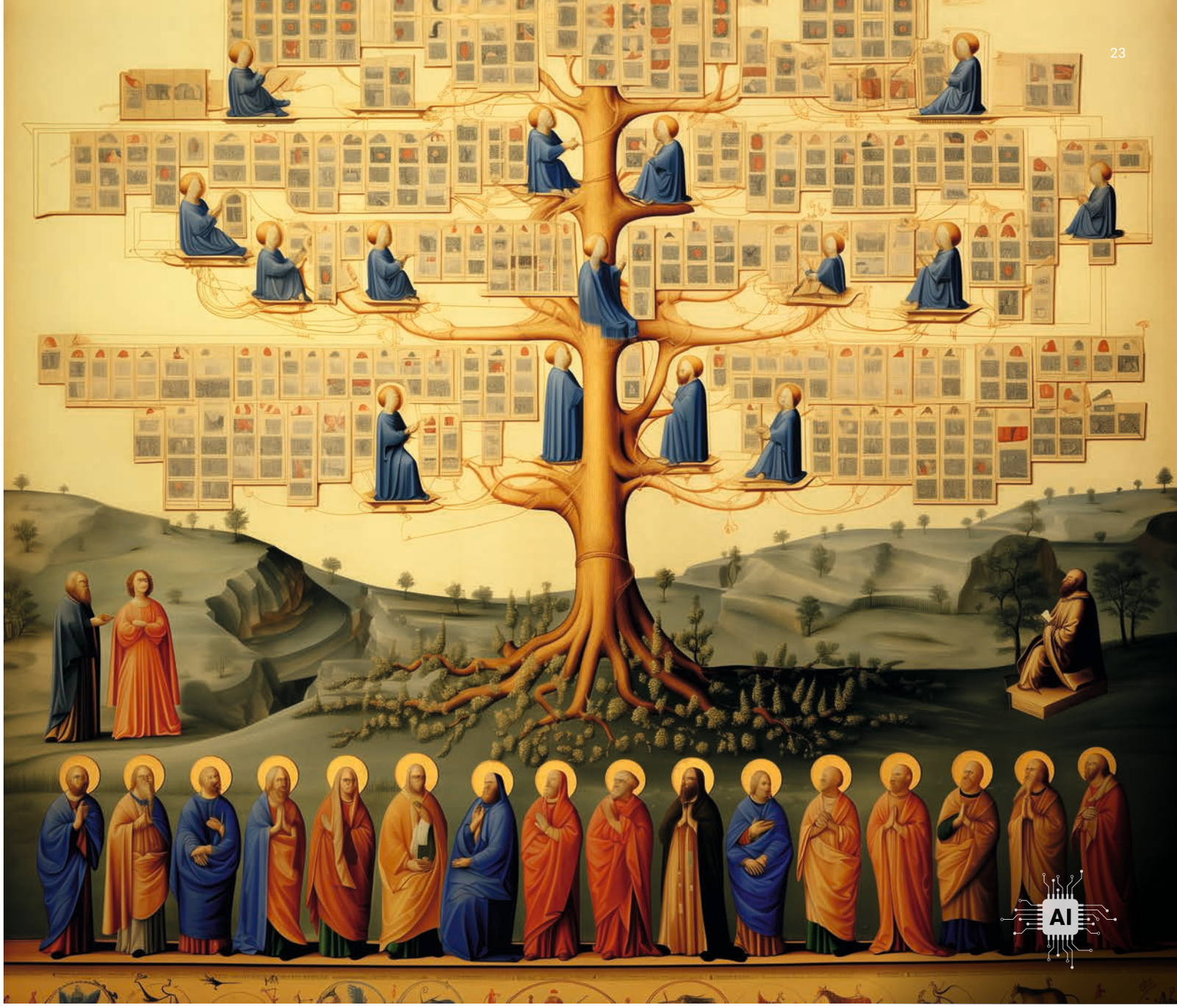
In order to make them easily usable for a wide range of scientific questions, the MEPHisto team uses AI-based methods to automatically filter out the factual information contained in the RG's regesta and translate it into structured data that can be stored in a conventional database. For this process, the team members rely on ANTLR (ANother Tool for Language Recognition), a parser generator that supports the automatic generation of text analysis tools. Before they can use algorithms to examine the regesta in relation to a specific research question, the team must first develop a formal grammar that appropriately describes the syntactical structure of the regesta according to the terminology used in these documents (i.e. the canonical terminology of the High Middle Ages). Based on this grammar, ANTLR then automatically generates a tailor-made software tool that can be used to analyse any text source of the same type.

However, developing this grammar is a laborious process: in addition to linguistic and historical expertise, it also requires extensive knowledge of computer science. To simplify this process, the MEPHisto team, which also includes the two doctoral students Clemens Beck and Johannes Mitschunas, is working on a grammar development environment called »Paredros.« Following the example of its namesake—in Greek mythology, a paredros is the helper of a god—this development environment will support researchers developing grammars for structuring their data. For example, Paredros uses source texts to automatically suggest standard building blocks for the hierarchical composition of these grammars. It also automatically identifies names and places that are thematized in the source texts. By using LLMs (Large language models), Paredros will also enable historians to interact with the development environment in a largely natural language while reconstructing the grammatical structure of the regesta.

With the help of the triad of ANTLR, Paredros, and a grammar of the Vatican's stenography for the Repertorium Germanicum (developed with the help of Paredros), the researchers can now automatically generate a complex data structure for any event in the Middle Ages that is described in the Vatican's vast collection of regesta. This data structure depicts the syntactical structure of the respective regest and includes all the content-related and domain-specific facts about which this regest speaks. Consequently, centuries after these documents were written and over 130 years after their processing began, researchers in Jena are laying the foundations for transferring the historical records in the Repertorium Germanicum project into a structured database of learned clergy members of the late Middle Ages, which will then be available for a wide range of historical research. US

Image top right: An image of a fictitious syntax tree created with the AI programme Midjourney. The text-to-image tool was instructed (prompted) to create a »parse tree in the style of Fra Angelico«. It solved the task by drawing on a form of tree visualization that was very popular in the late Middle Ages and early modern period, the genealogical family tree. Apparently, the AI was trained with corresponding image material. Fra Angelico, a Tuscan artist of the early 15th century, worked in Rome himself. His works—predominantly altarpieces—are characterized by a austere, simple visual language, which Midjourney captures well. · Illustration: Midjourney

Figure bottom right: A syntax tree (parse tree) of the head of the regest entry »RG III 00057« (http://rg-online.dhi-roma.it/RG/3/57) from the »Repertorium Germanicum« generated with ANTLR. It contains information on Heinrich Foet von Bochold, a cleric (clericus) from the diocese of Utrecht (Traiectum). Foet held the academic degrees of magister in artibus and baccalarius in decretis (i.e. in canon law). In the further text of the regest it is documented that in 1410 the Pope assigned him a parish church in what is now the Netherlands. · Figure: Research group MEPHisto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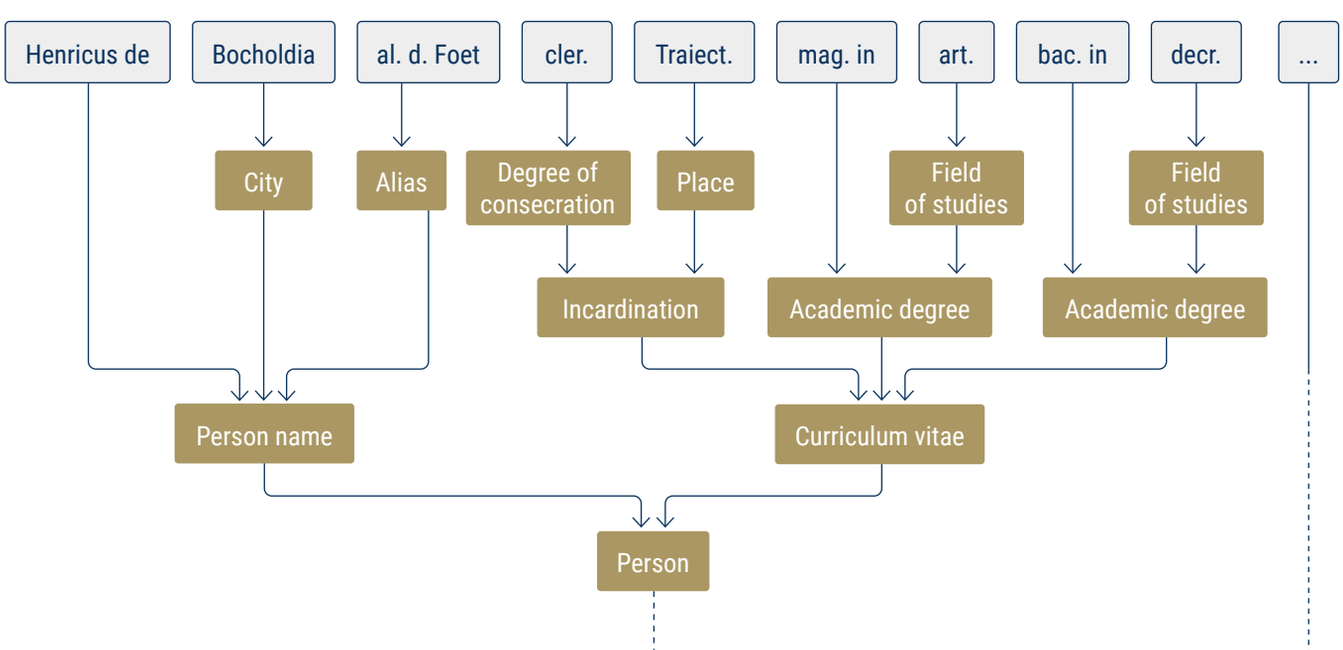
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A city stroll through time and space

Virtual strolls through Dresden's Old Town, taking in the city's history, are now possible thanks to a web application called »4D Browser«. The app has been developed by Prof. Dr Sander Münster and his team in the course of a research project funded by the Federal Ministry of Education and Research (BMBF). This interactive platform allows users to explore a 3D model of the city along with historical images and texts about its buildings and architecture.
»What's so special is that the historical photos in the model are shown from where they were taken and from the precise camera position,« as Sander Münster explains. »This makes it possible to see, for example, from which direction buildings were often photographed, the view of the city enjoyed by photographers in the past, and how they framed a given part of the city.« A timeline makes it possible to trace changes in buildings and neighbourhoods over time, documented in photographs. The 3D models and photos are also connected with text sources.

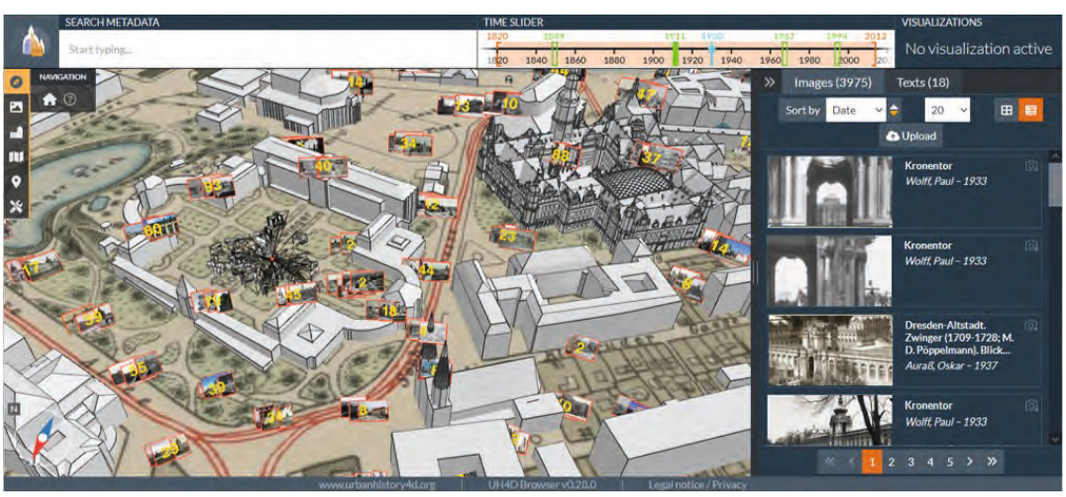
AI identifies the precise camera position

Data is constantly being added to the »4D Browser«, with new images automatically located and visual content linked with texts. In the past, photos were primarily selected and allocated to certain buildings using metadata. However, as this metadata is often inaccurate or incomplete, the researchers have now turned to a range of AI tools and are analysing similarities between images with the help of ML models. In order to locate a photograph at the exact location it was taken, the team apply neural networks that use feature identification and matching processes. Computer vision techniques help to fine-tune the positioning, drawing on AI-based edge detection and feature matching.

The researchers also apply AI technologies to connect a variety of image, text and 3D data and also to process text data. This includes automatically annotating the names of people and places in text sources as well as semantic text annotations based on similarities between words. The annotations in image, text and 3D data are analysed and compared in a graph database to establish links between similar content. The tool can also automatically generate suitable captions for these photographs. Although this is a rule-based process at present, it is set to be refined with AI in the future.

Limited data sets restrict the AI's performance

»None of the AI technologies we use are new or developed specifically for this project,« emphasizes Münster. »Instead, we adapt existing approaches and combine them with other techniques to achieve higher accuracy and reliability.« However, as Münster explains, working with historical sources presents a whole host of challenges. For example, the historical photos are digital copies that do not usually contain any information about the parameters of the camera. This limits the researchers' ability to draw on technologies that require such information to reconstruct the camera position in photos.
There is also one fundamental problem with regard to the use of AI in the historical sciences that has yet to be solved: the amount of historical data available to train AI models is rather small, which limits the models' capabilities. This is particularly evident with regard to architecture. While AI models are already proficient in the automatic identification of roofs and windows, they do not yet have the ability to identify other elements of a building's façade—such as pilaster or architraves. US



Interface of the »4D Browser« web application. Historical photographs are precisely located in a 3D urban model. The section shown here depicts the Old Town of Dresden, complete with the Zwinger complex and the Royal Palace. The project team includes researchers from the University of Jena, the University of Würzburg, Bielefeld University, LMU Munich and Cologne University of Applied Sciences.

Surgery to remove a head-neck tumour. At present, surgeons determine the tumour resection margins using pre-operative information on the tumour and white light imaging produced using microscopic or endoscopic techniques (as shown here). However, this approach is imprecise and is set to change with the development of sensorized surgery. · Photo: Orlando Guntinas-Lichius

Ultra-sensitive surgical robots

An interdisciplinary research team at the University of Jena and Jena University Hospital is working with other project partners to develop a sensor-based support system for tumour surgery. Launched in 2023, the »Sensorized Surgery« project is supported by the Carl Zeiss Foundation through its »Breakthroughs« funding programme. It aims to develop a system that assists surgeons with tumour removal by providing real-time visual and haptic feedback during the operation. In addition to teams from the fields of computer science and medicine, the project also includes researchers from the Leibniz Institute of Photonic Technology and TU Ilmenau.

Removing the tumour completely and conserving healthy tissue

Malignant tumours are often life-threatening and are therefore surgically removed where possible. »This involves removing all of the tumour tissue while conserving the healthy tissue surrounding it,« says Prof. Dr Orlando Guntinas-Lichius of the ENT department at Jena University Hospital, who is also coordinator of the project team. Surgeons need to identify the margin between the tumour and the healthy tissue and make precise incisions accordingly. To date, surgeons have used techniques such as white light video endoscopy before ultimately deciding where to make incisions based on their experience.

»In up to 30% of cases, however, this approach fails to remove the tumour completely, which significantly reduces the patient's chance of survival,« as Guntinas-Lichius states. Despite the fact that surgical robots can now work with increasing levels of precision, it is not possible to reduce this percentage without higher resolution and clearer views of the tissue margins.

This is exactly what the interdisciplinary team has set out to achieve by developing complex, sensorized surgical methods. Using novel biophotonic imaging technology and biomechanical sensors, the researchers hope to provide high-resolution, real-time outlines of the tumour margins during the operation, with haptic feedback so that surgeons can not only see the tumour but »feel« it, too.

AI plays a central role in this endeavour. It is based on data from histopathological examinations of head-neck and brain tumours, both from Jena University Hospital and later from a trans-regional network of hospitals. This data has been used to train several decentralized machine learning models. Histopathology is the term given to the examination of tissue samples, often collected through biopsies, which serves to diagnose malignant changes in cells and tissues.

The local ML models used at individual hospitals are to facilitate the creation of a shared, central ML model while ensuring that critical requirements, such as data security, are met—because sensitive patient data never leaves the treating hospital. »The global model will be continuously updated with data from local models and automatically determine stable characteristics, i.e. the causal characteristics for the task,« adds Guntinas-Lichius. Causal characteristics include specific molecular properties of tumours, which can be biophotonically detected. The global model is then made available to the local models and adapted to each specific environment. The researchers hope that, by the end of the project, they will have established a continuous federal learning system capable of reliably identifying the margins of any given tumour. US

Life-saving diagnostics

The research group for Applied Systems Biology led by Prof. Dr Marc Thilo Figge applies AI methods in their biomedical research. Based at the Institute of Microbiology and the Leibniz Institute for Natural Product Research and Infection Biology (Leibniz-HKI), the team hopes that this will enable them to identify infection processes caused by human-pathogenic fungi faster and more precisely.

