* EU Research

Winter 2021

EXPANDING THE HORIZON Extra €100 million allocated to Horizon Europe

New President of the ERC Maria Leptin: where research meets politics

Massive Attack: A sustainable road map for the entertainment industry

Technology that reads your thoughts. A look at brain to computer interfaces COP26 review: The key takeaways for the scientific community

Disseminating the latest research from around Europe and Horizon 2020

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* * * * * Editor's Note *



As a seasoned editor and journalist, Richard Forsyth has been reporting on numerous aspects of European scientific research for over 10 years.

He has written for many titles including ERCIM's publication, CSP Today, Sustainable Development magazine, eStrategies magazine and remains a prevalent contributor to the UK business press. He also works in Public Relations for businesses to help them communicate their services effectively to industry and consumers.



B uilding a knowledge thirsty culture through a well-connected network around research has the potential to be more productive than working in isolation. The world spanning work for Covid-19 vaccines proved this. In this respect, the European Union has developed some world leading eco-systems for research to thrive, for industry to connect and for knowledge to expand.

A key part of development is bringing the brightest minds together, to discuss, to exchange and to inspire. Investing resources into these small and large collaborative networks means that innovation has the best chance to flourish. The spirit of learning will always benefit from the hive-mind in hubs that accumulate a range of pioneers in a field. Often, the insular, focused nature of research means key questions, broader perspectives and opportunities can be easily missed without the involvement of others from similar or related areas. How many times have we heard that meetings between researchers in similar fields has accelerated the developments in projects?

For many researchers, the Covid-19 pandemic we have endured and are still enduring has shown us how much this kind of entwined, close collaboration counts, if only because it has been suddenly transformed in nature or been taken away temporarily. Over the course of 2020 and the beginning of 2021, I have spoken to several project coordinators through a webcam, who have said researchers have really missed that close connection of being on the ground with other researchers in other institutions. There is a feeling of lost moments that could count.

It's true that people are tribal in nature, we gravitate to like-minds, to those with aligned goals, with shared ideas and agendas and in research this rings true. Let's acknowledge the importance of these networks and eco-systems in scientific endeavours and let's keep building new ones, as when we do it's when the magic happens, it's when the returns occur and when science becomes a louder voice in the world.

Hope you enjoy the issue.

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© Blazon Publishing June 2010 ISSN 2752-4736



RESEARCH NEWS



The EU Research team take a look at current events in the scientific news

The most important research and innovation announcements

Science plotted the rise of global warming and brought it to worldwide attention. It is now central to dealing with it. With the Glasgow conference now closed, EU Research highlights the key announcements concerning R&D.

To follow the COP26 climate conference in Glasgow is to be caught in a blizzard of new announcements, initiatives and alliances, all with their own acronyms and breathless press releases. But for all the hype, there is plenty of solid research and innovation news to digest, ranging from high-level geopolitics to tech transfer in the developing world. Here EU Research picks through the two weeks of speeches, reports and declarations to summarise the most important statements from the conference - and tries to make sense of what they actually amount to.

Scientific geopolitics

U.S.-China Joint Glasgow Declaration on Enhancing Climate Action in the 2020s

In a surprise move at the end of the conference, Beijing and Washington agreed on the need to cooperate on "climate technology innovation" and in areas like carbon storage and air capture. While an improvement on the frosty relations that prevailed at the start of COP26 – president Xi Jinping didn't even attend – the declaration doesn't change the fact that China, the world's biggest polluter, still has not signed up to a number of key initiatives unveiled in Glasgow, such as the Global Methane Pledge, brokered by the US and EU to cut emissions by at least 30 per cent by 2030.

US-UK strategic energy dialogue

Originally agreed by Joe Biden and Boris Johnson back in June, COP26 saw the UK and US officially launch a series of regular dialogues to "deepen collaboration" in areas like clean energy technology, nuclear, energy security, and science and innovation. Exactly what, if anything, substantial will emerge from the chats is unclear, but the next ministerial get together is scheduled for "spring 2022".

This wasn't the only example of the UK cosying up to the US at COP26, just as future British research links with the EU remain under a cloud due to continued uncertainty over UK association to Horizon Europe. The pair also announced a partnership on quantum research that will see them exchange staff and students.

Clean technology diffusion

The Glasgow Breakthroughs

The goal of the 'Glasgow Breakthroughs' is to make clean technologies the cheapest and most accessible option globally across four heavily polluting sectors: power generation, road transport, steel, and agriculture, plus to make clean hydrogen "affordable" and "globally available" by 2030. The commitments are pretty broad rather than specific. The goal for zero-emissions vehicles is for them to be the "new normal" by 2030. The initiative involves a sprawling network of already existing groups, but environmental campaigners are pleased that neglected but polluting sectors like steel are finally getting the attention they deserve. The US and EU are on board in every sector, but China has only signed up for the hydrogen breakthrough.

Global Energy Alliance for People and Planet This is a \$10 billion initiative to try to create investible renewable energy markets in poorer countries, where currently, because of logistics, infrastructure and financing problems, renewables aren't competitive with fossil fuels. But even advocates admit it's a drop in the ocean compared to how much money is needed to actually scale up green power in the developing world.

The hope is that the alliance, backed by the Rockefeller Foundation, the furniture company IKEA, and Jeff Bezos's Earth Fund, can help governments set up the right policy to support renewables, allowing the private sector to then steam in with billions if not trillions of dollars.

Private sector to the rescue?

Glasgow Financial Alliance for Net Zero

Former Bank of England governor Mark Carney has managed to get more than 450 firms, including banks, pension funds, asset managers and pension funds, to commit to "transforming the economy for net zero". Collectively managing over \$130 trillion of private capital, if these institutions channel their investments towards clean energy rather than fossil fuels, the world might finally have the financial firepower needed to transition to a green economy. But there is scepticism from environmentalists. French campaigning group Reclaim Finance released a report that found the alliances headed by Carney do not actually prohibit investments in fossil fuel expansion.

The First Movers Coalition

Twenty-five of the world's biggest companies, including Amazon, Apple and Boeing made a series of purchasing commitments to buy green technology in areas that are hard to decarbonise, like road freight, shipping and steel. The idea is to convince investors that there will be a market for clean technologies that are still not yet mature. But the numbers involved are still pretty small. By 2030, first mover companies that buy steel will ensure than "at least 10 per cent" of it is produced in a "near-zero emissions" way. Airlines will replace at least 5 per cent of conventional jet fuel with sustainable alternatives by the same date.

Adaptation and agriculture

The Adaptation Research Alliance

Climate change is already happening, but there is concern that the latest research about how to adapt to heatwaves, floods, rising sea levels and other impacts isn't getting through to the people on the ground. This is the motivating force behind the Adaptation Research Alliance, a grouping of 90 organisations, mainly aid agencies, but including a handful of universities too. There is no word on whether the alliance will receive any more funding itself, but the UK and Canada also pledge an extra CA\$170 million for "action-orientated research" into climate adaptation through a new partnership, called Climate Adaptation and Resilience.