Fungal infections pose a potentially life-threatening risk, especially for people with a weakened immune system. Most of these infections are caused by mould-like fungi such as *Aspergillus fumigatus* and yeast fungi such as *Candida albicans*. These microorganisms are practically ubiquitous in the world around us and also appear in the human body. A properly functioning immune system keeps their growth at bay, meaning that the human body generally keeps these fungi well in check. However, if a person's immune defences are weakened, perhaps due to an illness or because they take immunosuppressants, the pathogens can spread and trigger life-threatening sepsis.

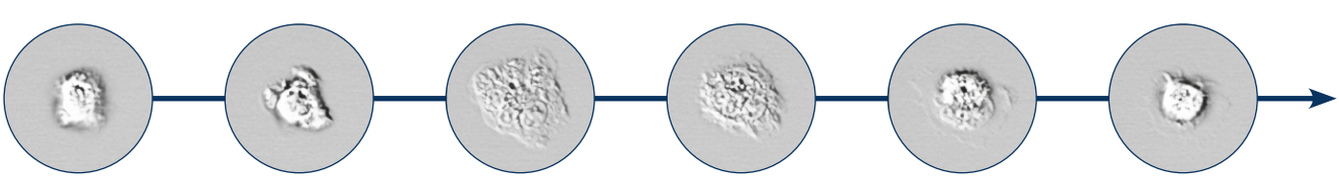
Prof. Figge explains the problem to date: »Diagnosing blood infections, such as those caused by fungi within the *Candida* genus, is a difficult and protracted process, which reduces the patients' treatment options and, ultimately, their chance of survival.« When it comes to invasive fungal infections, he says, precise—and, above all, swift—diagnosis can quite literally save lives.

This is where AI methods come in. Researchers are applying artificial neural networks to analyse both microscopic images and video data of whole blood samples. Although it is not possible to directly observe the pathogens, which occur in low numbers in the patients' blood, it is possible to detect their interactions with blood cells, which appear in high numbers. Neutrophils, for example, form part of the body's immune system and can be isolated from the whole blood. They demonstrate a characteristic, dynamic change in their outer form following contact with fungal pathogens. »This changing appearance over time, which we call the morphodynamics of neutrophils, is an indicator of infection,« explains Figge. Analyses that have been conducted to date by conventional means—that is, with the human eye—can now be carried out with the assistance of AI tools. Figge says that whole blood samples with no pathogens present can be distinguished from those with pathogens with 100% accuracy. But that's not all: »The AI can even reliably distinguish between two closely related fungal pathogens, such as *Candida albicans* and *Candida glabrata*.« Not only does the technology work more quickly than a human, it also delivers more precise results.

The team deploys different types of neural networks, using convolutional neural networks (CNNs) to analyse individual microscopic images and transformer neural networks to examine video data. Both models are trained using neutrophils isolated from whole blood.

»Inherently opaque black boxes«

Despite the considerable successes in applying AI methods in this area to date, Prof. Figge and his research team also look critically at artificial neural networks and their growing use. »The fact that these tools are inherently opaque black boxes leaves behind an unsatisfying aftertaste,« he says. Any insights into the characteristics upon which the decision-making processes in artificial neural networks are based remain concealed. »This lack of transparency is cause for concern, especially in critical biomedical research applications where AI-based decisions in diagnostic settings influence the treatment people receive.« In the future, Figge argues, researchers must devote greater attention to developing methods that enable us to interpret AI methods more effectively. This means finding a balance between the complexity of advanced algorithms and the need for transparency and accountability in decision-making processes. US



The morphodynamics of a neutrophil following infection with *Candida* in whole blood. These cells demonstrate dynamic changes in their morphology following contact with *Candida* pathogens. There are characteristic morphodynamic differences for different fungi, such as *Candida albicans* and *Candida glabrata* which can be used to differentiate the pathogens of a blood infection by means of AI. These images show the morphological change of the same neutrophil at different points in a two-minute period (series runs from left to right). · Figure: Team Figge

The assyriologist Dr Adrian Heinrich presents a clay tablet with cuneiform text from the Hilprecht Collection at the University of Jena (»Frau Professor Hilprecht Collection of Babylonian Antiquities«). · Photo: Anne Günther

Decrypting cuneiform with AI

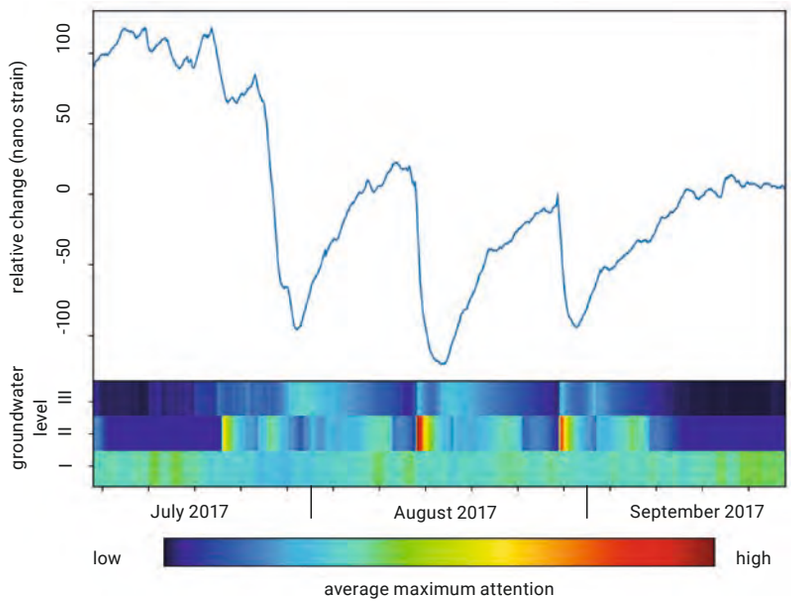
Cuneiform tablets are the oldest surviving written records of humanity. As early as 4,000 years ago, literate people would score characters in soft clay. Some surviving texts are domestic notices, others pertain to commerce, and some are liturgical and poetic texts. The most famous include the Epic of Gilgamesh and the Code of Hammurabi. These texts were produced in Mesopotamia, a region between the Euphrates and the Tigris. Many of the clay tablets are only the size of a bank card—and yet, they have endured for centuries. Even the destructive force of fire has not damaged them. Quite the opposite, in fact: when fired, clay becomes even more durable.

For a number of reasons, unravelling the mysteries of these cuneiform tablets is painstaking work. For one thing, there is the sheer quantity of these artefacts, with roughly half a million cuneiform objects around the world, according to Dr Adrian Heinrich. The 35-year-old assyriologist is an assistant to Prof. Dr Johannes Hackl at the Institute of Near Eastern Studies, Indo-European Studies and the Archaeology of Prehistory to the Early Middle Ages. The duo is examining the Hilprecht Collection together with its curator, Marie Young. This Jena-based collection comprises around 3,300 artefacts, making it the second-largest in Germany.

A further difficulty is the fact that collections are scattered around the world, which means that artefacts that originally belonged together are often sitting in display cabinets vast distances apart. There are also many broken pieces containing just a handful of cuneiform characters. The third challenge is the limited number of specialists in the field of Ancient Near Eastern studies. Despite this, researchers have been able to decipher cuneiform texts character by character since the mid-19th century. As Adrian Heinrich explains, artificial intelligence (AI) could significantly accelerate the entire process. The team in Jena is a cooperation partner on the Electronic Babylonian Library project initiated by Munich-based assyriologist Prof. Dr Enrique Jiménez, which aims to train an artificial intelligence to read and translate cuneiform texts. Precise scans that create three-dimensional images of artefacts are fundamental to this work. »We want to bring the perspectives of researchers and collection curators together,« says Heinrich. This would involve digital platforms making cuneiform texts accessible to everyone. The digital copies would also be available to scientists around the world.

Decrypting and reassembling tablet fragments

The first step, however, is to train the AI to read these texts. Hackl's predecessor, Prof. Manfred Krebernik, began to digitalize cuneiform tablets in cooperation with the Max Planck Institute for the History of Science. Further digital copies are now being produced in cooperation with the Thuringian University and State Library. It is vital to ensure that the tablets are legible from all sides. »Each character can have several meanings, which creates different levels of text,« says Dr Heinrich. This has to be taken into consideration when »feeding« the AI with data. At present, the AI models are still working on machine translation of training data. Existing translations are also input into the models, with some drawn from the estates of past researchers. As Prof. Hackl explains, an AI similar to one established in the field of genetic research is used for this. »The model searches for certain patterns.« The system learns to link pictorial elements with content. The researchers hope this will enable them to answer even complex search queries regarding entire corpora of text. This approach has already yielded results. According to Heinrich, the accuracy rate »is currently between 80% and 90%«. Yet, the application of AI promises to deliver another benefit: it will enable researchers to decrypt and reassemble small tablet fragments. This would represent a major step forward for scientific research. sl



The graph in the upper part of the figure shows the change in deformation (»strain«) of the earth's surface over the period from July to September 2017 at the site of the Geodynamic Observatory in Moxa.

The lower part of the figure shows changes in the groundwater levels of three different measuring points (I-III) based on the »attention values« of the artificial neural networks used. The colour gradients indicate different contributions of the water levels to the deformation changes, from blue (low) to red (high). This allows conclusions to be drawn about the influence of groundwater levels on the movements of the earth's crust near the surface.

Figure: Valentin Kasburg

A finger on the Earth's pulse

For the last 60 years, researchers have been taking the Earth's pulse in the Thuringian Slate Mountains. At the University of Jena's Geodynamic Observatory, around an hour's drive south of Jena close to the hamlet of Moxa—population 80—ultra-sensitive measurement systems collect data about our planet's natural signals. The Earth's »heartbeat« is sedate; these signals can generally only be filtered out of recordings spanning years or even decades. »In order to draw conclusions about the processes at work deep within the Earth, we need very long and precise data series,« says Prof. Dr Nina Kukowski, to whose Chair of Geophysics the Geodynamic Observatory is connected.

In addition to conventional instruments such as a superconducting gravimeter to register the Earth's gravity field, Moxa observatory houses several other very sophisticated measurement systems. The University of Jena is one of only a handful of institutions around the world to operate an array of three laser strain meters, which are installed in underground tunnels and record the deformation of the Earth's surface, sensitive to changes on the nanometre scale. The observatory's repertoire also includes tiltmeters as well as a nearly 100 m deep borehole, which contains an optical fibre provided by the Thuringian State Office for the Environment, Mining and Nature Conservation to measure the temperature of the Earth's interior. In addition, the observatory records weather data every 10 seconds. Given the combination of different sensors, the datasets generated at Moxa observatory are not only extensive but also highly heterogeneous, as Kukowski explains: »Deciphering natural signals within this data is a complex task. It would require a lot of work by a lot of people.«

In an effort to accelerate this process—and make some analyses possible in the first place—for several years, the researchers have been working with AI methods, especially machine learning. »We apply AI in two different approaches,« explains Valentin Kasburg, a doctoral candidate in Kukowski's team. On the one hand, the researchers use AI to identify anomalies in the long-term data, such as measurement errors and natural signals, and filter them out of the time series. On the other hand, AI techniques are applied to analyse the causes of signals identified in the data and thereby gain a better understanding of the processes at work in the subsurface.

Prof. Kukowski and computer scientists Prof. Dr Alexander Breuer and Prof. Dr Martin Bücker are therefore working with their team to apply artificial neural networks (ANNs) as part of a project supported by the Carl Zeiss Foundation. These ANNs are trained with different sets of long-term geodynamic data collected at Moxa observatory. Researchers can then apply the trained models to different data series and tackle specific questions.

AI distinguishes between earthquake signals and quarry blasting

In an ongoing study, the team has successfully analysed data from different seismic networks and distinguished between tectonic earthquake signals and anthropogenically induced signals, such as quarry blasts. In other studies, Valentin Kasburg explains, the team is working to identify causal relationships between different signals in the time series and distinguish them from mere correlations. »We look at weather data, precipitation events and seasonal effects in conjunction with geophysical data, trying to discover whether we can discern properties of the subsurface and how it behaves.« In this context, the team is particularly interested in groundwater. »We're hoping to identify factors and processes influencing groundwater movements, how it is changing, e.g. as a result of climate change, and how this is mirrored in our time series,« summarizes Nina Kukowski. US

Using GPT-3 for chemical research

GPT-3, the language model behind the renowned AI-based tool ChatGPT, can also be used in the field of chemistry to perform a range of research tasks. Its application has been demonstrated by researchers from the École polytechnique fédérale de Lausanne (EPFL), the University of Jena and the Helmholtz Institute for Polymers in Energy Applications (HIPOLE) Jena. As the team reported in a recent article in »Nature Machine Intelligence«, they have successfully circumvented a common problem in chemistry: the lack of high volumes of data needed to train AI.

Curated Q&As replace vast pools of data

»One of the various examples we used was so-called photosensitive switches,« explains Kevin Jablonka, lead author of the article. »These are molecules that change their structure when exposed to light of a certain wavelength. They also occur in the human body: our retinal cells contain a molecule called rhodopsin, which reacts to light and thus ultimately serves as the chemical switch that converts optical signals into nerve impulses,« he adds. »The question of whether and how a hitherto unknown molecule can be switched by light is highly relevant, for instance when it comes to developing sensors, « he summarizes. »But we've also incorporated the question of whether a molecule can be dissolved in water, « Jablonka mentions another example. »Solubility in water is an important factor for pharmacological agents to exert their desired effect in the body.«
In order to train their GPT model to tackle these and other questions, however, the research group had to resolve a fundamental problem: »GPT-3 is not familiar with the vast majority of specialist chemical literature,« explains Jablonka. »As a result, the answers we can generate from this model are usually limited to what's available on Wikipedia.«
With this in mind, the research group adopted a more targeted approach, enhancing GPT-3 with a comparatively small dataset of questions and answers. »We fed the model with questions—for example, about photosensitive switchable molecules, but also regarding the water solubility of certain molecules and other chemical aspects—and completed its training by providing the known answer to each question,« explains Jablonka. Proceeding in this way, he and his team created a language model capable of providing accurate insights into a variety of chemical queries.
Finally, they began to test the model. »The scientific question about a light-switchable molecule might look like this: What is the pi–pi* transition of CN1C(/N=N/ C2=CC=CC=C2)=C(C) C=C1C?« Jablonka says. He explains that, because the model is text-based, structural formulae cannot be used as inputs. »However, our GPT is able to handle so-called SMILES codes for molecules, like in this example.«. The tool is also capable of processing other notation methods, including chemical names following IUPAC nomenclature.

As easy as a literature search

During the testing phase, the model solved all manner of chemical problems. In many cases, it actually fared better than similar models developed to date by researchers using vast quantities of data. »The decisive factor, however, is that our GPT is as easy to use as a literature search function and works for an array of chemical problems—from substance properties such as solubility to thermodynamic and photochemical properties such as solution enthalpy and interaction with light and, of course, chemical reactivity,« adds Prof. Dr Berend Smit of EPFL Lausanne. MK

ILLUSTRATION: MIDJOURNEY

Digital building blocks for administration

The path to the digital state is a long and rocky one—as several federal administrations have discovered in pursuit of ambitious targets to digitalize their administrative activities. A working group at Friedrich Schiller University is now working to create reliable, long-term structures for digital administration, including by integrating artificial intelligence.

BY SEBASTIAN HOLLSTEIN

Marianne Mauch heads the »Open Design of Digital Administrative Architectures« working group at the University of Jena and coordinates several projects on the digitalization of administrative processes—making thick paper files a thing of the past. · Photo: Anne Günther

The purpose of digitalizing public administration is to create straightforward, efficient processes for everyone involved. Citizens should be able to apply for a new passport or register a change in their residential address from the comfort of their own home; public authorities should be able to digitally process incoming data without the need to shuffle through printed forms. This requires systems that are easy for both parties to understand and offer long-term functionality. In the course of three projects, computer scientists at the University of Jena are striving to create these long-term structures in collaboration with colleagues from the municipal administration Jena, the Institute for Data Science at the German Aerospace Center (DLR) in Jena, Bielefeld University, the Thuringian Ministry of Finance and other partners from the worlds of research and business.

»We want to map out the entire pathway from the legislation to the digitalized service and make it usable,« says Marianne Mauch, Head of the Working Group on Open Design of Digital Administration Architectures. »The starting point in any new regulation is the legislative text.« A project entitled »Computer-assisted analysis of electronically available legal norms« (or »Canarėno« for short) has computer science and computer linguistics experts developing a system that automatically reads and attributes all key information in a text. The aim of the project is to deploy AI trained with corresponding data to independently examine a legislative text and identify which key actor—in most cases, a public authority—provides the administrative service in question, who is eligible for this service and what they must do to access it. The categorization of terms in legal standards is based on the Federal Information Management (Föderales Informationsmanagement, FIM) System, a project pursued by the German federal and state governments to standardize administrative services nationwide.

»We thereby hope to automatically select all the data fields that a digital application form requires and which documents must be submitted,« explains Marianne Mauch. »In this way, public authorities can make new administrative services available more swiftly, respond more flexibly to amendments to existing legal norms, and draft and adapt both forms and information materials. This will save time and money.«

If such systems are to be straightforward to implement and use, it is vital that the underlying technologies are easy to handle. With this in mind, the team on another Jena-based project—»simpLEX: Making it easier to create and use digital application forms and processing procedures«—is concentrating on describing digital processing pathways as simply and

Instead of stacks of dusty files, efficient digital processes—this is the goal that computer scientists are pursuing together with partners from research and industry. · Illustration: Midjourney

permanently as possible, from the legislative text to the final service. In their efforts to develop a proposal for a reference architecture, the computer scientists have turned to no-code and low-code platforms which facilitate programming by way of visual diagrams in a form of modular system.
»This means that administration professionals can concentrate on legal procedures and official processes without having to master programming in order to make changes to digitalized systems,« explains Mauch. The researchers also rely on open-structured systems based on open-source applications and are integrating open standards and knowledge in such a way that machines can interpret it. Small enterprises and start-ups can therefore use the results for their own activities, which prevents public institutions from becoming dependent on individual providers for their digital administration structures. Together with the municipal administration in Jena and betterlaw Knowledge Tools Automation GmbH, the experts involved in the project are already building and testing a prototype administrative process for a specific social benefit case. However, before the system used as the basis for research into long-lasting, intelligent services is ready for long-term deployment and expansion into other areas, there are further questions to answer—such as how it can be integrated into existing systems.

Science and administration interlock with each other

In an effort to underpin this system and others like it with a foundation of basic knowledge, the team in Jena is working in parallel on a digital dictionary for public administration. »We hope to establish a nationwide platform that makes information accessible at all times and can be integrated into a number of systems,« explains Mauch. The data is stored in the form of knowledge graphs—a model that not only establishes a clear definition for each aspect, but also maps out the relationships between them in a way that enables machines to interpret them and draw conclusions. This makes it possible to swiftly identify different authorities' responsibilities for a given administrative act. »It is exactly these treasure troves of data that serve as the basis for AI,« emphasizes Mauch.
In this context, the projects verge on cutting-edge research, which explains why the working group is connected to the Heinz Nixdorf Chair currently held by Prof. König-Ries and the Competence Center Digital Research (zedif) at the University of Jena. Dr Frank Löffler, who heads zedif, notes the close collaboration between the fields of science and administration: »Thanks to intensive cooperation between administration specialists across Germany and Europe, the platform we're developing will not only serve research purposes but above all create an open, transparent source of knowledge about administrative authorities and their internal procedures and interfaces.« As Marianne Mauch adds: »A foundation of reliable knowledge is essential, especially in public administration.« This would certainly serve to benefit future development activities. ■

»We want to facilitate the use of AI«

Generative AI tools are conquering many areas of society at present. Yet, while the use of machine learning techniques in extensive artificial neural networks promises to bring about scientific advances, it also presents challenges for university researchers and teaching staff. In this interview, Prof. Dr Christoph Steinbeck outlines the position the University of Jena has adopted on this issue and explains how its researchers are contributing to the development of AI approaches through the German National Research Data Infrastructure (Nationale Forschungsdateninfrastruktur—NFDI).

INTERVIEW: UTE SCHÖNFELDER

The University of Jena has been pursuing a digitalization strategy for some time now. What role does AI play in this?
A comprehensive digital transformation is underway at our University. We are approaching this process through three sub-strategies focusing on digitalization in studies and teaching, in research and library, and in administration and infrastructure.
In all three areas, this includes engaging with AI applications. This ranges from developments in research data management and infrastructure to the use of AI tools in teaching and studying to AI applications in administrative settings, where they can help our staff to respond to queries and provide information swiftly and efficiently.

How is AI changing the work of scientists?
AI is undoubtedly one of the »disruptive« technologies changing our society—not just the world of science. Of course, the term »AI« is itself in a state of flux. AI has been a topic in the context of research for several decades and is now in widespread use, such as through machine learning applications. Even in the 1990s, researchers were able to use algorithms to train small neural networks to solve very specific problems. For some years now, we have been able to use extremely large artificial neural networks—including large language models like ChatGPT, which so many people are excited about.
That said, AI also poses challenges for us in research, as machine learning tools are only as good as the data used to train them. Training data of sufficient quantity is not yet available for all areas of research. However, realizing the potential of big data analysis involves training algorithms with huge quantities of data. If this isn't possible, the trained tools often deliver results that only appear reasonable. We primarily see major scientific breakthroughs with AI in fields where large volumes of data are available.

The German National Research Data Infrastructure (NFDI) aims to build precisely these data pools. To what extent are researchers from the University of Jena involved in this project?
The NFDI is funded and structured by the German Research Foundation (Deutsche Forschungsgemeinschaft – DFG). Its purpose is to systematically connect and open up all databases from the fields of academia and research for the entire German science system. It brings together and networks data that has only been available to date on a decentralized, project-specific or temporary basis, thereby making it accessible on an ongoing basis and for all manner of research topics. There are now 26 different NFDI consortia nationwide, each focusing on a different field of research. Researchers from the University of Jena are involved in a number of these consortia, including in the fields of biodiversity, geosciences, microbiology and history, along with my field, chemistry. Together with my colleague Oliver Koepler from the Leibniz Information Centre for Science and Technology in Hanover, I am leading the NFDI4Chem consortium.

Do you use AI in your own research?
Yes. Even in the 1990s, my team and I used machine learning to predict nuclear resonance spectra from chemical structures. These methods make it possible to determine the structures of previously unknown substances. However, we only had a limited amount of data available to train the algorithms, which remains the case to this day. Extensive pools of data simply do not exist in this area. If nothing else, that's what we're hoping the NFDI will achieve.

The Vice-President for Digitalization of the University of Jena, Prof. Dr Christoph Steinbeck (centre left), here together with Prof. Dr Georg Pohnert (right), Interim President of the University and Vice-President for Research, during a tour of the Federal Government's »Digital Summit« on 21 November 2023 in the campus building. · Photo: Jens Meyer

We are currently really enjoying our work in which we are using deep learning to automatically translate chemical structural formulae from specialist publications into machine-readable code. In this way, we're uncovering »old knowledge« in past publications and making it available to the world of science in open databases (see p. 34).

Nowadays, AI has a role to play not only in research but also in teaching. In 2023, the »AI in Teaching« task force was established at our University. Who are its members?

It was an initiative led by the Academy for Teaching Development (Akademie für Lehrentwicklung—ALe) when it became clear that we would need to formulate recommendations for handling generative AI tools, which are increasingly used by teaching staff and by students. The task force comprises members of the ALe as well as representatives of faculties, students, the Vice-President for Learning and Teaching, the Service Centre for Higher Education Didactics (LehreLernen), the Michael Stifel Center, the Multimedia Centre, the Legal Office and the Student Affairs Division. As Vice-President for Digitalization, I chair the task force.

What topics does the task force deal with?

Very generally, we consider how AI tools such as ChatGPT and Dall-E can be used in teaching and learning, and how we can anchor knowledge of these applications in our curricula. In addition, we primarily focus on very specific issues. Our first topic, for example, was modifying the declaration of independent work our students routinely submit together with their theses. In this declaration, students confirm that they have completed their thesis independently and only drawn on permitted tools and resources. Given the emergence of various AI tools, we had to reflect on how to proceed.

What general regulation does the University's management consider necessary in relation to AI applications in teaching?

As the University's management, we resolved to regulate the use of AI as little as possible and adopt a positive, enabling position. Rather than creating restrictive policies, our aim is to support lecturers and students in the application of these tools.

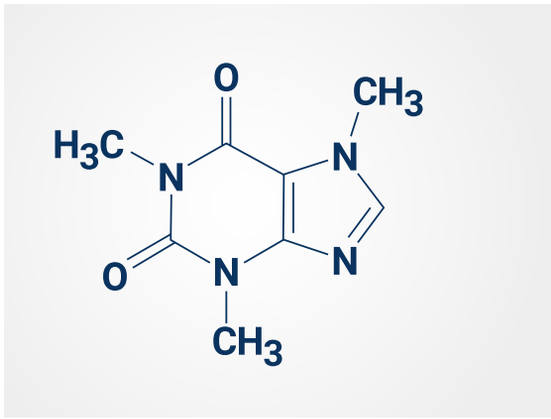
This also means that teaching staff can decide for themselves the extent to which they wish to allow their students to use AI tools in writing their theses. In the »AI in Teaching« task force, we have developed an interactive form that enables lecturers to create a suitable framework of rules and adapt the student declaration accordingly. The consequence is, of course, that we continue to punish cheating and attempts to cheat. ■

From game boards to chemical AI tools

A research team led by chemist Prof. Dr Christoph Steinbeck has developed a platform that uses artificial neural networks to translate chemical structural formulae into machine-readable form. With the platform »DECIMER.ai«, they have created a tool with which this information from scientific publications can be automatically fed into databases. Until now, this had to be done literally by hand and was time-consuming.

BY UTE SCHÖNFELDER

Structural formulae show how chemical compounds are constructed, i.e. which atoms they consist of, how these are arranged spatially and how they are connected.
Chemists can deduce from a structural formula, among other things, which molecules can react with each other and which cannot, how complex compounds can be synthesized or which natural substances could have a therapeutic effect because they fit together with target molecules in cells.
Developed in the 19th century, the representation of molecules as structural formulae has stood the test of time and is still used in every chemistry textbook. But what makes the chemical world intuitively comprehensible for humans is just a collection of black and white pixels for software. »To make the information from structural formulae usable in databases that can be searched automatically, they have to be translated into a machine-readable code,« explains Christoph Steinbeck, Professor for Analytical Chemistry, Cheminformatics and Chemometrics at the University of Jena.
And that is precisely what can be done using the artificial intelligence tool »DECIMER«, developed by the team led by Prof. Steinbeck and his colleague Prof. Achim Zielesny from the Westphalian University of Applied Sciences in Recklinghausen. DECIMER stands for »Deep Learning for Chemical Image Recognition«. It is an open-source platform that is freely available to everyone on the Internet and can be used in a standard web browser. Scientific articles containing chemical structural formulae can be uploaded there simply by dragging and dropping, and the AI tool will immediately get to work.



Picture right:
Chemical structural formula of caffeine.

Picture left: The idea of using AI to recognize chemical images came to the two researchers Christoph Steinbeck (left) and Achim Zielesny (right) in 2016, when the AI »Alpha-Go« defeated the world's best human Go player at that time.
· Photo: Anne Günther

»First, the entire document is searched for images,« explains Steinbeck. The algorithm then identifies the image information contained and classifies it according to whether it is a chemical structural formula or some other image. Finally, the structural formulae recognized are translated into the chemical structure code or displayed in a structure editor, so that they can be further processed. »This step is the core of the project and the real achievement,« adds Steinbeck.

A formula becomes a code

In this way, the chemical structural formula for the caffeine molecule (pictured) becomes the machine-readable structure code CN1C=NC2=C1C(=O)N(C(=O)N2C)C. This can then be uploaded directly into a database and linked to further information on the molecule.
To develop DECIMER, the researchers used modern AI methods that have only recently become established and are also used, for example, in the large language models (see p. 16) that are currently the subject of much discussion. To train its AI tool, the team generated structural formulae from the existing machine-readable databases and used them as training data—some 450 million structural formulae to date. In addition to researchers, companies are also already using the AI tool, for example to transfer structural formulae from patent specifications into databases.
Steinbeck and Zielesny came up with the idea of developing an AI tool for decoding chemical images a few years ago. The two chemists were interested in the development of AI methods in connection with the millennia-old Asian board game Go. In 2016, together with millions of people around the world, they watched the spectacular tournament between the best Go player at the time, the South Korean Lee Sedol, and the computer software »AlphaGo«, which the machine won 4:1.
»It was a bolt from the blue that showed us how powerful AI can be,« Steinbeck recalls. Until then, it had been considered practically unthinkable that an algorithm could rival human creativity and intuition in this game. »When, a little later, an AI tool developed quasi-superhuman playing strength by not being trained laboriously through countless sessions of human games—as was still the case with AlphaGo—but simply through the process of the system playing against itself again and again, and optimizing its playing style as it did so, we realized that these new methods could also solve other very complex problems with enough training data. We wanted to use that for our research area.«

Making scientific information sustainably usable

With DECIMER, Steinbeck and his team hope at some point to be able to machine-read all chemical literature of interest to them, going back to the 1950s, and translate it into open databases. After all, a key concern for Steinbeck, also the coordinator of the National Research Data Infrastructure for Chemistry in Germany, is to sustainably secure existing knowledge and make it available to the global scientific community.

The DECIMER AI tool is available under: https://decimer.ai. ■

Original publication:
DECIMER.ai: an open platform for automated optical chemical structure identification [...]. Nat Commun 14, 5045 (2023). https://doi.org/10.1038/s41467-023-40782-0

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How AI is transforming communication

Communication scientist Prof. Dr Edda Humprecht uses machine learning to analyse social media posts, which AI tools are now also capable of producing. In this interview, she explains the impact of AI on journalistic reporting, how users engage with AI-generated social media content, and the potential impact of AI-produced information.

INTERVIEW: IRENA WALINDA

Where do we encounter artificial intelligence in our communication processes?
Artificial intelligence is ubiquitous in communications: algorithms offer recommendations when shopping online and streaming music; news sites suggest articles that might interest us. Beyond that, there are translation services like DeepL and Google Translate, as well as chatbots, which companies deploy in customer support to solve problems and improve customer service.

How do you apply AI in your research and teaching?
AI plays an important role in research. We work with machine learning. AI helps us to understand the content of digital communication and we train algorithms with manually coded data. However, artificial intelligence is the subject of research because we are interested in how the use of AI affects journalism and news use, and how AI should be regulated. I use ChatGPT to write letters of recommendation, which students can use in applications. I prompt ChatGPT to produce a draft and then edit it. It lightens my workload and speeds processes up.

Do news desks and media organizations harness AI?
AI is already a vast topic in journalism and news production. A lot of editorial teams are experimenting with it. They are trying to work more efficiently, generate images with Midjourney and Stable Diffusion, or produce simple articles like stock market reports and recipes. So far, these have only been trials, but many newsrooms are working on it.

What are the impacts of the deployment of AI-based technologies?
Communication is changing—but that has always been the case. Generative AI systems (see p. 16) such as ChatGPT can provide significant advantages. They can assist in or take over certain tasks, accelerating processes and allowing journalists more time to focus on investigative research, for example. Additionally, machine learning and deep learning tools are used in journalism to analyse large amounts of data. For instance, in the case of leaks, research networks use these tools to decipher vast amounts of data.

Does the use of AI in journalism also present risks?
There are risks, of course, regarding misinformation and deepfakes, i.e. manipulated videos, audio and images generated using AI tools to put information in a false context. This can lead to users developing a general scepticism towards online content. Although it is positive if people don't believe everything they see, it can also lead to a general loss of trust in online media. Some people then adopt the mindset that everything is relative, or perhaps nothing is true anymore; they feel a sense of powerlessness. We have been seeing that in our research even before the use of AI in communications. Users are intentionally turning away and no longer want to read or watch the news. This is more prevalent during times of crisis, such as during the pandemic. It is associated with being overloaded to a certain degree with all the negative information we are exposed to. This trend could be further exacerbated if deepfakes become more widespread.

What new skills do people need to learn in dealing with AI?
People need to be able to examine AI output because, time and again, we can see that this output is flawed. The accuracy of AI translations is questionable, and there may be issues with images, text, and other content.
We can currently observe this conflict in the Middle East with great clarity. AI-generated images are being disseminated, with incorrect information being spread or interpreted in the wrong context. There is the example of an image showing a young boy in Gaza, looking towards the camera in search of help. If you examine the image closely, you can notice several discrepancies: some of the shadows do not look right, the Palestinian flag is not accurately printed on the t-shirt,

Edda Humprecht is Professor of Digital Communication and the Public Sphere. Her research covers topics including how disinformation on social media is changing society. · Photo: Jens Meyer

and he has six fingers on one hand. This example clearly shows how important it is for informed people to correct this kind of disinformation.

What can journalists do?