Agricultural reform and innovation

The UK government committed to a grab-bag of new research spending to try to make agriculture and land use more sustainable. It pledged £38 million for CGIAR, a global agricultural research organisation. There will also be up to £40 million for a new "Global Centre on Biodiversity for Climate", which will address "critical research gaps" in biodiversity and conservation scholarship.

Transatlantic Collaboration Platform on Agriculture The EU and the US have diverging views on the use of new technologies such as precision breeding and gene editing, but Brussels and Washington agreed during COP26 to work more closely together on climate change and agriculture, including how science and innovation can make farming more sustainable.

Controversial and emerging tech

The US's long-term net zero strategy

Speaking at the beginning of COP26, Joe Biden unveiled a new report that sets out exactly how the US will reach net zero by midcentury, and crucially, which technologies will be in the mix. There are repeated mentions of nuclear power, and more speculative tech that can suck carbon from the atmosphere, despite warnings in the very same report that this is currently very far from being ready for wide-scale deployment.

Small modular reactors

The US announced it would build a trial nuclear small modular reactor in Romania to help decarbonise and secure the country's energy supply. Although the mini reactors are still a relatively unproven technology, they promise to be easier to deploy than conventional reactors, as they can largely be assembled in a factory beforehand. The UK also said it would contribute £210 million towards them.



Bushfires below Stacks Bluff, Tasmania, Australia / Photo by Matt Palmer on Unsplash.





IN PARTNERSHIP WITH ITALY



EU teams up with Bill Gates in €820M climate tech investment deal

The EU-Catalyst partnership aims to scale up and create markets for green technologies. The Commission hopes the partnership will serve as a template for similar initiatives around the world.

The European Commission and the European Investment Bank (EIB) are to join the Bill Gates Breakthrough Energy initiative, in a €820 million deal intended to put some impetus behind the scale-up of critical climate technologies developed in the EU and create markets for them.

The new EU-Catalyst partnership will enable the Commission, EIB and Breakthrough Energy to mobilise up to €820 million between 2022-2026 to accelerate the deployment and rapidly commercialise technologies that help the EU reduce carbon emissions by 55% by 2030. "We will support the so-called Green Premium, that is the additional cost that companies face by taking the risk of deploying new technologies," EU president Ursula von der Leyen told delegates at the COP 26 conference in Glasgow on Tuesday. Not all the money will come from the EU budget, EIB and Breakthrough Energy, as the three partners expect private investors and philanthropists to join the cause.

New green technologies that could cut EU emissions are ready for translation, but could take too long to reach the market without additional investments. New climate technologies are often expensive to produce and their markets are too small, posing particular problems for undercapitalised EU-based start-ups. The EU aims to reduce the financial risk for companies by propping up their business models until they can be scaled up. Money will go into projects across four sectors of clean hydrogen, aviation fuels, carbon capture and energy storage. The EIB will receive an EU budget guarantee from the Commission and, together with Breakthrough Energy, will provide equivalent amounts of investment in projects selected on a competitive basis.

Breakthrough Energy, founded in 2015 by billionaire philanthropist Bill Gates, invests in companies that have the potential to speed up innovation in sustainable energy and other technologies that could help reduce CO_2 emissions. So far, Gates said, the fund has raised over \$2 billion and funded over 80 companies from 11 countries, across four continents.

Speaking at the COP 26 conference alongside Von der Leyen, Gates said additional investments are needed to scale up net zero innovations and to reduce the cost difference between current products and their green competitors. "The cost of transition must be low enough that the whole world can afford it," said Gates. Von der Leyen said she hopes the Breakthrough fund will serve as a template for similar initiatives around the world. "I am especially glad that at this COP 26, finally, we prioritise the importance of innovation, because it's only through innovation that we're going to get to our goal of net zero," she said.

US president Joe Biden announced a similar initiative at COP26 on Tuesday, saying the US and the World Economic Forum will launch the First Movers Coalition, a group of two dozen of the world's largest and most innovative companies, including Apple, Boston Consulting Group, Volvo, and Fortescue Metals Group, which have committed to scaling up climate innovations.

Biden hopes these companies will help the US push for commercially viable ways to decarbonise industrial cities. "We recognise that our current technology alone won't get us where we need to be, so it must also be a decisive decade for innovation, developing, demonstrating and commercialising new clean energy technologies by 2030," he said. The Biden administration has previously announced efforts aimed at quadrupling funding for clean energy research and development over the next four years. The US has also announced a \$4 billion global agriculture innovation mission together with United Arab Emirates and 75 other partners. "I invite all of you to join us, working to double the investment by the time we meet at COP 27," said Biden.

New head of ERC says 'Politicians shouldn't meddle'

Developmental geneticist Professor Maria Leptin says her priority is to keep the European Research Council true to its founding mission.

On 1 November, Maria Leptin will become the new head of the European Research Council (ERC), Europe's premier funding agency for basic research. Leptin, whose background is in developmental genetics, previously served as director of the European Molecular Biology Organization, Europe's life-sciences organization, based at the European Molecular Biology Laboratory (EMBL) in Heidelberg, Germany. She will take over from interim president Jean-Pierre Bourguignon, following the brief and controversial tenure of nanobiologist Mauro Ferrari, who resigned in April last year. Leptin spoke about her plans for the ERC, its role in European science and its significance for early-career researchers.

What are your top priorities as incoming president? The ERC is a fantastic organization with fantastic aims and a fantastic staff. I know it well from having been on panels, and I wouldn't dream of coming in and saying we have to change everything. My first aim will be to keep the ERC stable and emphasize its strength. Of course, there are always things that can be improved, such as attaining broader public engagement. The ERC's service to the scientific community might need tweaking, because different fields have different needs.

The ERC aims to be independent from politics. What is your plan to keep the ERC true to its founding mission? I'm hoping this doesn't need a plan. We have sufficient examples to remind people of how important it is not to meddle with the autonomy of basic research. Everybody recognizes that COVID-19 vaccines were developed so fast because a range of fields, which had been receiving basic-research funding for a long time, suddenly came together. It illustrates that necessary and topical science comes bottom-up from the best scientists.

New methods have been arising, for instance in genomics or data management and statistics, that allow researchers to do or study things that would have been impossible ten years ago. At the ERC, we will look at all types of research, from the humanities to physics and biology.

How will you promote the value of basic research? That's really not easy, and I wouldn't say that I have a recipe. The ERC's budget is decided by EU member states but also by the European Parliament, and parliamentarians listen very strongly to their home constituencies. It's clear that the public needs to realize what basic research is about and what it does for them. We will have to think very hard about new routes to get to the public — and it's not just going to be senior people giving lectures. One way to get there is working with locally engaged media experts that reach the people who need to be reached.

Do you envision special ERC programmes, such as on climate or COVID-19 research?

All I can say is give the best researchers a chance to come up with ideas that they want to pursue. When something unforeseen happens in ten years' time, then people will have access to a lot of good stuff that's been done. COVID-19 and climate change are just the best examples we have.

But I would not go for top-down research. We have programmes for that, including the European Innovation Council and the rest of Horizon Europe, the European Union's seven-year research programme. Not all research is there for exploitation. If scientists find out about the history of the Lascaux caves, discover the Higgs boson or work out how people lived in Pompeii, that's just exciting, and people love hearing about it. There is an inherent sympathy for human curiosity in citizens, and I think we have to point that out. It's not just about curing the next disease or saving us from climate change. ERC funding is very sought after by early-career scientists, but success rates for starting grants are very low (13.5% in 2020). What's your plan to keep young researchers happy? Well, I think all researchers should be kept happy. Of course I'd like to be able to fund more of them. I also would like to not let them fall off a cliff after getting their first starting grant, when they apply for consolidator or advanced grants and find out it's even tougher to get one (2020 success rates were 13% and 8%, respectively). For every funding call, there are lots of good proposals that cannot be funded. I really would like the award rates go up, but there's only two ways to do this: you have either fewer applications or more money.

An interview for an ERC starting grant is a potentially career-defining moment for an early-career scientist. What's your advice for a nervous applicant? You'll be nervous; there's nothing you can do about it. If you're not nervous, you might come across as arrogant — which is the worst thing. Be as honest and well-prepared as you can be. The committee will see through gloss and bad preparation. If you have a good project and know the background well, the committee will recognize that.

The United Kingdom and Switzerland are still negotiating access to Horizon Europe. What does this mean for grant applicants from these countries?

We are all desperately hoping that Switzerland and the United Kingdom will associate with Horizon Europe. We care about our colleagues in these countries and their science, and we want them in the ERC. At the moment, UK-based researchers can apply for funding, but grants can be awarded only once the association agreements have been signed.

Do you think it would be better to keep politics out of science? It's the prerogative of elected governments to determine what goes on in their constituencies, and if science is part of that they should have a say. But politicians who are not trained in science should not meddle in our day-to-day business, or tell scientists what's right or wrong. I would see it as my duty to explain to politicians what's best, and to get them to realize that. They distribute the money, so we have to make them understand what's good for people, rather than say, "Just stay out."

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Extra €100 Million approved for Horizon Europe in 2022

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European Parliament gets Council to agree on increase to Horizon Europe budget.

The EU's research programme Horizon Europe will receive an additional €100 million (£84 million) next year following negotiations over the bloc's budget. The agreement will see support for the programme rise to €12.2 billion in 2022. Horizon Europe is the EU's main mechanism for financing fundamental research and innovation across the continent. The programme, launched this year to replace the previous Horizon 2020 initiative, will see almost €100 billion invested in research over seven years.

Representatives of the European parliament and the Council of the European Union have now reached an agreement over the EU's budget for 2022 that includes greater support for the Horizon programme. The move comes after MEPs sought to increase spending on programmes that are considered key to the

post-pandemic recovery. Horizon Europe will be granted €100 million above the amount originally planned in the European commission's draft budget. The EU's Life programme – which provides funding for environment and climate action – will receive an additional €47.5 million taking its annual budget to €755.5 million. Meanwhile the Erasmus+ student exchange scheme will receive an increase of €35 million to its €3.4 billion annual budget.

The Parliament and Commission are also trying convince member states to invest more money from their national budgets in R&D. Countries are expected to commit to a non-binding pact to raise R&D public expenditure from 0.81% to 1.25% of GDP by 2030, as the Commission wants more member states to increase public and private R&D expenditure to 3% of their GDP.

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A Spotlight on Long Covid

What researchers say about the long-term effects of COVID-19.

The World Health Organization (WHO) has issued a definition for "long COVID," a term used to describe the persistent health problems that affect some survivors of COVID-19. Scientists are still working to understand the syndrome. Here is what they know so far.

The WHO defines long COVID as a condition with at least one symptom that usually begins within three months from the onset of confirmed or probable infection with the coronavirus, persists for at least two months, and cannot be explained by another diagnosis. Symptoms may start during the infection or appear for the first time after the patient has recovered from acute illness. Among the most common persistent symptoms are fatigue, shortness of breath, and cognitive problems. Others include chest pain, problems with smell or taste, muscle weakness and heart palpitations. Long COVID generally has an impact on everyday functioning. The WHO's definition may change as new evidence emerges and as understanding of the consequences of COVID-19 continues to evolve. A separate definition may be applicable for children, the agency said.

The exact number of affected people is not known. A study from Oxford University of more than 270,000 COVID-19 survivors found at least one long-term symptom in 37%, with symptoms more frequent among people who had required hospitalization. A separate study from Harvard University involving more than 52,000 COVID-19 survivors whose infections had been only mild or asymptomatic suggests that long COVID conditions may more often affect patients under age 65. More than 236 million infections caused by the coronavirus have been reported so far, according to a Reuters tally.

In a study published in the Lancet, Chinese researchers reported that 12 months after leaving the hospital, 20% to 30% of patients who had been moderately ill and up to 54% of those who were critically ill were still having lung problems. The Harvard study also found that new diagnoses of diabetes and neurological disorders are more common among those with a history of COVID-19 than in those without the infection.

Many symptoms of long COVID resolve over time, regardless of the severity of initial COVID-19 disease. The proportion of patients still experiencing at least one symptom fell from 68% at six months to 49% at 12 months, according to the study published in the Lancet. The WHO said long COVID symptoms can change with time and return after showing initial improvement. Small studies have suggested that some people with long COVID experienced improvement in their symptoms after being vaccinated. The U.S. Centers for Disease Control and Prevention said more research is needed to determine the effects of vaccination on post-COVID conditions.

Forgotten your password? Why your brain won't let you remember

Multiple experiments in a new study indicate certain kinds of information never enter working memory.

Whenever you reset your email password, you probably don't remember the temporary one—that autogenerated, meaningless string of numbers and letters. You pay careful attention to typing it only as you log in, before thinking up a new permanent password—maybe a fresh variation of your childhood pet's name.

It's not clear whether this kind of information, which individuals must pay careful attention to but isn't needed in the future, enters the working memory. Researchers at Zhejiang University in Hangzhou, China wanted to see if it does. Through multiple experiments, the researchers discovered that human brains may have mechanisms that block this kind of information from staying. In fact, their research published on November 19 in Science Advances found that people are more likely to remember information they deliberately ignored than the kind of information they pay attention to once and don't expect to need in the future.

"Our brain seems much more selective than we believe," says Hui Chen, one of the study authors and a researcher in behavioural psychology. Chen explains that even when people pay close attention to detail, these details might not stick. To test whether these kinds of details enter working memory-the temporary information holder in your brain-the team carried out various trials testing the participants' memories. The scientists presented subjects with information they were either told to pay attention to or ignore. For example, the researchers presented participants with coloured shapes, and told them to ignore the shape but pay close attention to the colour.