The work of journalists who conduct research, analyse and report on issues, particularly from crisis zones that we only learn about through media, is more significant now than ever. It would be highly risky to publish unverified AI-generated information, as it would lead to even more inaccurate information spreading. Therefore, news desks that focus on fact-checking are essential. Our research indicates that correcting misinformation has a definite impact.

Are there any control mechanisms or models to highlight AI-generated content and expose manipulation?

It can be challenging to detect manipulated images since the technologies used for manipulation are advancing rapidly.

One way to safeguard copyrights is by incorporating digital watermarks, especially when AI-generated images are reused. It is essential to recognize that the attempts at manipulation are made by humans rather than AI tools. Therefore, humans are accountable for the manipulation. At the same time, humans are the only ones capable of interpreting an image and identifying whether it was misused or published in an inappropriate context.

Don't politicians have a responsibility to act?

The European Union's AI Act proposes a series of regulations. These rules will be extremely important—including for us as researchers, because access to data is a huge problem. Big tech companies like Microsoft and Meta lack transparency in their operations, making it difficult for us to understand how certain algorithms work or what data is used to train them. Additionally, we often face difficulties in obtaining the social media platform data we require for analysis. These regulations in the AI Act not only safeguard users from potential manipulation but also provide us with access to data required for scientific research. ■

Who owns AI-generated works?

From the Pope in a thick puffer jacket to Vladimir Putin kneeling before the Chinese President, AI-generated disinformation is advancing to a whole new level. Yet, these forged images—which often go unrecognized to begin with—are far from the only AI-related challenge we face. Instead, the rise of AI technologies raises questions in various areas, including in relation to intellectual property. For instance: Who do the images generated using AI-based programmes actually »belong« to?

BY LAURA WEISSERT

Prof. Dr Volker Michael Jänich holds the Gerd Bucerius Chair of Civil Law and German and International Intellectual Property Law at the University of Jena. As he explains, AI brings new levels of nuance to his work on intellectual property law: »It has forced us to resharpen our previous research questions and reflect on why exactly we are protecting something.«
Intellectual property can include text and images that are protected by copyright as well as inventions and brands subject to patent law and trademark law. »These are human, intellectual creations that we consider worthy of protection,« explains Jänich. Copyrights, patent rights and design rights are all exclusive rights. This means that exploitation rights lie solely with the author, artist, inventor or designer. For a work to be eligible for copyright protection, it must demonstrate a minimum degree of individuality or originality. Or, to put it another way, the work must express the personality of its author or artist. Whether an artist uses tools and aids like Photoshop to create their work is beside the point. But does the same apply to AI?

Can AI be a creator in a legal sense?

Let's consider an example: Viktoria Schrön, a research associate at Jänich's Chair, uses a software called DeepDream to generate images. She wants to create »an image of two cats meeting on another planet« and specifies »digital art« as the style. Based on this original prompt, DeepDream uses an artificial neural network to generate an image (see right). »I didn't like the first attempt, so I refined the prompt and made adjustments time and again until I was happy with the result.«
So, are these space-faring cats generated by DeepDream eligible for copyright protection? »Do I receive the copyright in my role as the user of the AI tool? Or do I only get it if I also programmed the AI myself? Does the copyright go to the AI or to nobody?« asks Schrön.
The first thing to remember is that an AI cannot be a creator or an inventor because, in copyright law and patent law, these terms refer to people—for the time being, at least.
That leaves two options: either the image is not eligible for legal protection at all, or it is eligible for legal protection by the person who contributed to its creation. »The question here is whether the creative decisions that I made in advance by giving the AI a prompt are sufficient to justify eligibility for legal protection,« says Schrön. As it stands, academics are yet to reach a consensus on this issue.
Viktoria Schrön recently wrote her dissertation on the topic of AI and patent law. She believes that the distinction between patent law and copyright law lies in the level of personal involvement. »There's still a connection between a patent and the inventor, of course, but that connection isn't as decisive in patent law because of the constraints imposed by the laws of science. In copyright law, though, there are no limits to our imagination, which is why the decisive factor here is whether a

Prof. Dr Volker Michael Jänich and Viktoria Schrön explore issues of copyright law in the use of generative AI tools. · Photo: Anne Günther

These cats are AI-generated. Nevertheless, the AI is not considered the creator of this image in a legal sense. · Illustration: DeepDream

work expresses a person's spirit.« For this reason, Schrön believes it is conceivable that a person would be granted the intellectual property rights for an invention, even if AI were used in its creation.

AI training with copyright-protected material

There is, however, another side to the debate surrounding AI and copyright law. Generative AI cannot create new works out of thin air. Before programmes like ChatGPT are capable of generating texts, they need to be trained. And, before a software like DeepDream can generate images, it needs to be »fed« a wealth of existing images. This training also draws on copyright-protected works—often without the rights holders giving their consent or even being aware. Many creatives claim that artists and authors are being exploited by the developers of generative AI programmes. Consider, for example, asking AI to design a book cover: it will inherently draw on images created by human graphic designers.

Section 44b of the German Copyright Protection Act (UrhG), which was introduced in 2021, permits text and data mining, i.e. »the automated analysis of individual or several digital or digitized works for the purpose of gathering information, in particular regarding patterns, trends and correlations.« Rights holders do have the opportunity to implement a condition of use and object to text and data mining. However, whether this will have any practical impact is questionable, to say the least. From a legal perspective, it remains unclear whether this paragraph covers the training of AI models using copyright-protected works. For his part, Jänich has a clear opinion on the matter: he believes that such AI training represents a breach of copyright. At the same time, he concedes that there is currently no effectively legal protection to prevent this.

Yet, resistance is growing: The New York Times became the first major publisher to protest such practices and filed a lawsuit against Microsoft and OpenAI in late 2023. It believes that the two companies have infringed its copyright by »feeding« ChatGPT with millions of copyright-protected articles, thereby effectively operating at the newspaper's expense. High-profile authors in the USA have also sued OpenAI because they believe that their books have been used to train AI models. Asked about similar legal suits in Europe, Jänich and Schrön are sceptical about their prospects of success.

The Axel Springer media group, for example, opted not to object to the use of its works and instead agreed to a partnership with OpenAI. Under this arrangement, the publisher is getting paid for providing ChatGPT with access to journalistic texts from Springer-owned publications.

Protecting copyrights in the age of AI

In the meantime, researchers are working on ways for artists to fight back against the unauthorized use of their works by AI. A recently launched tool called »Nightshade«, for example, can manipulate individual pixels of an image. Although such changes are imperceptible to the human eye, they disrupt AI programmes that use images manipulated in this way without permission. The »Nightshade« developers claim that the tool could cause the AI to produce an image of a handbag floating in space, even though the prompt was to produce a cow floating in space.

AI will undoubtedly make inroads into more and more areas of our lives in the future, raising new questions in the process. Legal scholars, however, have only just begun to assess such questions and examine intellectual property law in relation to AI. Finding answers will require new avenues for rights holders to protect their intellectual property. Ultimately, there is one thing AI cannot do: replace human creativity. ■

Lacking consciousness and rationality

AI is a powerful tool and is becoming even more powerful still. However, Prof. Dr Christoph Demmerling does not believe it will ever exceed the status of a tool. In this interview, he explains why there is no reason to fear »global domination« at the hands of AI and why this scenario is, above all, borne out of deep-seated human fears.

BY STEPHAN LAUDIEN

Some things are difficult to describe. Consider the sensation of biting into a ripe peach, for example, tasting the fibrous flesh within and feeling a bead of juice trickling down from the corner of your mouth. While it can be tricky to put this feeling into words, most people will probably be able to recall the experience, or something similar.

»By contrast, artificial intelligence might be able to determine the substances within the peach but will never be able to understand the enjoyment of eating one,« says a convinced Prof. Dr Christoph Demmerling. His argument is based on the notion that the experience of taste requires a consciousness that artificial systems lack. Demmerling, a philosopher at the University of Jena, does not share the hype revolving around AI at present: »AI is a tool, just as a saw, a car and a pocket calculator are all tools.«

Comparing AI with a hammer or a saw, he perceives—at best—shades of the same colour, with no qualitative differences in their nature. It all depends, he says, on how people use these tools: they can be misused and abused, such as by creating and disseminating deepfakes online. While he recognizes that forgeries are now easier to produce with the help of AI, the philosopher also notes that forgeries have always existed; identifying them in the age of AI simply requires greater attention and alertness.

Instead, Christoph Demmerling believes that artificial intelligence poses rather different dangers. People who always rely on navigation systems, for instance, are quite literally lost when the technology fails. Demmerling also believes that the use of AI applications in administration can be problematic:

Prof. Dr Christoph Demmerling. · Photo: Anne Günther

although they can markedly accelerate and simplify processes, they reach their limits when encountered with a special case that requires a »tailored« approach. This, he says, is where true human judgement comes in. »Although data-based AI tools can assist people, they are not capable of independently performing bureaucratic or even scientific tasks.«

Manifold connections to the world

Over the past year, calls for a moratorium on AI models have made headlines. Its advocates aim to secure a pause in AI development in order to discuss the potential dangers involved.

So, is AI set to take over the world someday? Christoph Demmerling smirks. Such notions, he says, are an expression of deep-seated human fears of a tool turning against its master, not unlike in Goethe's »Sorcerer's Apprentice«. Demmerling believes that such a reversal of the roles occupied by humans and machines would require something to be important to the machine, for the machine to be affected by something and be able to establish relevant connections. Machines cannot do any of this, he posits, as they do not possess consciousness. »Such consciousness cannot be created by artificial means because it requires manifold connections to the world, including emotional connections.«

Demmerling contends that AI is equally incapable of making rational decisions because access to vast amounts of data is not sufficient in and of itself. Instead, it is crucial to identify relevant contexts for the given situation. »That is not possible without consciousness and feelings,« he says. It requires an intuitive feel for the things that matter. ■

Ahead of her time

A century ago, in the autumn of 1923, Mathilde Vaerting became the first woman to become a full professor in Germany when she was appointed at the University of Jena. Yet, she was repudiated by her colleagues—first and foremost because she was a woman.

BY SEBASTIAN HOLLSTEIN

The first woman to be made a full professor at a German university: what might sound to us today like a significant societal event and a historical turning point proved a tremendous, lifelong burden for Mathilde Vaerting. Upon her arrival in the winter semester of 1923/24, the University of Jena and its professors did not welcome her with open arms, but showed the proverbial cold shoulder. Entitled »Childcare for Cultural Evolution«, her inaugural lecture should have been cause for celebration. But instead of the ceremonial surroundings of the assembly hall, she gave her speech in a small lecture theatre, on a Saturday morning, without the wider public taking any notice. Why exactly did her appointment encounter such resistance?

Johanna Mathilde Vaerting was born in 1884 to a prosperous farming family in Emsland, Lower Saxony. One of many siblings, she studied mathematics, physics, philosophy and Latin in Bonn, Munich, Marburg and Giessen. In 1911, she received her doctorate in the field of philosophy in Bonn. After completing her studies, she worked as a teacher in Berlin, conducted research in her spare time and took classes in medicine and sociology.

Gender plays no role in education

Already at an early stage, Mathilde Vaerting's research scrutinized established doctrine and teaching practices: she attacked rote memorization as a teaching method and advocated equal status for teaching staff and students. Over time, she increasingly devoted her attention to a field of research that barely existed at the time: gender studies. Vaerting emphatically stated that gender plays no role in education. She contended that girls are no less capable in scientific subjects than boys: any differences were merely the result of different positions of social power, while alleged gender-specific characteristics were the result of power relations. By combining pedagogical, psychological and sociological approaches, she paved the way for new scientific issues.

The thesis she submitted to the University of Berlin for her post-doctoral lecturing qualification (Habilitation) in 1919 was rejected, not least due to reservations about the field of research. Despite this, the published version of her thesis—entitled »A New Basis for the Psychology of Man and Woman«—achieved renown and recognition, possibly turbo-charging her academic career. In 1923, the Thuringian Minister for Public Education, Max Greil, appointed Vaerting as a Professor of Pedagogy at the University of Jena as part of extensive reforms to the Thuringian education system. The University's leadership, however, saw the move as an attack on the institution's autonomy—especially as this was the first time a woman was appointed to a full professorship. Vaerting's colleagues claimed that she lacked the professional ability for the role. Ludwig Plate, a zoologist and anti-Semite, even published a diatribe about her, entitled »Feminism under the Guise of Science«. Peter Petersen, who Greil also appointed to a position in Jena, encountered considerably less resistance and consolidated his position at the University—at Vaerting's expense.

When the National Socialists seized power in 1933, Vaerting lost her professorship and was excluded from working at the University. She decided to move back to Berlin. A ban on leaving Germany prevented her from accepting appointments to universities in the Netherlands and the USA. Meanwhile, a ban on publications prevented her from continuing her academic work.

Even after World War Two, she was not allowed to return to work at a university. She turned her attention to state sociology but was unable to gain a foothold in the academic sphere. Mathilde Vaerting died on 6 May 1977 in Schönau im Schwarzwald. In the 1990s, however, her work began to garner renewed attention. Today, she is regarded as a little-known but highly significant pioneer of an educational theory that takes account of social power relations and the impact of categories of difference.

Photo: University Archives Bielefeld

In 2023, a memorial plaque commemorating Vaerting's appointment was unveiled in the University of Jena's Main Building. Furthermore, the Society for the Study of the History of Democracy (Gesellschaft zur Erforschung der Demokratiegeschichte, GEDG) partnered with the University to publish a comprehensive brochure on the life and work of the first woman to be appointed to a full professorship at a German university.

■

»You have to find a way to get yourself into the game«

Prof. Dr Anika Klafki is well-known to many people across Germany: when the onset of the COVID-19 pandemic caused politicians to implement drastic restrictions in 2020, the junior professor and lawyer gave numerous TV interviews and appeared in panel discussions to outline the legal latitude and limitations. With the pandemic now over, Klafki faces a new challenge that again entails considerable responsibility: the position of judge at the Thuringian Constitutional Court.

BY UTE SCHÖNFELDER

After Anika Klafki and her husband moved to Jena from Hamburg in the autumn of 2019, everything started to move very quickly. She had just been appointed to a Tenure Track Junior Professorship for Public Law, especially Transnational Administrative Law, at the University of Jena. Around that time news began to filter through of an unknown virus causing severe lung disease in China. Although nobody could have expected then that »SARS-CoV-2« would hold the world in its grip for the following three years, Anika Klafki was immediately alarmed. She had already conducted years of research into the topic of pandemics. It soon became clear to her what humanity could be facing.
Anika Klafki had already gained attention in the legal world for her doctoral thesis, entitled »Risiko und Recht« (Risk and Law). Examining legal issues that arise in relation to pandemics, it won Klafki the doctoral thesis prize at Bucerius Law School, where she completed her doctorate. It was also listed as one of the five best law books of the year in 2017. »And that was despite pandemics being an absolute niche topic at the time,« recalls Klafki.

A sought-after expert for media outlets and politicians within weeks

Yet, as the coronavirus pandemic reared its head towards the end of 2019, this niche became a paramount focus of people around the world—and Anika Klafki made a name for herself as a sought-after expert, including beyond her field. Within a matter of weeks, she had become a prominent face in the media, explained Germany's Infection Protection Act (IfSG) and the legal consequences of COVID restrictions in an array of interviews, contributed to the prime-time TV news programme »Tagesthemen«, appeared on Maybrit Illner's high-profile talk show and been invited to appear as an expert witness before the German Bundestag and the Thuringian state parliament.
Four years later, in November 2023, Anika Klafki has invited us into her office on the Ernst Abbe Campus. She has made coffee and speaks quickly, as she does not have much time. Klafki informs us that she will have to leave at noon because her two-year-old son is ill and cannot go to day care. She will take over from her husband, who has been on childcare duty that morning.
The current situation of reduced media attention is perfectly acceptable for Klafki. It consumed a substantial amount of her time and energy, which are crucial resources that she must now allocate to her fresh obligations. This is not only concerning her family, but also her new role as a judge at the Thuringian Constitutional Court, which she assumed in 2022 at the young age of 35.

Not satisfied with small steps

Klafki was born in Marburg, Hesse, and spent her childhood moving frequently due to her father's job in development assistance. The family lived in various locations, including Africa, India, Bonn during its time as the German capital, and later in Berlin. Klafki completed her Abitur while residing in Berlin.
Even while she was at school, she never wanted to be anything but a lawyer—even though she wasn't entirely clear on what exactly a lawyer does. »Somebody told me that lawyers argue a lot and I thought OK, I'm pretty good at that! It sounds like a good job for me,« she remembers, laughing. Later on, she says, she was primarily focused on finding a profession that focused on high-quality arguments on issues of socio-political relevance. For a long time, she concentrated on human rights and imagined herself working at an international human rights organization or the United Nations. »Then I experienced the UN from within,« says Klafki. She describes returning thoroughly disillusioned from an internship at the German Mission to the United Nations in New York.
»Paper is patient« is her concise summary of the experience. She was dissatisfied to see an armada of well-paid diplomats spending every day tinkering with resolutions and tussling

An academic, constitutional judge and sought-after expert: the lawyer and junior professor Anika Klafki. · Photo: Anne Günther

over every last word. »In reality, these texts have next to no impact.« Hardly surprising, she says, because when the entire world comes together, the steps on which everyone can agree are only ever going to be small in scale. For Klafki, these steps are just too small.