Participants immediately did multiple tests to evaluate exactly what they were remembering. One test asked them to look for a tilted line within four images of shapes, but either the colour, shape, or both colour and shape of one image was the same as initially presented. The researchers knew that any characteristics in participant's working memory would be distracting, according to previous research, and increase the time it took participants to find the tilted line they were looking for. Another test showed them the same shape and asked whether the colour changed.

People were distracted by and recalled what they were told to ignore-the shape-better than what they had been told to pay attention to. The study authors conducted six different variations of these tests, using different sample sizes, recording eye movements, and more, to see whether the results were repeatable. "Our study shows that people were automatically encoding shapes in the working memory," says Chen. Furthermore, people were not storing key features they were told to pay attention to, such as colour, in their working memory.

Chen explained that these results could have major practical implications in two ways: First, many treatments for people with PTSD involve tactics to help forget experiences by not thinking about them, but this study shows that giving memories some attention may be worth pursuing or studying in treatment. Second, this research contributes to continuing conversations on eyewitness testimony and its potential inaccuracies, including careful analysis of just how well individuals actually recall memories when asked to pay close attention.

"Our studies tell us that we should be very careful about memory, especially for those details and information, because our brain is very, very selective," says Chen. Your brain might not be remembering that temporary string of passcodes, but it remembers more than you think.



Bouncing back from breast cancer

A diagnosis of breast cancer can lead to other significant psycho-social problems, causing anxiety and depression in some patients. Researchers in the BOUNCE project are developing a model of patient resilience that can then be used to guide decision-making and help patients to bounce back to healthy functioning and maintain satisfactory quality of life while facing breast cancer, as **Dr Paula Poikonen-Saksela** from Helsinki University Hospital explains.

A diagnosis of breast cancer is often upsetting for the individual concerned, and alongside the direct implications for physical health it can also lead to psychological problems such as anxiety and depression. "The results of the BOUNCE project can enhance adaptive coping and resilience trajectory and support patients to maintain their everyday lives and functioning in various life domains while they complete their course of treatment." says Dr Paula Poikonen-Saksela, the project's coordinator. The Bounce project is an international initiative, in which researchers from five different countries are studying breast cancer patients who have been recently diagnosed with early

stage breast cancer, and have good prospects of a full recovery. "The aim is to facilitate the resilience trajectory from the very beginning of the oncological treatment, outlines Dr Poikonen-Saksela.

Bounce project

Naturally, there is a large variability in the ways patients respond to their initial breast cancer diagnosis and this heterogeneity is likely to be based on their personal characteristics, the severity of the medical situation, and their supportive resources. The aim in the project is to develop a model of personal resilience to breast cancer, focusing specifically on women between the ages of 40-70. "Breast

cancer is rare in women under the age of 40, and we decided to include in our study typical breast cancer patients. The median age of breast cancer patients is around 60," says Dr Poikonen-Saksela. The Bounce project targets different multi-faceted aspects of resilience in the various domains of life and functioning such as anxiety and depression symptoms, sense of coping efficacy, flexibility in coping, functional impairment, compliance with medical treatment and perceived support. "We consider resilience as a potential that can be built and change over time and we are keen to enhance the related factors to facilitate healthy trajectory of coping with breast cancer. Resilience is manifested in everyday life in the form of optimal mental health and overall quality of life," outlines Dr Poikonen-Saksela.

Researchers in the BOUNCE project are currently analysing data gathered from patients from four oncological medical centres in Italy, Portugal, Finland and Israel. Dr Poikonen-Saksela highlights that, alongside the medical information on these patients, the researchers are examining the interrelationships between the different aspects of their psycho-social and physical wellbeing. "We have conducted a prospective study over 18 months of coping with breast cancer, collecting information every three months, from the start of treatment." These questions were focused on different aspects of the patients' background and context, responses and system of support. The BOUNCE consortium collaborates in analysing significant impact on individual resilience, including cross-cultural context and the influence of various lifestyle, diet and exercise habits.

The comprehensive data base will be incorporated in the development of an innovative predictive model that will reveal the most important parameters affecting resilience trajectory and wellbeing. Artificial intelligence and other advanced methodological methods are used to develop an algorithm that integrates all suggested resilience factors. The aim is to create models which will reveal the most important parameters for patient resilience trajectory and wellbeing. "Our early results so used to provide information and help patients cope better," she outlines. However, it's also important for patients to maintain contact with others facing similar challenges. "For example, we can suggest group meetings and other interpersonal options for contacts with peers," continues Dr Poikonen-Saksela. "Personal face-to-face meetings will definitely be needed for optimal care for patients with special needs and disabilities."

Decision support tool

Digital services can relieve the pressure on healthcare services who are already overburdened due to the pressures caused by the ongoing COVID-19 pandemic, and may help to improve the existing services. The goal of the project is to develop a feasible and practical model of decision making tool that will help clinicians assess patients and support their recovery. "We are particularly interested in patient trajectories. How are they doing over time, constantly well or badly, or are there fluctuations. Is their wellbeing increasing or decreasing?" says Dr Poikonen-Saksela. As mentioned above, the project will produce algorithms and predictive models to predict patient resilience, which can then be used to inform decisions on interventions. "The models will help clinicians to identify which interventions will best support individual patients, and that can also make treatments more effective." outlines Dr Poikonen-Saksela.

The BOUNCE project is about the development of **innovative predictive model and decision support tool** that will help clinicians assess the **resilience trajectories** of breast cancer patients and **support their recovery**.

far suggest that psycho-social characteristics are particularly important in terms of patient resilience and quality of life," says Dr Poikonen-Saksela. Personal lifestyle might also be of importance. "We can educate patients about their lifestyle and give them information about changes they could make to boost resilience in addition to psychological support. That's the type of intervention we could further develop," says Dr Poikonen-Saksela.

Unfortunately the number of people diagnosed with cancer is increasing, says Dr Poikonen-Saksela. However, Dr Poikonen-Saksela believes that educating patients can have a positive impact on the way individuals cope with cancer and can enhance their personal resilience. This will likely lead to wider benefits for the healthcare systems. "We need to allocate the available resources effectively, so I think there is a place for patient education. Digital services can be

A set of guidelines for clinicians are being drafted in the project, which are designed to help clinicians identify the most appropriate interventions for individual patients, based on their personal circumstances and background. This is particularly important in the context of demographic changes which will lead to more people being diagnosed with cancer in future. "With the aging population and new screening techniques, more people are being diagnosed," explains Dr Poikonen-Saksela. A model capable of predicting patient resilience holds great potential in these terms, helping improve efficiency in healthcare systems, and Dr Poikonen-Saksela hopes to look into the possibility of more clinical application and broad dissemination in the future. "After completion of the project new possibilities will emerge for wide implantations and perhaps commercialising the product. That's definitely something we will further explore," she says.

BOUNCE

Predicting Effective Adaptation to Breast Cancer to Help Women to BOUNCE Back

Project Objectives

 To built a predictive model of resilience, a decision-support tool to be used in routine clinical practice to provide physicians and other health professionals with concrete, personalized recommendations regarding optimal psychosocial support strategies at the correct time point.

Eventually increase resilience in breast cancer survivors and help them remain in the workforce and enjoy a better quality of life.
To further develop the operational model and the care path for breast cancer patient.

Project Funding

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 777167.

Project Partners

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Paula Poikonen-Saksela



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How does Hydra regenerate?

A type of freshwater organism, the Hydra appears to be completely ageless, with a remarkable ability to regenerate and renew after suffering injury. Researchers at the Friedrich Miescher Institute for Biomedical Research are using chemical screens to gain deeper insights into the underlying mechanisms behind this regenerative capacity, as **Dr Charisios Tsiairis** explains.

Hydra is an important model system in biology, with many researchers deeply interested in its remarkable ability to regenerate itself after suffering an injury. While the Hydra is a very good model system, it has one major shortcoming in comparison to others like Drosophila or C.elegans, which are also widely used in research. "It's not practical to do genetic screens using Hydra. It's not very easy to cross Hydra between themselves, to achieve reliable production of eggs and sperm," explains Dr Charisios Tsiairis, a researcher in self-organising cellular systems at the FMI in Basel. Instead of doing a genetic screen, Dr Tsiairis is using chemical screens to gain deeper insights into the regenerative capacity of Hydra. "We know that many chemicals have specific functions in inhibiting certain kinases, transcription factors, or receptors, and so on. If we can get

a big library of these chemicals, and expose Hydra to them separately, then we could identify the effect of disturbing the product of a certain gene," he outlines.



Hydra regeneration

This will help researchers identify the specific chemicals that disturb the proper regeneration of the Hydra, as well as those that enhance

or accelerate it. With the chemical screen. researchers first bisect the Hydra, then place them under different conditions. "We examine which conditions allow these Hydras to regenerate, and also how fast," says Dr Tsiairis. Normally a Hydra takes four days to regenerate, and now Dr Tsiairis aims to identify which factors may slow this down or speed up regeneration, using large-scale chemical screens. "The big challenge with screens like this is doing it in a high-throughput manner. We plan to screen about 4,000 chemicals and for a lot of conditions, so we want to find ways to do this automatically," he says. "It's a high-throughput screen, so we don't want to have to identify the ideal concentration for every single chemical, as that would be highly time-consuming. We have conducted a preliminary screen to pick out what would be a good concentration for the majority of chemicals, and we are using this concentration throughout."

The main priority then is to compare these animals and assess whether they are regenerating normally. Researchers are developing machine-learning algorithms to do this in an automated manner. "Ideally, we want to train a system to identify which Hydras are regenerating properly and which are not," explains Dr Tsiairis. Proper regeneration here relates to the appearance of specific elements of the body. "For example, a non-regenerated Hydra lacks tentacles. We expect our regenerating Hydras to have developed tentacles within four days. If they haven't, then we clearly have a hit," continues Dr Tsiairis. "The regenerative process could also be sped up by some chemicals. Normally it takes four days, but we may find that some Hydra successfully regenerate in just two days. These Hydras might also start regenerating supernumerary heads, as well as additional or ectopic tentacles. This is not good for the animal, but it can help us understand how the genetic make-up of the Hydra enables the organism to regenerate."

considered a peripheral behaviour of the animal, Dr Tsiairis says recent research suggests the contrary. "What we have been finding recently is that this mechanical response is important for activating the wnt pathway, which we know is central to regeneration," he says. One of the goals of the chemical screen is to identify genes, or factors, that enable cells to transform mechanical signals into signals compatible with the wnt cascade. "This screen is ongoing, and so far we have identified several factors which are important in terms of regeneration," continues Dr Tsiairis. "Besides wnt signalling, we see that FGF (fibroblast growth factor) signalling is also important - this is another way by which cells communicate. If we eliminate the cellular receptor for these signalling factors, problems emerge in regeneration."

A deeper understanding of these signalling pathways could open up new insights into how humans and other animals regenerate, which is a major point of interest among many researchers. Alongside systematically

A non-regenerated Hydra lacks tentacles. We expect our regenerating Hydras to have developed tentacles within four days. If they haven't, then we clearly have a hit.

Researchers can then follow-up on these initial results with more detailed investigation of the chemicals that have been identified in the screen. A chemical that inhibits a receptor or channel has to be verified; if the gene responsible is known then it can be eliminated, and the chemical hit can be verified. "Then we can see how a mutation works in different environmental and genetic backgrounds," explains Dr Tsiairis. This would help researchers understand not just which genes are important for regeneration, but also how those genes are incorporated in the system and what they do to help or hinder regeneration; Dr Tsiairis believes this may hold relevance to wider biomedical questions. "For example, we already know that the wnt signalling cascade is involved in Hydra regeneration. This signalling cascade is also known to be important in many human pathologies, including certain types of cancer," he outlines.

Mechanical response

Hydra need mechanical stimulation in the form of stretching to stimulate its regenerative mechanisms, a topic Dr Tsiairis is exploring. While this was previously cataloguing the genes that play an important role in Hydra regeneration, Dr Tsiairis hopes to gain new insights into how cells in Hydra communicate. "We are interested in understanding how Hydra are able to read mechanical inputs, and to incorporate mechanical information for regeneration," he says. A second major goal is to demonstrate that this chemical screen approach can also be used for other types of analysis. "We want to show the feasibility of this approach, for example in investigating the formation of a nervous system, and this may open up more research avenues," continues Dr Tsiairis. "I also want to draw comparisons between the regeneration of Hydra and other regenerating systems."

This could potentially extend to certain human conditions, such as how the gut regenerates after an injury. However, Dr Tsiairis says it is essential to first learn more about Hydra if such comparisons are to have solid foundations. "We know a certain amount about the genes and proteins involved in regenerating the gut and how cells behave. We want to be able to compare this to how the Hydra cells behave, and how they respond," he says.

CHEMICAL SCREEN ON HYDRA REGENERATION

Chemical Screen on Hydra Regeneration

Project Objectives

How do cells build tissues? This is the fundamental question we try to address, and Hydra offers a great relevant system to study. Small groups of Hydra cells can regenerate a complete animal. It is unclear how the cells communicate to split responsibilities and a chemical screen offer the opportunity to uncover some of these mechanisms.

Project Funding

Our lab is funded by the FMI. The chemical screen is funded by an SNF grant (31300A_182674)

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Dr Charisios Tsiairis

Dr Charisios Tsiairis was born in Greece and studied biology at the University of Patras. He received his PhD from Harvard University on developmental biology. After postdoctoral work on Hydra and mouse development in Heidelberg, he established his lab on "Self-Organizing Cellular Systems" in the FMI Institute in Basel.