Some time later, after completing her first degree, she accepted a position as a research assistant to the Chair led by Prof. Hermann Pünder at Bucerius Law School in Hamburg. She quickly realized where her professional aspirations lay. »I enjoyed the academic work a lot, right from the outset.« She worked as part of a high-performing team that provided wide-ranging encouragement and inspiration. Klafki began to publish her first papers, visit conferences and hold lectures. She also became active in a network of young lawyers—»Junge Wissenschaft im Öffentlichen Recht e. V.«—and regularly posted articles on current legal policy issues on its platform, »juwiss.de«.

Anika Klafki did not become an expert by chance

During the onset of the coronavirus pandemic, it was not by chance that Klafki became a highly sought-after expert by media outlets and politicians for insights into the German Infection Protection Act and lockdown restrictions. »I drew attention to myself with targeted blog posts.« After all, neither journalists nor parliamentarians had the time to pore over thick volumes of literature to find suitable specialist advice. »You have to find a way to get yourself into the game.«

It is also not by chance—though perhaps somewhat more surprising—that Klafki later received a call from the leadership of the Social Democratic Party (SPD) in the Thuringian state parliament to ask whether she would consider standing for a judgeship at the Thuringian Constitutional Court. The SPD, which Klafki has been a member of since 2005, wanted to nominate a successor to constitutional judge Manfred Baldus, who had recently passed away. »I hadn't expected it and needed some time to think it over,« she says. She was in the middle of her postdoctoral lecturing qualification at the time. Her interim evaluation was coming up, which she needed to pass in order to turn her junior professorship into a tenured professorship. It is an undertaking that requires considerable commitment to teaching and research. And, of course, she was the mother of a young child.

Yet, her colleagues, friends, and family all encouraged her to seize the opportunity. Klafki put herself forward for selection and secured the necessary two-thirds majority approval in the state parliament, despite the fact that the governing coalition that proposed her did not have a majority in the parliament.

Since her appointment, Klafki has integrated this new challenge into her work schedule. »But it wouldn't be possible were it not for my husband,« she emphasizes. He is a vital source of support, she says, both on professional matters—given that he is also a judge—and as a husband and father to their son.

Speaking of which, she really does have to look after her soon now—and, suddenly, everything starts moving quickly once again. »I have to go,« she says, her voice friendly yet firm, before grabbing her bicycle helmet and setting off. ■

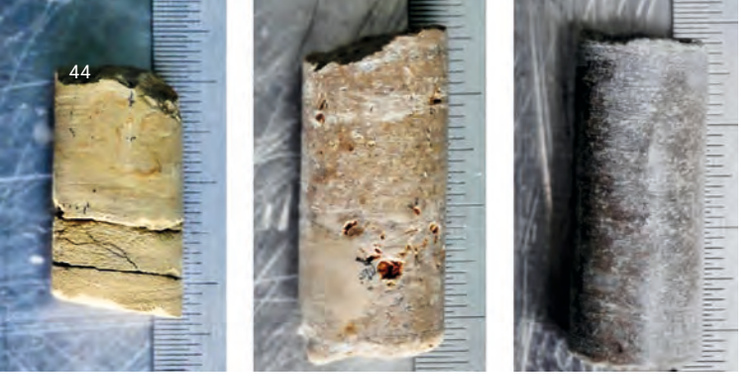


PHOTO: ROBERT LEHMANN

DNA from the past

The majority of microbial biomass in the Earth system is hidden below ground. Estimates suggest that microorganisms could extend to a depth of five kilometres below the surface and are also capable of colonizing solid rock. Given the difficulty in accessing this deep biosphere, researchers have learned little to date about the composition of these microorganisms and their role in biogeochemical cycles. A research team led by Prof. Dr Kirsten Küsel and Prof. Dr Christina Warinner at the »Balance of the Microverse« Cluster of Excellence has now discovered that chalk serves as an archive of underground microbial communities. The initial results of the study have been published in the specialist journal »Microbiome« (DOI: 10.1186/s40168-023-01647-2). Gold/Nieber

PHOTO: ANNE GÜNTHER

Hydrogen through sunlight

Sustainable, sunlight-powered hydrogen production relies on a catalyst system that is not only efficient but, ultimately, also cost-efficient, widely available and resource-friendly.
A team led by Prof. Dr Kalina Peneva (photo above, left) of the Institute of Organic Chemistry and Macromolecular Chemistry has now taken a step in this direction. Her group has developed dyes that can make do without metals, are easy to produce and transfer absorbed light energy to a catalyst, which then produces hydrogen. The team has published their results in »Journal of Materials Chemistry A« (DOI: 10.1039/D3TA04450E). The article describes not only the dyes but also their interactions with the catalyst. MK

PHOTO: STOCK.ADOBE.COM

Resistant starch as a prebiotic

Resistant starch, which can be found in whole-grain cereals, legumes, green bananas and potatoes, could have an important role to play in the future treatment of non-alcoholic fatty liver disease. The results of a study led by Prof. Dr Gianni Panagiotou at the »Balance of the Microverse« Cluster of Excellence show that a diet featuring resistant starch can not only have a positive impact on the gut microbiome but also ease the course of the illness.
The researchers identified reduced fat build-up in the livers of test subjects and also observed an increase in certain types of intestinal bacteria that positively influence the breakdown and transport of fat in the liver. The results have been published in »Cell Metabolism« (DOI: 10.1016/j.cmet.2023.08.002). Nieber

PHOTO: J. LINDSEY

Insects on the retreat

The decline in terrestrial insects like beetles, moths and grasshoppers can be attributed above all to the loss of locally abundant species. These are the findings of a current study (DOI: 10.1038/s41586-023-06861-4). Led by researchers from the German Centre for Integrative Biodiversity Research (iDiv), University Halle-Wittenberg and the University of Jena, this meta-analysis of 923 sites around the world highlights two key tendencies. Firstly, abundant species with many individuals have declined more significantly than rare species. Secondly, the increases in some insect species have been too small to achieve previously observed levels of abundance. This confirms the widespread observation that there are fewer insects today than was the case 10, 20 or 30 years ago. The analysis reviewed 106 studies running for periods of up to 64 years. Coester/iDiv

PHOTO: JENS MEYER

Mummies under the microscope

The archives of the University of Jena contain a wealth of artefacts—including around 20 mummy fragments. Researchers from the fields of biology, medicine and the archaeology of prehistory to the Middle Ages have now examined these fragments for the first time, presenting their findings in »Annals of the History and Philosophy of Biology« (DOI: 10.17875/gup2023-2486). They include four skulls, a torso fragment, a pelvis, two lower jaws, two groups of vertebrae, three left feet and some tissue remains from Egyptian mummies, as well as two child mummies from South America which are almost completely preserved. The leader of the study, Dr Enrico Paust, says that it is not yet possible to say for certain where these artefacts came from, the circumstances under which they were found or how they came to Jena. sh

ILLUSTRATION: ESA/ATG MEDIALAB; BACKGROUND IMAGE: ESO/S. BRUNIER

Planets between multiple suns

Kai-Uwe Michel and Dr Markus Mugrauer of the Institute of Astrophysics of the University of Jena have conducted a study examining how many stars with extrasolar planets (exoplanets) have one or even more companion stars, and what impact this stellar multiplicity has on the properties of planet systems. The researchers drew on observation data from the Gaia space observatory (image) operated by the European Space Agency, examining more than 2,200 exoplanet hosts for possible companion stars. They made a find with roughly every fifth exoplanet hosts. In total, the astrophysicists have demonstrated the existence of several hundred new companion stars, as they reported in »Monthly Notices of the Royal Astronomical Society« (DOI: 10.1093/mnras/stad3196). US

PHOTO: JENS MEYER

Alone doesn't necessarily mean lonely

Around 20% of Germans live alone—and this figure is on the way up. In fact, this trend can be observed in most Western countries. Yet, despite prevailing preconceptions to the contrary, living alone does not necessarily entail isolation and loneliness. These are the findings of a team led by psychologist Prof. Dr Franz Neyer of the University of Jena, with the results detailed in the »International Journal of Behavioral Development« (DOI: 10.1177/01650254231206329). The researchers surveyed around 400 people aged between 35 and 60 over a three-year period. Around one-third of those surveyed were particularly pleased to have an extensive network to draw on and engage with different social contacts on a daily basis, including friends and family as well as acquaintances such as work colleagues and neighbours. sh

PHOTO: MYRIAM HIRT

Artificial light threatens ecosystems

A collection of studies into artificial light at night has demonstrated that the impacts of light pollution are more extensive than previously thought. Even small quantities of artificial light can disrupt species communities and entire ecosystems.

A special issue published in the journal »Philosophical Transactions of the Royal Society B« focuses on the effects of light pollution on complex ecosystems, including soil, grassland and insect communities. Researchers at the German Centre for Integrative Biodiversity Research (iDiv) and the University of Jena contributed to the publication, describing the domino effect that light pollution can have on ecosystem functions and stability. Dr Myriam Hirt and Dr Remo Ryser served as senior editors on the issue. Coester/iDiv

»PAPAS« slows down breast cancer growth

A research team from the University of Jena, Jena University Hospital and partners from Shenzhen University has deciphered a molecular mechanism that regulates the synthesis of ribosomal RNA. Ribosomal RNA plays a key role in protein biosynthesis, which is necessary for the development and growth of cells. If the synthesis of ribosomal RNA is reduced, cells can therefore grow less—the researchers want to take advantage of this in the case of breast cancer cells.

BY SEBASTIAN HOLLSTEIN

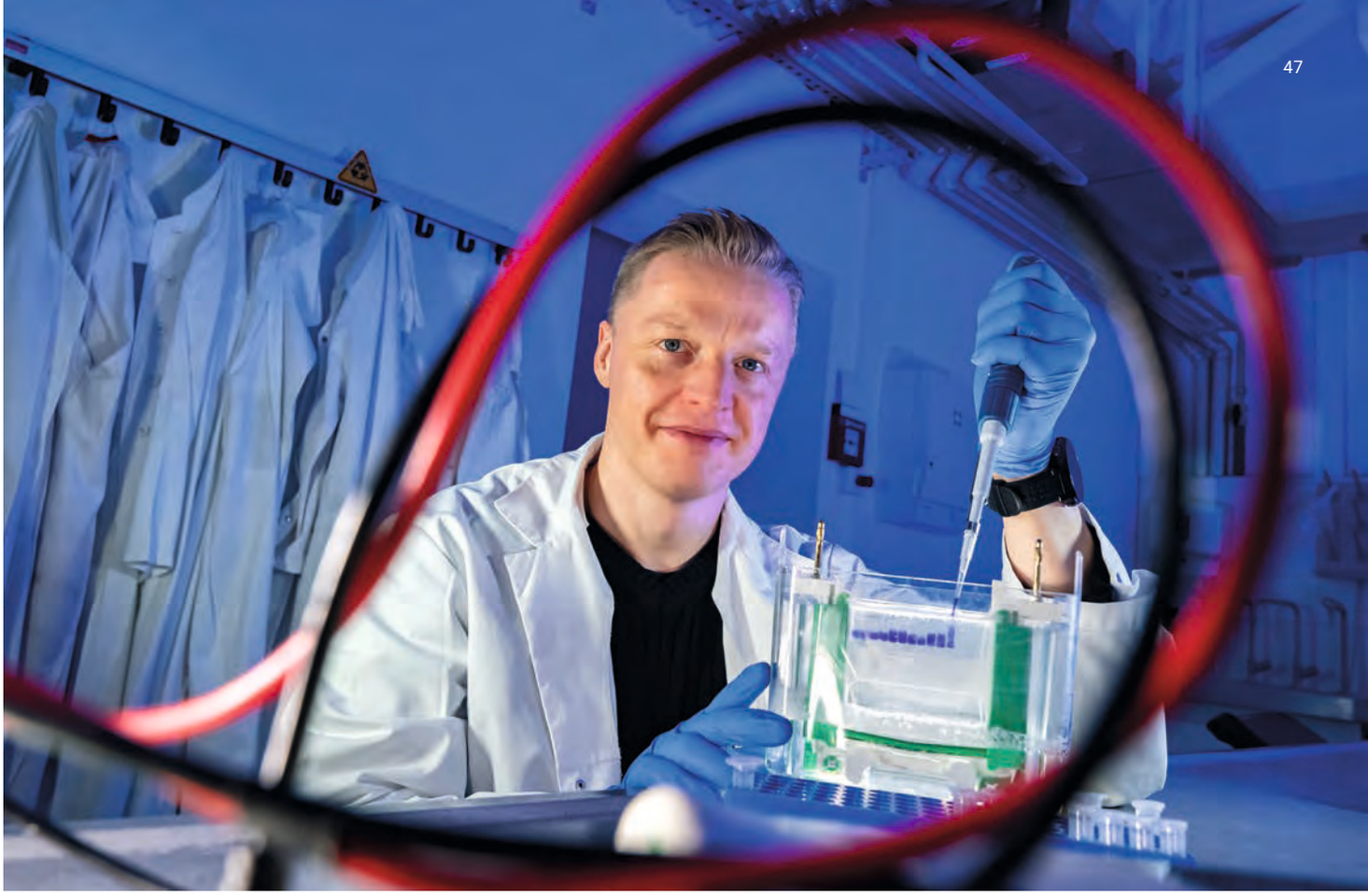
Breast cancer is the most common cancer in women. The development of breast cancer often originates from epithelial cells in the mammary gland—the very cells that specialize in milk production during and after pregnancy.
A team of researchers from Friedrich Schiller University Jena, the University Shenzhen (China) and Jena University Hospital has taken a closer look at this specialization process and deciphered a molecular mechanism that also appears to play an important role in cancer development. It may be possible to develop new diagnostic procedures and treatment methods for breast cancer based on these research findings. The scientists report on their work in the scientific journal »Cell Reports«.

Switching RNA synthesis on and off

Cell differentiation, i. e. their specialization, is an essential component of an organism—only through this specialization can cells take on different tasks. During lactogenesis—the process triggered by hormones that enables the mammary glands to produce milk—the relevant cells multiply first. The proteins required for this are produced by the ribosomes. A fundamental building block of ribosomes is ribosomal RNA, or rRNA for short. If more proteins are required, the demand for rRNA also increases, and its synthesis in the cell nucleus is ramped up accordingly. At the end of lactogenesis, the specialized cells stop growing and reduce rRNA synthesis again. This regulatory mechanism takes place at the epigenetic level, which means that it is not the DNA itself that changes, but its packaging, for which another type of RNA is responsible.
»We've found out that a long, non-coding RNA called PAPAS, which I had discovered a few years ago, acts on the packaging of the DNA and reduces rRNA production,« explains Dr Holger Bierhoff, who is leading the project at the University of Jena. »More precisely, PAPAS influences access to the active regions of the DNA and determines whether these are copied into RNA or not. If a lot of ribosomes and proteins, and thus a lot of rRNA are needed, the synthesis of PAPAS is reduced. If this process is to be stopped, the PAPAS level is increased.«
The experts in Jena also discovered that PAPAS not only plays an important role in cell proliferation, but also in specialization. »When we switched off PAPAS through gene manipulation in cells originating from the breast epithelium, we observed that lactogenesis no longer functioned properly,« says Bierhoff.