Friedrich Miescher Institute for Biomedical Research



Fonds national suisse Schweizerischer Nationalfonds Fondo nazionale svizzero Swiss National Science Foundation

New T-cell targets in Multiple Sclerosis

Destruction of the myelin sheath that insulates nerve cells is known to cause the symptoms of multiple sclerosis, yet the underlying cause of the disease is unclear. We spoke to **Prof Renaud Du Pasquier** and **Dr Sylvain Perriot** about their research into how this damage to myelin occurs and its wider importance to the treatment of multiple sclerosis.

The underlying cause of multiple sclerosis is not fully understood, yet researchers do know that one of the first events is the invasion of the central nervous system by immune cells, leading to the degradation of the myelin sheath which surrounds axons. This degradation disrupts normal signalling processes, leading to the symptoms that can be observed in patients with multiple sclerosis (MS). "It's the destruction of the existing myelin that causes the symptoms of MS," says Dr Sylvain Perriot, a researcher in the laboratory of neuroimmunology at Lausanne University Hospital. In this research headed by Prof Du Pasquier, the team is now investigating how this damage to myelin occurs, work which holds wider relevance to the treatment of MS. "We know that these immune cells enter the brain, and we have an advanced picture of the composition of those cells. But we don't know about the mechanisms by which the myelin is disrupted," he outlines.

CD8+ T cells

One hypothesis is that CD8+ T cells, immune cells that form an important part of our immune defence, are the primary actors in this destruction. CD8+ T cells can recognise and kill cancer cells, while they also kill cells infected with viruses, using HLAs (human leukocyte antigens) expressed on the surface of cells to identify which should be destroyed. "These HLAs are expressed by your cells. On those molecules there are some peptides - little pieces of proteins - that are produced by the cells and presented on it. When a CD8+ T cell recognises one as foreign to the body, it destroys the accompanying cell, to prevent the development of cancer or infection," explains Dr Perriot.



With only 10ml of blood from any donor, we can generate induced pluripotent stem cells and differentiate them into brain cells: astrocytes, neurons and oligodendrocytes. This allows us to put them in culture with fully autologous CD8+T cells from the same blood draw and assess if these T cells do recognize one or several brain cell types.

Prof Du Pasquier's group is investigating the theory that in MS patients, this system is not functioning well in CD8+T cells. "Our theory is that for some reason those cells recognise peptides of the body as foreign, and so they are destroying these cells," outlines the researcher.

This would lead to the destruction of oligodendrocytes, the cells responsible for producing the myelin sheath, indirectly causing damage. Because the CD8+ T cells recognise their targets on the basis of this HLA complex which is unique to each person, it's essential to have the target cell and the CD8+ T cell from the same donor in order to ensure compatibility. Since it is impossible to obtain biopsies of brains from MS patients and, that this is a difficult area to investigate using recombinant proteins or other classical immunological techniques, Dr Perriot and colleagues are using human induced pluripotent stem cells (iPSCs) to probe deeper. "With iPSCs we can change any cell from a given donor into a pluripotent

stem cell. This means that this stem cell has the ability to differentiate into any cell of the human body," he says. Researchers draw blood from patients, culture cells in vitro, then re-programme them into pluripotent stem cells. "Then, again in vitro, we re-differentiate these cells into brain cells," continues Dr Perriot. "So we can have access in the petri dish to all the different cell types from the brain, in a completely autologous manner, i.e. having a full HLA compatibility with the donor's CD8+ T cells."

Induced pluripotent stem cells as T cell targets

Researchers are currently refining the experimental set-up. First, they need to actually differentiate these human iPSCs into brain cells which is not an easy task to do. "The reprogramming part of the process takes a long time but we can rely on wellestablished protocols and does not pose any difficulty anymore, it's the differentiation process that is more complicated to handle" says Dr Perriot. Prof Du Pasquier's team has been working on these techniques for many years and is now able to generate neurons, astrocytes and oligodendrocytes from any wanted donor. He hopes to move towards direct experiments with the cells from MS patients in the early part of next year. "We will use CD8+ T cells from patients, with their own brain cells, a very innovative project" he says. If researchers are able to find the antigen, the target of these CD8 T cells, then this could lead to the development of more precisely targeted therapies against MS. "Current therapies for MS target the immune system, but very broadly," explains Dr Perriot. "The most effective therapies are those that prevent immune cells from entering the brain. There are different mechanisms for this, but the problem is that these therapies typically prevent all immune cells from entering the brain, and not just the pathogenic ones thus leaving the brain without defence against some pathogens."

Characterising pathological T cells

The next stage in research will be to find and characterise these aggressive T cells. While the team has devoted a lot of their attention in research to oligodendrocytes, other cells may also be targeted by immune cells, which can then lead to degradation of the myelin sheath. One possibility is that the targeting of astrocytes or neurons by CD8+ T cells is what leads to the destruction of myelin, rather than the oligodendrocytes themselves being directly targeted, an issue the researchers are looking at. "Experiments conducted in mice have shown that targeting of either of these three cell types can lead to demyelination, and at this point we don't know what happens in MS". Preliminary experiments using this iPSC-derived



Human iPSC-derived neurons expressing MAP2 (red) and synaptosin (green) proteins.

system have allowed the researchers to identify CD8+ T cells targeting neurons in healthy individuals. "The presence of these neuron-targeting CD8+ T cells in healthy donors is of importance and so far not widely reported, and we believe that in this context the T cells are what we call naïve, so they don't attack the brain." On the contrary, the ones that the team will be looking for in the blood of MS patients may present some pathogenic features. "The characterisation of these autoreactive CD8+ T cells in MS will take some time, and that's what we will be busy doing over the next 2-3 years," Dr Perriot says. The results of this work are of course difficult to foresee, but Prof Du Pasquier is confident that with the experimental setup, researchers have a great opportunity to make significant progress. "Assessing whether these pathological T- cells exist in MS is very important," he stresses. "It would be more interesting to find them, because that might open up opportunities for the development of new therapies. Either way, this is of crucial importance to understanding how the lesions in MS develop."

With human induced pluripotent stem cells, we can change any cell from a given donor into a pluripotent stem cell. This means that this stem cell has the ability to differentiate into any cell of the human body,

STEM CELL-DERIVED BRAIN CELLS AS T CELL TARGETS IN MULTIPLE SCLEROSIS

Project Objectives

Multiple sclerosis is commonly regarded as driven by autoreactive T cells but the precise targets of these cells is still unknown. Our objective is to use induced pluripotent stem cell-derived brain cells to elucidate what are the targets of CD8+T cells in MS. This unique autologous system is allowing us to screen for brain autoreactivity in a completely unbiased manner directly on the patients' own cells.