High PAPAS level—low tumour growth

Synthesis of rRNA is also increased in cancer cells, as they multiply rapidly and require a lot of proteins—and accordingly a lot of ribosomes. »We therefore asked ourselves whether the regulatory mechanism we observed also plays a role in the development of breast cancer. The answer is clearly yes,« explains cell biologist Bierhoff. »When we reduced PAPAS synthesis and switched off cell specialization, we observed that the cells adopted the characteristics of cancer cells.«
In contrast, the researchers showed both in cell cultures and in mice that a high PAPAS level reduces tumour growth as well as the spread of metastases.
But how do cancer cells manage to switch off PAPAS production and thus boost rRNA synthesis? »We have also found a mechanism for this,« explains Bierhoff. »Production of PAPAS requires a molecular signal at the start of the PAPAS gene. This signalling



Dr Holger Bierhoff is preparing a gel electrophoresis to separate proteins from a cell extract according to their size and charge: The samples, which are mixed with a blue dye, are loaded into a gel made of polyacrylamide and separated by applying an electric field. · Photo: Jens Meyer

structure is regulated by particular proteins, which can resolve or block the structure. We've observed that the production of these proteins is particularly high in breast cancer cells. The more aggressive the tumour, the more of them are present.«

Jena researchers are developing RNA therapy

For Holger Bierhoff, the research results are promising in two respects: »Firstly, we see that PAPAS can be an interesting marker for assessing the aggressiveness of a breast tumour. This information could potentially be used as a diagnostic tool,« he says. »Secondly, we're already working on developing an RNA therapy for cancer treatment. We know the mechanism by which PAPAS regulates rRNA synthesis and we know which region of the RNA is required for this. Now, the idea is to produce this part of PAPAS artificially, package it in nanoparticles, and introduce it into the cancer cells, thereby restoring its function. In this way, we would reduce rRNA synthesis, which the cancer needs to proliferate.« This strategy would be similar to mRNA vaccines, like the one against COVID-19, however, here a regulatory RNA instead of protein-coding RNA would be applied. ■

Original publication:
PAPAS promotes differentiation of mammary epithelial cells [...], Cell Reports, 2024; https://doi.org/10.1016/j.celrep.2023.113644

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Age is also a matter of perspective

As the saying goes, you're only as old as you feel. Well, it turns out that this is spot on. A person's age is not simply a question of the duration of their life to date, but is instead affected by a number of factors, including a person's perception of old age. IMPULS, an interdisciplinary research network based in Jena and supported by the Carl Zeiss Foundation, is examining how our various biological and psychosocial clocks »tick« and influence each other.

BY UTE SCHÖNFELDER

For some people, it is demise by a thousand cuts: the gradual loss of hair, vision, muscular strength, physical fitness and cognitive abilities. For others, it is an enticing prospect comprising freedom, autonomy and inner peace. Everyone experiences the ageing process and old age in their own, unique way. Although nobody can escape the constant process of deterioration that inevitably ends in death, there are significant differences in how and at what speed people age.

»In this context, chronological age—that is, the duration of a person's lifespan to date—only provides limited information about how old a person is perceived as being and how old they feel,« says age researcher Prof. Dr Christoph Englert. The biochemist is spokesperson of IMPULS, an interdisciplinary research consortium between the University of Jena, the Leibniz Institute on Aging—Fritz Lipmann Institute (FLI) and Jena University Hospital (see info box). »Although we can detect ageing processes at the biological level, in cells and in genetic material, these biological clocks do not reliably reflect a person's age,« explains Englert. Instead, he contends, there is often an astonishing discrepancy between biological and chronological age.

Ageing is a process that can be shaped

»No human age group is as heterogeneous as the elderly,« emphasizes Prof. Dr Klaus Rothermund. The psychologist, who holds a Chair for General Psychology at the University of Jena, is also part of the IMPULS team. Rothermund previously led »Ageing as Future«, an international longitudinal project financed by the Volkswagen Foundation. He primarily identifies differences in the subjective perception of age but also in societal ageing norms. »Ageing is an individually malleable process and, in many respects, a self-fulfilling prophecy.« A person's image of old age therefore has a decisive influence on the mental and, above all, physical condition in which they experience this phase of life.

However, the interaction and links between the two aspects of the ageing process—physiology and psychology—remain unclear. Researchers have examined age and its processes as predominantly separate issues to date. Now, however, Christoph Englert, Klaus Rothermund and their team have combined the two aspects to create a holistic model of the ageing process, which the researchers have now published in the journal »Gerontology«.

Picture left: People who look forward to old age with positive expectations generally experience this phase of life as physically and mentally fitter than their peers who have more negative expectations. · Photo: Anna Schroll

The IMPULS project has been financed by the Carl Zeiss Foundation since 2021 as part of its »Breakthroughs« funding programme. The IMPULS project's full, official title is »Identification and manipulation of the physiological and psychological clocks of lifespan«. The project team includes experts from the fields of biochemistry and epigenetics, medicine, neuroscience, nutritional science, pharmacy, epidemiology, bioinformatics, biostatistics, gerontology, psychology and the social sciences.

The novel aspect of the model developed by the Jena-based IMPULS team is that it provides interdisciplinary access to human ageing, along with its causes, consequences and subjective experience, by integrating all factors: biological, psychological, lifestyle-related and socio-cultural. »In doing so, we want to make it possible for us and other researchers to construct empirically verifiable hypotheses and identify targeted intervention measures that could increase an individual's ability to resist ageing and mitigate its negative impacts,« says Englert. Over the long term the aim is for the theoretically possible life expectancy determined by an individual's genetic make-up to be experienced in practice and in good health.

Buffering ageing processes

»Our model distinguishes between the phenomenon of ageing, the subjective experience and the causes and consequences of these processes,« explains Rothermund. A major focus of the model is on the role of buffering mechanisms that influence physical and mental health and thereby regulate the ageing processes. »These include biological repair mechanisms and how a person adapts to their situation in life,« adds Englert.

The biological buffering mechanisms that counteract the ageing process include, for example, DNA repair and cell renewal, which ensure that tissues and organs function properly. The buffering mechanisms in turn depend on individual behaviour, which includes physical exercise, healthy nutrition, but also avoiding harmful influences such as smoking and excessive sun exposure. In addition, certain social aspects can cushion the ageing process: people who maintain wide-ranging social relationships and play an active part in society age more slowly on average than people who do not. The efficiency of these mechanisms varies from person to person and over the course of a person's life, which is why people age at different speeds.

Comprehensive study of test subjects

In the next phase, the researchers hope to apply their model in an IMPULS study and find out whether a person's perception of age corresponds to their ageing at the biological level. To this end, they are analysing blood and saliva samples from hundreds of subjects whose perception of ageing and attitude to the process have already been examined over several years in the previous »Ageing as Future« study. »It will be interesting to see whether, for example, a positive attitude towards old age is reflected epigenetically in the subject's cells or whether epigenetically young people also defy the psychological effects of old age,« as Rothermund anticipates. The team expects the study to produce results by early 2025.

One thing that Englert and Rothermund are sure about, however, is that healthy ageing is also a societal challenge. »Older people in particular benefit from wide-ranging social relationships and participation,« underscores Rothermund, who, as a member of the expert commission, also co-authors the current German Federal Government's Report on Ageing. At present, however, Rothermund says that older people often feel increasingly pushed to the fringes of society as soon as they leave the world of work. This is not just a social problem, he says, but a health problem. »The feeling of no longer being needed—which many people get when they enter retirement—can have a considerable impact on physical and mental health and, consequently, accelerate the ageing process,« says Christoph Englert. ■

Original publication:
Explaining variation in individual aging, its sources, and consequences [...]
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Hemp helps to heal

The hemp plant, scientifically *Cannabis sativa*, is one of the oldest medicinal and agricultural plants known to humankind. Its therapeutic effects, for example against pain and spasms, have been utilized for thousands of years. An international research team led by researchers from Jena has now discovered that the plant has even more healing potential and has shown how cannabinoids work in the case of inflammation.

BY UTE SCHÖNFELDER

In the summer 2023, the federal government took the controversial decision to make the acquisition and possession of small amounts of cannabis exempt from punishment. After the Bundestag approved the cabinet draft, the »Cannabis Act« will come into force on 1 April 2024. While some consider this move to be long overdue, others continue to warn urgently against the health risks of cannabis use.

Researchers from the University of Jena and their colleagues from Italy, Austria and the USA are taking a different look at cannabis—at the traditional medicinal plant—with a study published in the journal »Cell Chemical Biology«. The team from the Institute of Pharmacy investigated how certain ingredients from the cannabis plant counteract inflammation.

It was already known from previous studies that cannabis is not only an analgesic and an antispasmodic, but also has an anti-inflammatory effect. »However, the reason for the anti-inflammatory effect was largely unclear until now,« says Dr Paul Mike Jordan, who led the study together with Prof. Oliver Werz.

Cannabinoids with anti-inflammatory effect

The researchers studied how different cannabinoids, including the psychoactive THC (tetrahydrocannabinol) and CBD (cannabidiol), which is already found in freely available products today, act on human immune cells. »We found that all eight cannabinoids we studied had anti-inflammatory effects,« says Lukas Peltner, doctoral student and first author of the study. »All the compounds we studied were found to inhibit the formation

Dr Paul Mike Jordan (l.) investigates the actions of cannabinoids in humans with Lukas K. Peltner (r.). · Photo: Anna König

Cannabis is a traditional medicinal plant whose ingredients could also play a role in the treatment of inflammatory diseases in the future. This is suggested by the results of the team led by Dr Paul Jordan and Prof. Dr Oliver Werz. · Photo: Marco Körner

of pro-inflammatory messenger substances in cells while enhancing the formation of inflammation-resolving substances.«

CBD induces a switch in immune cells

CBD in particular proved to be highly effective and the team investigated it in more detail with regard to its mode of action.
The researchers were able to determine that CBD activates the 15-lipoxygenase-1 enzyme, which triggers the production of inflammation-resolving messenger substances that subsequently cause the inflammation to subside. »CBD thus induces a switch in the affected cells, so to speak, which steers the inflammatory process from the promoting to the inhibiting side,« explains Dr Jordan. The researchers were also able to confirm these results, which were obtained in cell cultures, in animal experiments on mice.
In the long term, the insights gained could lead to new therapeutic strategies for treating inflammatory diseases, the researchers conclude. The focus should be on CBD, which was the most effective cannabinoid in the study. Previously approved preparations with cannabinoids contain CBD, »but also the psychoactive THC, which can be associated with a variety of side effects«, notes Dr Jordan. Therapeutics containing only CBD would reduce this problem. ■

Original publication:
Cannabidiol acts as molecular switch [...], Cell Chemical Biology (2023), https://doi.org/10.1016/j.chembiol.2023.08.001

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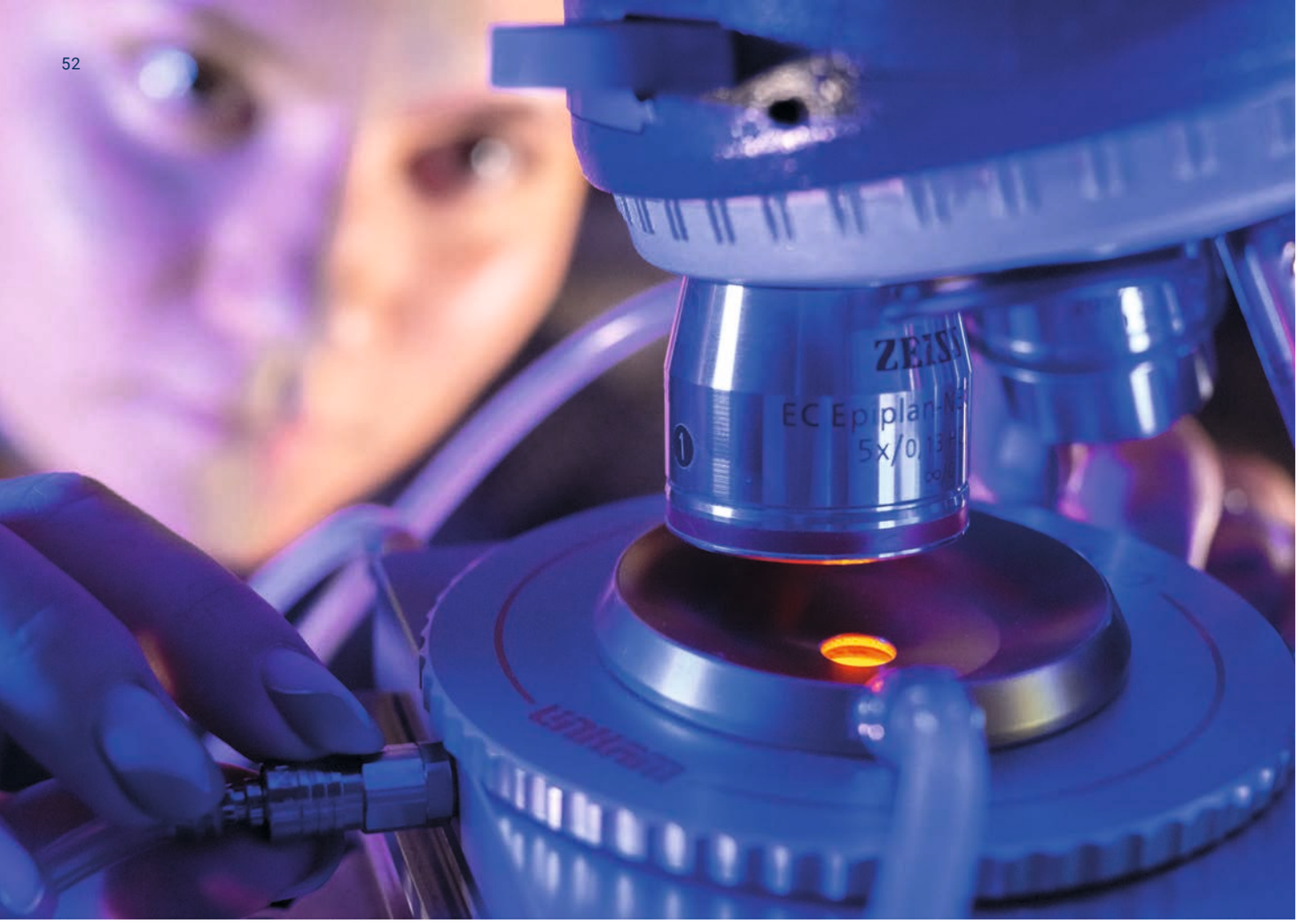


Glass separates gas—a filter for CO_2

If the greenhouse gas carbon dioxide (CO_2) could simply be filtered out of the atmosphere, humankind would have one less major problem. A small step in this direction has now been taken by a research group at the University of Jena: The team from the Otto Schott Institute for Materials Research has developed a glass material that can precisely separate gases from one another.

BY MARCO KÖRNER

Separating carbon dioxide molecules from gas mixtures requires materials with extremely fine pores. Researchers from Friedrich Schiller University Jena, in cooperation with the University of Leipzig and the University of Vienna, have now found a possibility for such a »molecular sieve«. They transformed crystalline metal-organic framework compounds, so-called zeolitic imidazolate frameworks, into glass.

The team led by Dr Alexander Knebel from the Otto Schott Institute at the University of Jena succeeded in reducing the size of the pores of the material in such a way that they were impermeable to certain gas molecules. The researchers report their findings in the journal »Nature Materials«.

»Actually, these glass-like materials were previously considered non-porous,« explains Knebel: »The starting material, i.e. the crystalline framework compounds, have very clearly defined pores and also a large internal surface area. Hence, they are also researched as materials for storing or separating gases. However, this defined structure is lost during melting and compression. And we took advantage of that.« »Metal-organic framework compounds consist of metal ions linked together by rigid organic molecules,« describes the leader of the junior research group, explaining the material.

Compressed metal-organic frameworks

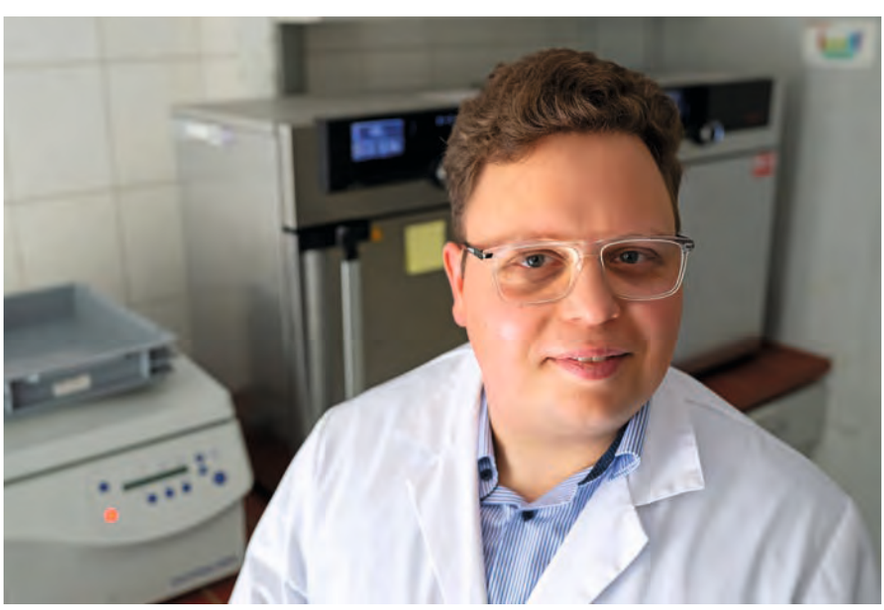
»In the spaces of these three-dimensional, regular grids, gas molecules can move easily. During the glass processing, we compressed the material.