Project Funding

Project funding was provided by the Swiss National Fund

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Renaud Du Pasquier, MD is a specialist in neuroinflammatory pathologies. He is currently Head of the Neurology division as well as of the Neuroimmunology Unit at Lausanne University Hospital and was appointed Vice-dean of the faculty of Biology and Medicine at the University of Lausanne in 2021.

Sylvain Perriot, PhD is a specialist in using pluripotent stem cells to model neuroinflammation and neurodegeneration. He is currently leading research projects on the role of CD8+T cells in multiple sclerosis and the link between neuroinflammation, aging and neurodegeneration.





Behind the social lives of bacteria

Bacteria cooperate in many different ways, and this cooperation can increase the virulence of infections. Researchers in the SESE project are developing a model system for looking at social behaviours in infection, as well as exploring the possibility of disrupting infection through social cheat bacteria, as **Professor Ashleigh Griffin** explains.

The propensity to cooperate has evolved in many species over time, from ants, to humans, to monkeys, as it has become apparent that it can have a positive effect on the fitness of another individual. Cooperative behaviour can also be observed in bacteria, says Ashleigh Griffin, Professor of Evolutionary Biology at the University of Oxford. "Previously I worked to show that bacterial cells affected the fitness of their neighbours through their actions, either positively or negatively. These behaviours are then expected to evolve as a result of these fitness effects on others," she outlines. This idea has largely entered the scientific mainstream, now Professor Griffin is the Principal Investigator of the SESE project, in which she and her collaborators are looking at social behaviour in bacterial infections. "In this project we're trying to develop a model system to look at how social behaviours evolve in infection," she explains.



Cooperative green colonies and selfish white colonies growing on an agar plate.

Social behaviour

This primarily means how cells influence each other. One way in which bacteria do this is by releasing enzymes into the surrounding environment to extract nutrients. "In the case of bacteria, enzyme degradation has to happen outside the organism, as they don't have a gut. Bacteria must release enzymes into the environment," outlines Professor Griffin. If a bacterial cell's neighbour is doing the same thing then they both have the opportunity to benefit from each other's behaviour, an example of the kind of cooperative behaviour that Professor Griffin is investigating with her postdoc, Dr Melanie Ghoul. "We have been able to understand these cooperative behaviours by growing cooperative and non-cooperative bacteria together in test-tubes and watching how they evolve over time," she says.

The aim here is to identify the different factors that affect the extent to which bacterial cells cooperate. Researchers typically take a number of different issues into consideration. "We can look at what happens if we mix them together with relatives or non-relatives for example, or if we mix them together very densely. We can make all kinds of different adjustments to the conditions in the flask and ask the question; what's the effect on

EU Research

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Cooperative green colonies and selfish white colonies growing on an agar plate.

cooperation?" outlines Professor Griffin. It has been shown in the lab that microorganisms do in fact cooperate, now Professor Griffin is investigating the importance of this to bacterial infections. "Does this cooperative behaviour have any relevance to bacteria in the real world?" she asks.

The focus in this research is on a group of patients with cystic fibrosis whose lungs are infected with a bacteria called Pseudomonas aeruginosa (P. aeruginosa), which is known to be resistant to antibiotics. This particular species of bacteria is what's called an opportunistic pathogen. "It makes the best of the circumstances in which it finds itself. You can find it in seawater, in mushrooms you buy from the supermarket, in plugholes and other places. When it gets into someone's lungs it's able to carve out a living there. It's very versatile," outlines Professor Griffin. The bacteria can persist for many years in cystic fibrosis patients once it has established a foothold, leading to long-term lung infection. "Because cystic fibrosis patients' mucus is so thick, anything they breathe in gets stuck," explains Professor Griffin.

Bacteria form biofilms in the lung, formed through cooperative behaviour among bacteria, which makes them even harder to treat. These biofilms can become less sticky over time, which was described in a paper by the Danish microbiologist Professor Soeren Molin almost twenty years ago. "I suggested to Professor Molin that this could be due to an invasion of cheater cells. We've since worked together several times, and we're collaborating on this grant," says Professor Griffin. This collaboration gives Professor Griffin access to a lot of information. "Soeren has been systematically taking samples from patients for many years in collaboration with Professor Helle Krogh-Johansen from the Rigshospitalet in Copenhegen," continues Professor Griffin. "We have got detailed information on the history of these samples."

Cystic fibrosis patients are typically infected for a long time with P. aeruginosa, so researchers have been able to monitor changes over quite long periods. "There's many more generations of bacteria than there are with humans. So we're able to observe a huge sweep of evolutionary time: bacteria can have as many generations in a ten year infection as we have had since our species first existed." explains Professor Griffin. The sputa samples provide a picture of a patient's current condition, while Professor Griffin says it's also possible to monitor trends over time. "We can tell whether the cells we isolate from patients lungs are evolving to potentially be more cooperative, or less," she continues.



Disrupting infection

The project's agenda includes not just research into the social evolution of bacteria, but also social engineering, as identifying conditions under which bacteria won't cooperate with each other could represent a route to disrupting infection. This is a topic Professor Griffin and her team are exploring through the use of social cheat bacteria. "These social cheats are often less virulent than the cooperative ones, because they don't release these toxins and enzymes into the environment in the same way as the cooperative bacteria," she explains. The basic idea would be to replace a cooperative, virulent wild-type infection with these cheats that can't communicate with one another effectively. "That would reduce virulence. We can go one step further, by using synthetic biology to make a cheat that is engineered to carry a medically beneficial trait," says Professor Griffin.

Researchers are trying to create a social cheat in the lab that's very good at invading an infection, but is also sensitive to antibiotics. Driving sensitive alleles into the bacterial



Bacterial cells can be engineered to cheat (C) and invade a population of virulent wild type bacteria (W). The cheating strain can also be engineered to carry medically beneficial alleles such as antibiotic sensitivity. Using this approach, it may be possible to turn manipulate the genetic composition of infections to become more susceptible to antibiotic treatment.

SESE

Social Evolution and Social Engineering of bacterial Infections

Project Objectives

 I have three primary objectives:
 (1) to develop a model system for investigating social behaviour in long-term bacterial infections;
 (2) to identify evolutionary mechanisms driving dynamics of social behaviour in longterm infections and;
 (2) to evolution to an infections and;

(3) to exploit social dynamics in the treatment of bacterial infection. My project applies evolutionary theory to the clinical challenge of bacterial infection to develop novel intervention strategies beyond the scope of conventional medicine.

Project Funding

The project is funded under H2020-EU.1.1. -EXCELLENT SCIENCE - European Research Council (ERC). ERC CoG SESE Social Evolution and Social Engineering - ERC Consolidator Grant agreement ID: 647586. Overall budget € 1 954 633

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Ashleigh Griffin is Professor of Evolutionary Biology in the Department of Zoology at the University of Oxford. She began her career as a PhD student studying cooperative behavior in meerkats and since then has developed two main areas of focus in her research: looking for patterns in behavior across cooperatively breeding mammals and birds, and trying to understand social behavior in bacteria, especially in species which cause human disease.