PhD student Oksana Smirnova observes the melting process of glass under a microscope. · Photo: Jens Meyer

Put simply, we were able to squeeze the pores down to the desired size,« he illustrates.
Even though the overall structure of the crystal disappears during melting—parts of the crystal retain their structure. »In technical terms, this means: during the transition from crystal to glass, the long-range order of the material is lost, but the short-range order is preserved,« explains Knebel.
Oksana Smirnova, a doctoral student at the University of Jena and the lead author of the work, adds: »When we now melt and compress this material, the porous interstices also change.« As a result, channels with constrictions—or even dead ends—are created, and consequently, some gases simply no longer fit through.

Pore size is a thousand times smaller than the thickness of a human hair

In this way, the group achieved pore diameters of 0.27 to 0.32 nanometres in the material, with an accuracy of one hundredth of a nanometre. »For illustration: This is about ten thousand times thinner than a human hair and a hundred times thinner than a DNA double helix. With this pore size, we were able to separate, for example, carbon dioxide from ethane,« explains Knebel. »Our breakthrough in the field is probably the high quality of the glasses and the precise adjustability of the pore channels,« Knebel categorizes the work. The fact that the glasses are several centimetres in size also demonstrates the scalability of the new materials, he adds.
According to the researchers, one aim of their work is to develop a glass membrane for environmental applications. After all, separating carbon dioxide from gases is undoubtedly one of the great technological challenges of our time. ■



Dr Alexander Knebel heads a junior research group at the Chair of Glass Chemistry that develops novel hybrid glasses for gas separation. · Photo: Jens Meyer

Original publication:
Precise control over gas transporting channels, Nature Materials (2023), https://doi.org/10.1038/s41563-023-01738-3

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Deceptive memories

»It all happened far too quickly« is a common response in crime thrillers when eyewitnesses are questioned about the details of a crime. Was the perpetrator tall or short, young or old, what colour jacket did they wear? And even if the witnesses are able to give a detailed description of the perpetrator, there are often mistakes—both in crime fiction and in reality. Psychologists are investigating why people often remember things incorrectly. A young researcher from the University of Jena has now created novel 3D study material to analyse eyewitness accounts.

BY SEBASTIAN HOLLSTEIN

Eyewitness statements are one of the key sources for identifying perpetrators—and one of the most error-prone. For example, the Innocence Project—an organisation that works to clear up miscarriages of justice in the US—states that incorrect eyewitness statements played a role in two out of three cases in which it was able to secure the release of people who had been wrongly convicted.

Why eyewitnesses are so often wrong

Further research is needed to find out why eyewitnesses are so often wrong, and this will require extensive visual material. Psychologist Ulrike Kruse of the University Jena has now created such visual aids, through the unusual method of shooting mini crime stories. Together with her colleague, Prof. Stefan R. Schweinberger, she reports on her work in the current issue of the specialist magazine PLOS ONE.

»I've been working intensively on this topic for years and I continually find that there's hardly any material available for study programmes in this field, because images are mostly subject to data protection and cannot easily be distributed,« says Ulrike Kruse.

»For this reason, I decided to create such stimuli myself, use them for my own studies and, above all, make them available to colleagues worldwide.« To this end, Kruse shot six short film sequences with the support of amateur dramatics groups, in which minor offences are re-enacted, such as pickpocketing in a busy park. In order to use Virtual Reality (VR) methods and thus make the eyewitness situations even more realistic, the psychologist also used 3D technology.

In the next step, the Jena researcher looked for 16 people who looked similar to the perpetrators in the videos, in order to photograph them for simulated identity parades and also make 3D portraits of them. »I created flyers, searched on social media and approached people personally. In total, this phase took up the most time,« says Kruse, who spent around a year on the project.

Facing suspects in virtual reality

Compiling the photo database also took such a long time because Kruse tested objectively whether the men really did look confusingly similar. For this purpose, several people watched the videos and then provided a written description of the perpetrators.

In an online survey, 130 mock witnesses, as they were called, then identified the person who matched the characteristics by viewing the photos. »In such a fairness test, in the best-case scenario all the people in this virtual line-up are selected a few times because they should all fit the

Ulrike Kruse with a participant in the test lab. The psychologist has staged film sequences that eyewitnesses can use to identify suspects wearing VR glasses. · Photo: Anne Günther

description. In this case, it worked very well,« says Kruse.

The Jena University psychologist initially used the material for her own research. As part of her doctorate, for example, she is investigating the question of whether people who are generally good at remembering faces are also good eyewitnesses.

»If this is the case, you could—put simply—subject witnesses in court to a general test of their abilities in this area and in this way better assess their credibility,« she explains. However, final results are still pending.

With the visual material she has created, the Jena researcher is exploring completely new avenues, as there have hardly been any studies to date in which the test subjects have used VR goggles to immerse themselves in virtual reality for their role as eyewitnesses.

»So far, it has turned out that it's very difficult to remain attentive when you're fully immersed in the situation,« says Kruse. »In one experiment, for example, fewer than a fifth of 68 participants demonstrated correct recognition.« Further research in this area is therefore urgently needed. ■

Original publication:
The Jena Eyewitness Research Stimuli (JERS) [...]. PLOS ONE (2023), https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0295033

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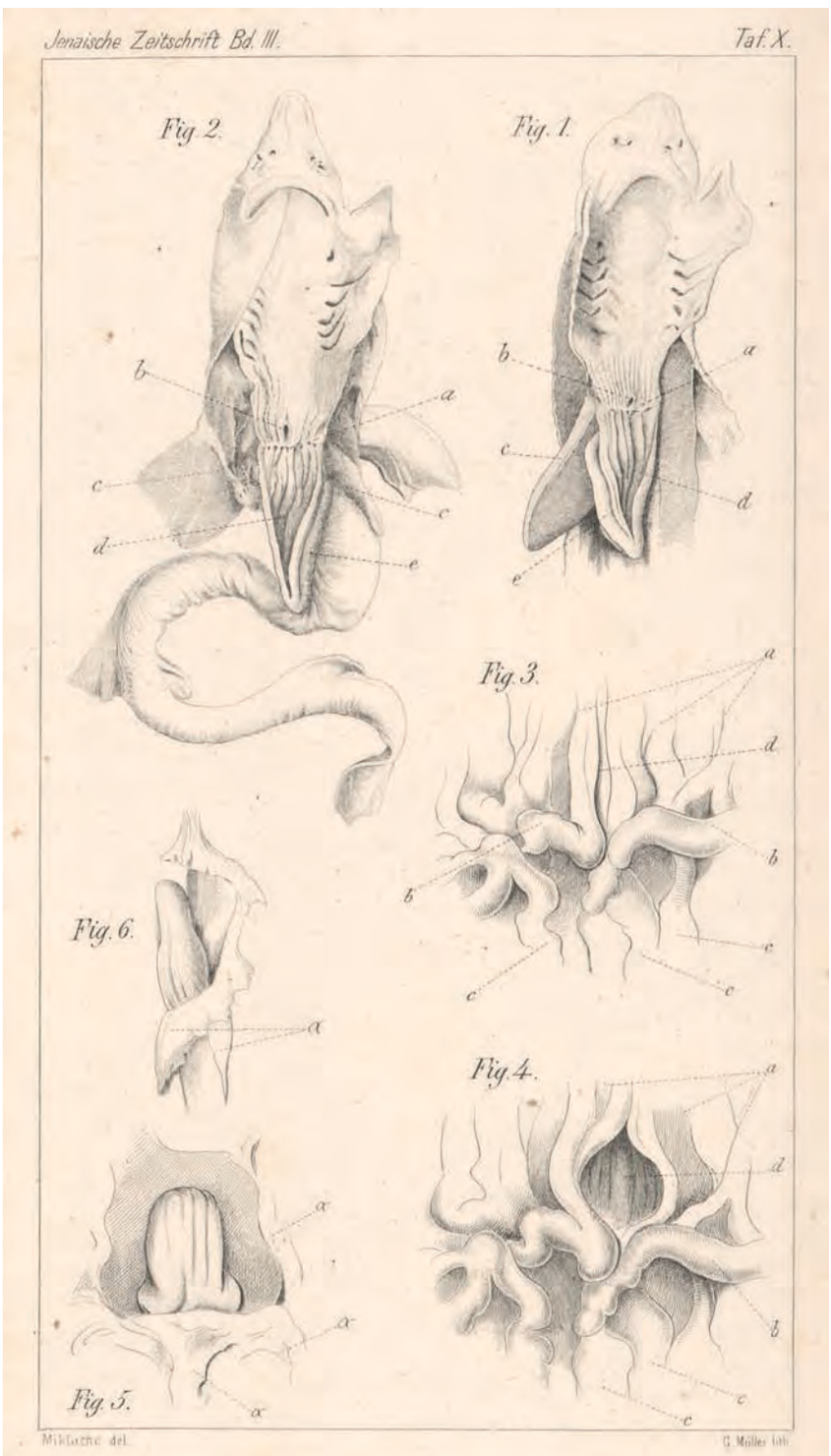
Swim bladders or lungs?

Recently rediscovered letters between Charles Darwin and Ernst Haeckel from 1868 have provide fresh inspiration for evolutionary research on early vertebrates. The notes of Haeckel's assistant Nikolai Miklucho-Maclay play a central role here.

BY SEBASTIAN HOLLSTEIN



Drawings of a dissected shark by Miklucho-Maclay.
Image: »Jenaische Zeitschrift für Medicin und Naturwissenschaft«

Do sharks have a swim bladder, like most fish, that helps them to swim freely in water? This question—which modern biologists can answer with a resounding »no«—sparked heated debates around 150 years ago. Researchers from the University of Jena and the Senckenberg Centre for Human Evolution and Palaeoenvironment (SHEP) at the University of Tübingen have now demonstrated just how enriching those discussions in the 19th century can be for modern research. They have discovered letters exchanged between Charles Darwin and Ernst Haeckel, two pioneers of evolutionary research, dating back to 1868. The colleagues discussed in detail the possibility of a swim bladder rudiment in sharks. The correspondence between the two pioneers provides a first-hand perspective of the evolutionary research of that era. It has also inspired researchers today to critically examine the viewpoint of modern science. The leading role in the letters, however, is played by a less prominent junior colleague.

Haeckel excited; Darwin sceptical

A critical issue in their correspondence is the research conducted by Haeckel's assistant at the time, Nikolai Nikolajewitsch Miklucho-Maclay. The Russian scientist, who later gained renown primarily through his work as an ethnologist, accompanied his tutor on a research trip to the Canary Islands in 1866. During his stay, he examined the brains of sharks and discovered, rather by chance, an evagination behind the branchial clefts, at the transition to the animal's intestinal area. Miklucho-Maclay interpreted this feature as a swim bladder rudiment, which must have been present in the ancestors of all vertebrates. Haeckel was excited

by this discovery, as it confirmed his theory that sharks were the original vertebrates and gave rise to bony fish, lungfish and, later, land vertebrates. In this case, the swim bladder would be an evolutionary predecessor of the lungs.
Haeckel shared this discovery with his colleague, whom he revered. Darwin's response, however, sent on 6 February 1868, was rather sceptical: »I do not quite understand what you tell me about his discovery in regard to the swim-bladder […].« As Darwin used the Russian nickname »Miklusˇka« rather than »Miklucho«, the connection to Haeckel's assistant long remained hidden from the history of science. Darwin had a different image of the interrelationships of vertebrates in his head, which contributed to the confusion. He believed that lungfish were the primordial fish from which all vertebrates—including cartilaginous fish, such as sharks—had developed. Darwin believed that the lungs were the original »gas organs«.
Haeckel, however, was largely correct in his version of the phylogenetic tree. Of course, sharks have also undergone certain changes since the first vertebrates appeared, so current sharks are not fully representative of the first sharks.
Yet, there was another point of contention: Darwin did not believe that the evagination discovered by Miklucho-Maclay was a swim bladder rudiment; instead, he thought that it was an undifferentiated structure from which a swim bladder could develop at some later evolutionary stage. Today, researchers broadly agree that Darwin was correct on this point.
»It is rare for two intellectual giants of any science to concern themselves with the research outcomes of an unknown, poverty-stricken student,« says Prof. Dr Uwe Hoßfeld of the University of Jena. Together with his colleague PD Dr Georgy S. Levit, Hoßfeld has been researching Miklucho-Maclay's impact for several years. For him, this rediscovered passage is further evidence of the young Russian's scientific legacy and the influence he exerted on the history of zoology—at the University of Jena and beyond—in only a few years of research before he died aged just 41.

Lungs or swim bladders—that is the question

So, what exactly had Haeckel's assistant discovered? To illustrate this, Tübingen-based evolutionary biologist PD Dr Ingmar Werneburg has analysed cross-sections of shark embryos and can confirm the insights gained in the 100 years of research following the Darwin-Haeckel exchange. »Sharks and other fish breathe through gills, which are connected internally with gill pouches. Today, sharks commonly have five gill openings on either side. Their ancestors may have had more, which is why shark embryos today have some undifferentiated gill pouches as anlagen. They are only visible as small extensions that do not form into gills and instead only protrude to different sides,« says the zoologist. »Miklouho-Maclay found similar features in adult sharks.«
In the course of evolution, these embryonic anlagen have developed into lungs or swim bladders, researchers have concluded. The examination of the over 150-year-old letters caused the author team to reconsider why animals have only developed one of the two gas organs, and why there are no animals with both swim bladders and lungs. This might have to do with the available space within the body cavity, which is in turn determined by the animals' living conditions. »For example, fish that swim in open waters have a more vertical cross-section, which leaves more space in the upper part of their body where an unpaired swim bladder can expand, primarily performing a hydrostatic function,« says Ingmar Werneburg. »By contrast, fish that tend to live on the stony or vegetated bottom of shallow waters are more likely to develop a two-winged lung. Their fins tend to be positioned more sideward, which creates space within the fish for the formation of lateral respiratory organs from two of the lower embryonic protrusions.« ■

Original publication:
Darwin, Haeckel, and the »Mikluskan gas organ theory«, Developmental Dynamics (2023), DOI: 10.1002/dvdy.661

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»Earthquakes« in living cells

Carl Zeiss Foundation supports innovative project targeting 3D analysis of cell interiors with €750,000

The Carl Zeiss Foundation has announced its support for the »Geoscientifically inspired, molecule-specific 3D depth analysis with nanometre solution« project, which includes Prof. Dr Volker Deckert (photo) of the Institute of Physical Chemistry in Jena, as part of its »CZS Wildcard« funding programme. Launched at the start of 2024, the project aims to apply seismic techniques to the minute structures in living cells and thereby gain non-destructive insights into their interiors. The researchers fire pulses of infrared light to trigger nano-»earthquakes« that propagate to the cells' surface in the form of waves, where—the researchers believe—they can be measured. The team initially hopes to develop reference methods during the two-year project term. sl

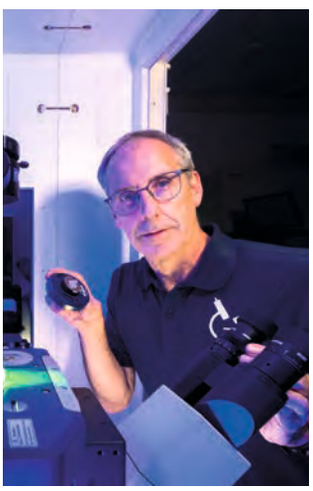


PHOTO: JENS MEYER

Bias detection tool

Federal Ministry of Education and Research supports communication science project

Political bias is commonplace in many public debates today, especially when it comes to controversial topics such as climate change and the COVID-19 pandemic. A team of communication scientists led by Prof. Dr Tobias Rothmund and Prof. Dr Christian Thiel is examining ways to overcome this bias.

Their project »SensipoV—Sensitization for political bias in dealing with political scientific evidence as a challenge for science communication« has now secured funding from the Federal Ministry of Education and Research (BMBF). The researchers' approach involves raising awareness of the problem and developing a tool that anyone will be free to use to check and reflect on their political bias. sh

PHOTO: ANNE GÜNTHER

PHOTO: ANNE GÜNTHER

»DeKarbon«

State of Thuringia provides €980,000 of project funding

A team led by Prof. Dr Martin Oschatz (photo) is working on new methods to capture and convert carbon dioxide (CO_2). The researchers hope their efforts will contribute to reductions in the emissions and atmospheric concentration of the greenhouse gas, which can be harmful to the environment. The state of Thuringia has agreed to support the project through to the end of 2025.

The »DeKarbon« project group is developing new polymer materials capable of filtering and sequestering the greenhouse gas from industrial and power plant exhaust emissions and from the air. The researchers then aim to convert the gas into chemically useful compounds such as methane, benzine, diesel and kerosene. These processes are primarily powered by renewable energy, which renders the whole process sustainable. Krauß

PHOTO: EVELYN SCHONFELD

»Merian-CALAS«

New funding phase for Latin America region centre

From war and the climate crisis to biodiversity loss, crisis is ubiquitous at present. This global phenomenon is particularly acute in Latin America due to the region's extreme social, economic and cultural inequalities. These crises and approaches to solving them will be explored in »Knowledge Laboratory 4« with its focus on »Strategic identities and crisis in Latin America«. It connects researchers at the Jena/Buenos Aires regional centre as part of the »Maria Sibylla Merian Center for Advanced Latin American Studies in the Humanities and Social Science« (Merian-CALAS), a joint project to which the Federal Ministry of Education and Research (BMBF) has provided total funding of €19 million. The regional centre is headed up on the Jena side by Prof. Dr Claudia Hammerschmidt, a Romance studies expert. The project was launched in 2017 and will run until the end of 2025. sl

Super-strong magnetic fields

DFG funds collaborative German-Polish research project on neutron stars

The »MERLIN« project (The Magnetic Field Dynamics in Neutron Stars) has secured around half a million euros in funding from the German Research Foundation (DFG) and the Polish National Science Centre (NCN). It is led by physicist Prof. Dr Sebastiano Bernuzzi of the University of Jena and Prof. Dr Brynmor Haskell of the University of Warsaw, who hope to decipher the configuration of magnetic fields within neutron stars (see image). Neutron stars can form after a supernova explosion, when a star collapses in on itself. The magnetic field of such objects can become a hundred million times more intense than that of the Earth. The specific research questions include whether there is an equilibrium configuration for the magnetic field within such neutron stars. sl

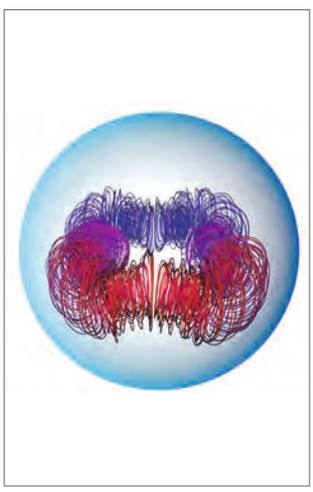


IMAGE: W. COOK

Illustrative numerical experiments

Physicist secures funding for enhanced digital teaching in STEM subjects

Physicist Dr Christin David (photo) has secured funding through the »Fellowships for Innovations in Digital University Teaching« programme. This funding is awarded by the Thuringian Ministry of Science together with the Stifterverband. In her work, David develops illustrative numerical experiments for new students in STEM subjects, especially those studying to become teachers.

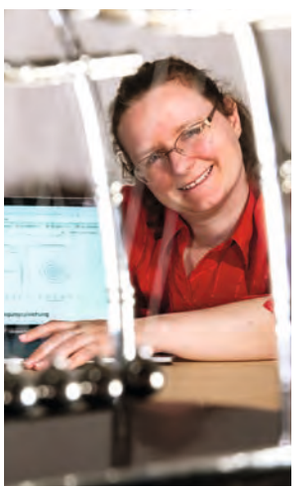
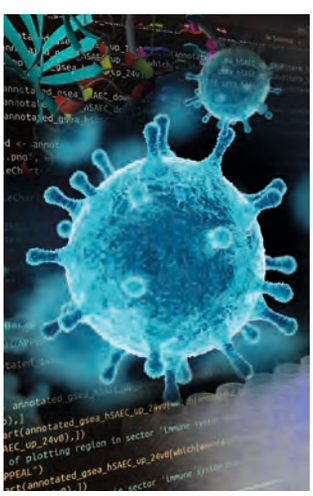


PHOTO: JENS MEYER

»Our aim is to develop new teaching methods and generally provide new ideas and inspiration for teaching,« says Christin David. This includes building virtual experimental set-ups that recreate real phenomena. Students are then expected to convert that set-up into a formula with variable parameters and learn to actively develop programmes that translate these formulas into computer code. sl



COLLAGE: JUH

»APPEAL«

JUH establishes platform for antiviral development

Together with 12 partners from a total of six countries, the Jena University Hospital (JUH) is establishing a European research platform called APPEAL with total funding of €8.1 million from the EU and UK across a five-year term. It is hoped that the platform will help to create a pipeline for the development of antiviral agents as a precaution against future pandemics. In its search for new agents, the team—which is coordinated from JUH—plans to focus its efforts on host cells. This is because there is a far lower risk of pathogens developing resistance to agents that target host cells compared to agents that attack viruses directly. The researchers are striving to identify target proteins in cells, using self-learning algorithms to review and analyse previously published data from high-throughput gene knock-out studies with infected cells. vdG

PHOTO: ANNE GÜNTHER

»Nexus«

Carl Zeiss Foundation funds two projects with €1.5 million each

The Carl Zeiss Foundation has awarded funding for two interdisciplinary research projects at the University of Jena this year through its »CZS Nexus« programme. In February 2024, Dr Sina Saravi (left) secured funding to develop optical neural networks with the aim of making image recognition faster and more resource-efficient. This innovation is similar to an intelligent, nanostructured camera lens.

Since January 2024, Dr Desirée Leistenschneider (right) has been working on a project to develop novel aluminium-nitrogen batteries. In addition to their lightweight design and high energy density, the established recycling processes for the materials involved means these batteries could also be rechargeable.

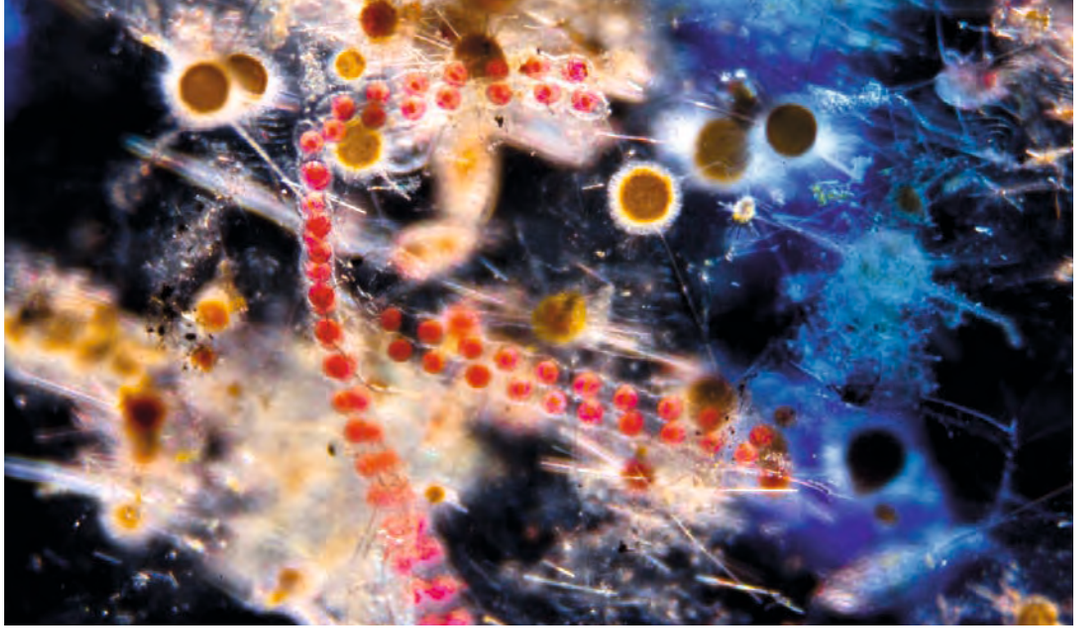
Each research group will receive €1.5 million for a five-year period. MK

The 36-metre-long, two-masted schooner »Tara« docked in Amsterdam in April 2023. Its current mission—»TREC: Traversing European Coastlines«—is scheduled to end in Malta in mid-2024. · Photo: Margault Demasles, Fondation Tara Océan

In-depth research

The crew of the French research vessel »Tara« is sailing along the coasts of Europe until mid-2024, collecting thousands of water samples in an effort to decode the language that microorganisms use to communicate in water. Doctoral candidate Maïa Henry of the University of Jena has been on board for part of the voyage.

BY UTE SCHÖNFELDER



Left: Microscopic image of a plankton community. · Photo: Christian Sardet, Fondation Tara Océan

Bottom: Maïa Henry on board »Tara«. · Photo: Margault Demasles, Fondation Tara Océan

Tiny creatures of huge significance

Microplankton are microorganisms, including bacteria and microalgae, that drift in water and play a vital role in the Earth system, producing a significant proportion of the oxygen in our atmosphere. But that's not all: they also create the building blocks for reefs and coastlines and, as part of the food chain, provide the basis of existence for marine animals, thereby laying the foundations for the fishing industry.

Since April 2023, an international research team has been working on a survey project of vast scale: researchers aboard the schooner »Tara« are sailing along more than 25,000 kilometres of European coastline to collect water samples. In parallel with this, samples are also being taken from the soil and shallow waters along the coast. This expedition—titled »TREC: Traversing European Coastlines«—aims to index all lifeforms in the water, sediment, soil and air along European coasts in order to facilitate a detailed understanding of the interactions and biological functions that connect species and ecosystems. The researchers also hope to examine the impacts of chemical pollutants and climate change on biodiversity in marine environments.

The European Molecular Biology Laboratory (EMBL) is coordinating the expedition in collaboration with over 70 scientific institutions. Around 150 researchers from roughly 30 countries are involved in the undertaking, including Prof. Dr Georg Pohnert of the University of Jena, who is one of the project leaders.

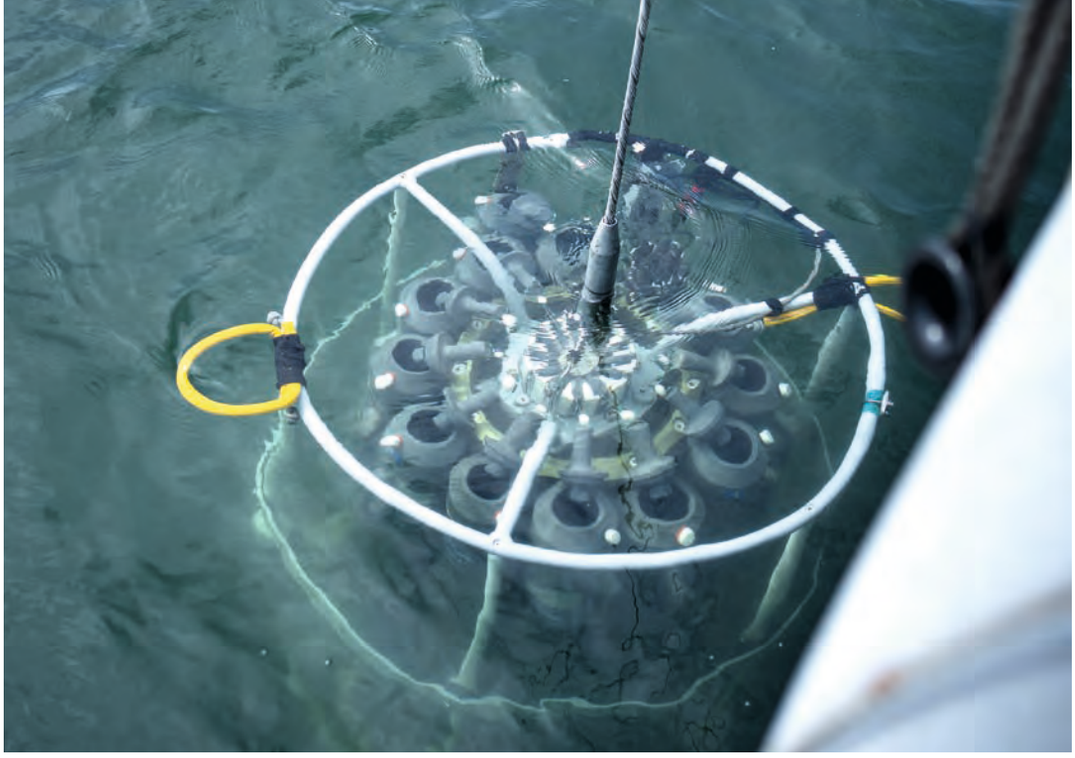
Information about the TREC mission

Seasickness and shift work

Early career researcher Maïa Henry has also spent time on board »Tara«. The 24-year-old is working on her doctoral thesis as a member of Pohnert's team, which is part of the »Balance of the Microverse« Cluster of Excellence. Henry's research, which focuses on the metabolism of marine microorganisms, involves analysing the chemical substances these organisms emit in certain environmental conditions.

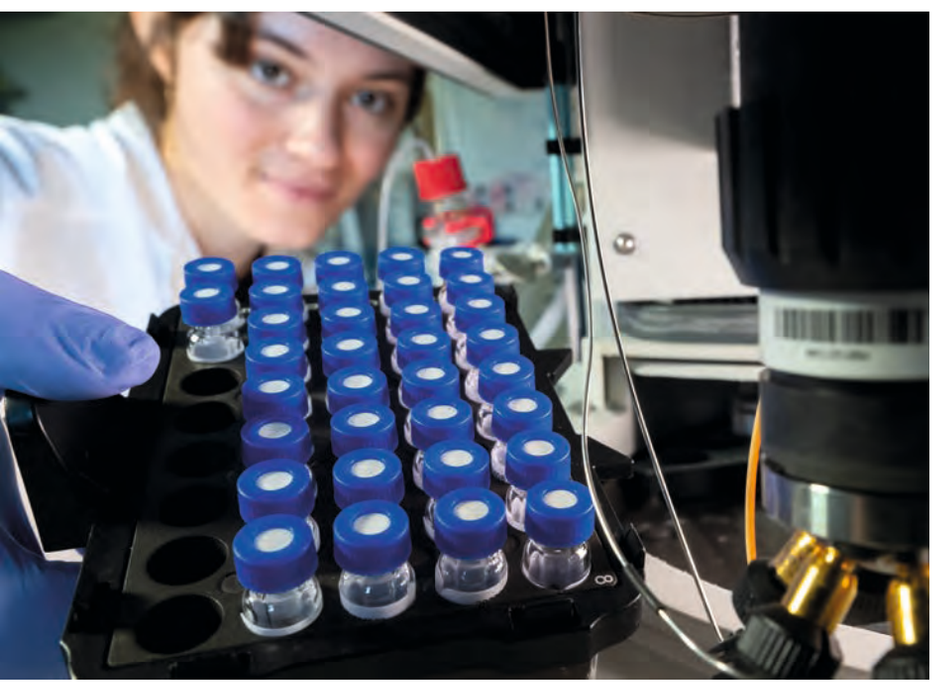
She worked as part of the research crew aboard »Tara« during two stages: from Ostend in Belgium to Aarhus in Denmark, and from Galway in Ireland to Bilbao in Spain. For the entire two months, Maïa Henry—like the other 14 members of crew—worked shifts to conduct her research. However, the duties extended far beyond that: besides collecting and preparing water samples, the team communicated their research to school groups and the wider public, and were also responsible for day-to-day operations, from washing dishes to the night watch.

The crew of the »Tara« work around the clock, seven days a week. Their shift schedule is determined by the tides, so while shifts sometimes start at 8am, others start at 4am. Seasickness—which also proved an issue for Maïa Henry, who had no previous sailing experience of any kind—is no excuse. Everyone on board has a vital role to play.



Right: A rosette sampler, which collects samples of plankton at different depths. · Photo: Margault Demasles, Fondation Tara Océan

Bottom: Maïa Henry examines the samples in the analysis lab. · Photo: Jens Meyer



Searching for chemical traces in the lab

Back on dry land, the thousands of collected samples are extracted and concentrated in the course of further processing. The next step in their analysis involves liquid chromatography-mass spectrometry (LC-MS). Each sample passes through a column in which the individual components of the sample are separated depending on their interactions with the column material. The chemical compounds are then transferred into the mass spectrometer, where they are ionized and analysed depending on their mass-to-charge ratio. The resulting mass spectra are compared against databases, which makes it possible to identify the chemical compounds in the original sample.

The research team is particularly interested in the metabolic products that marine microbes generate, which can provide resistance to certain stress factors. One example is the »ectoine« molecule, an osmolyte that protects certain species of plankton against environmental stresses such as temperature fluctuations and high salinity levels.

Researchers are also collating their data on the chemical composition of plankton communities with insights from other research groups to form an oceanographic map of microorganisms and their chemistry. This data will pave the way for a better understanding of microbial dynamics in the oceans.

Submerged

A rosette sampler is a submersible device capable of collecting samples from different depths of water. It is equipped with a number of sensors that measure a variety of parameters simultaneously, from salt and oxygen content to pressure and temperature.

In addition to this device, the sailing vessel has a range of nets. These include a »Manta« net, which can capture objects floating on the surface, such as plastic waste, and plankton nets, which can capture small organisms at depths of up to 700 metres and bring them to the surface. Changing the mesh size enables the nets to collect different types of plankton. In addition, the team collect water samples from the surface as well as aerosols from above the surface, which can also contain bacteria and viruses.

The water samples are processed while on board. They are pumped through filter cartridges in a multi-stage process, which increases the concentration of the organisms and substances in the water. The samples are then frozen at –20°C and transported to land-based laboratories participating in the project.

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