European Commission

Horizon 2020 European Union funding for Research & Innovation population through cheat invasion could turn a resistant population into a sensitive one, although Professor Griffin says this approach is still at an early stage. "We're in the process of trialling that first in vitro, in the lab, as well as in various in vivo models, like beans and potatoes." she outlines. The idea of introducing bacteria into an infection may sound counter-intuitive, but with concern growing over the spread of antibiotic-resistant strains, there is a need for new ideas. "It might eventually work in humans, but the first step is to make it work in a petri-dish or a plant, or in anything!" cautions Professor Griffin.

This will involve further research into the nature of these social cheat bacteria and the conditions in which they can successfully invade an infection. While these cheats are very Further investigation is required before this research can be translated into therapeutic application, which forms a major part of Professor Griffin's plans for the future. The aim is to move on from the basic proof-ofprinciple that has been established through the ERC grant, and to try to develop it further. "We call it a Trojan horse because we're using these cheating bacteria to drive medically beneficial alleles into a population," outlines Professor Griffin.

Alongside her research into the social behaviour of P. aeruginosa in lungs, a member of Professor Griffin's team, Josh Thomas, is also investigating another opportunistic pathogen called Staphylococcus aureus. "We've got a longtitudinal study of samples

Pseudomonas aeruginosa makes the best of where it finds itself. You can find it in **seawater**, in **mushrooms** you buy from the supermarket, in **plugholes** and other places. When it gets into someone's **lungs** it's able to carve out a living there.

good at invading when there are cooperating bacteria around, they're often less effective at colonising an uninfected host or starting off their own population. "This may be because they don't cooperate by producing a compound like pyoverdine, an iron chelator," says Professor Griffin. Without pyoverdine, the bacteria have to exploit their neighbours' resources in order to get enough iron. "They need to be with those neighbours, and acquiring iron, otherwise they're iron-starved," continues Professor Griffin. "When pyoverdine disappears from someone's lung these invaders can take over the whole lung, there's no longer any cooperators there. Then they're iron-starved, and they switch to a different iron-acquisition mechanism."

from people with nasal infections of staphylococcus aureus, as well as samples from healthy people. We're looking at the bacteria in noses, and how they interact with one another," she says. This study is throwing up new questions and new mysteries that would never have been discovered by just looking at lab strains. "The only way to understand bacterial interactions is to investigate how they live, where they live, wherever that might be," explains Professor Griffin. "Funding from the ERC has helped me to show that cooperative behaviours in bacteria are real and driving evolutionary change which has the potential to alter clinical outcomes for infected patients."



New techniques to repair cartilage

Articular cartilage in our joints prevents bones from rubbing directly against each other, and damage can lead to osteoarthritis. We spoke to **Professor Martin Stoddart**, Program Leader of the Regenerative Orthopaedics Program at the AO Research Institute in Davos, Switzerland, about his research into the way cartilage is maintained and repaired.

The articular cartilage in our joints, such as the knee, acts essentially as a shock absorber, preventing bones from rubbing directly against each other and so enabling us to move without pain. "When cartilage starts to break down initially there's no pain. because there are no nerves in cartilage. This is one of the reasons why defects often only become apparent long after the initial problem," explains Professor Martin Stoddart. The damaged cartilage areas can be treated using a surgical technique called microfracture, where the bone is punctured and then bone marrow comes into the defect, although the environment in healthy cartilage is different to damaged cartilage. "There are bone marrow stem cells, immune cells, and then the matrix around the cells, which is a fibrin clot. Whereas in normal cartilage you would have chondrocytes, in a glycan-rich matrix. So, the environment is very different," says Professor Stoddart.

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Bioreactor system

A bioreactor system developed in the AO Research Institute enables researchers to apply these different loads in cell and tissue culture. This effectively bridges the

We're trying to stop **acute**, **traumatic cartilage injuries** from becoming long-term problems with **osteoarthritis**.

Professor Stoddart investigates how to turn stem cells into chondrocytes, a type of cell which plays an important role in maintaining healthy cartilage. "Cells have the potential to turn into chondrocytes, which is a system we've been studying for many years. We're not looking just at whether we can induce the formation of chondrocytes, but also at how frequently this can be done," he outlines. As the head of an SNF-backed research project, Professor Stoddart, together with his colleagues Dr. Angela Armiento and PhD student Yann Ladner, is now looking into how mechanical forces change the molecules and growth factors produced by bone marrow stem cells, research which could hold wider implications for the treatment of certain conditions. The wider aim in the project is to identify novel therapeutic targets for cartilage repair, taking the mechanical load that it absorbs into account. "We know that the way cartilage is maintained and repaired is heavily regulated by mechanical load," he says. "The knee joint bends, while it also rotates, and slides backwards and forwards."

gap between standard, static cell culture techniques and animal models, opening up new opportunities in research. "We can use human cells from older people, and more realistically reflect what would happen in a patient. For example, in rehabilitation following knee surgery medics have a wide range of decisions to make. When do they start? How often should the therapy be applied per day? Is it just bending, should they load and bend?" continues Professor Stoddart. These different options can now be studied in cell culture, which can then be used to guide rehabilitation. "We're interested in what should happen immediately after surgery," he says. "We're looking at how mechanical forces affect these stem cells."

This research holds wider relevance to the treatment and management of osteoarthritis, a condition caused by damage to cartilage. While this damage may be due to long-term wear and tear to the joint, in other cases it may be caused by an accident. "If you have a traumatic cartilage injury in your twenties, this almost invariably leads to osteoarthritis later in life. We're trying to stop acute, traumatic cartilage injuries from becoming long-term problems with osteoarthritis," says Professor Stoddart.

Identifying novel therapeutic targets for articular cartilage repair

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Prof. Martin Stoddart, FRSB, (left) is head of the Regenerative Orthopaedics Program at the AO Research Institute Davos, Switzerland. He completed his bachelors in Biology in 1995 and M.Phil in 1996 at the University of Aberystwyth, Wales, UK. He completed his doctoral thesis in Oncology (University of Nottingham, UK) in 1999.

PhD Student **Yann Ladner**, (centre) registered at ETH Zürich and **Dr. Angela Armiento**, (right) Research Scientist at AO Research Institute Davos.

Research Institute Davos

More than meets the eye

Humans use eye contact to communicate everything from encouragement, to hostility, to empathy, and the ability to interpret gaze behaviour is an important element of social understanding. We spoke to **Dr Anne Böckler-Raettig** about her research into how we process information conveyed through eye contact.

A period of eye contact between two people can mean a variety of different things, from interest, to encouragement, to hostility. The variety of meanings that a single gaze can hold seems to be particularly large in humans. "In many species, eye contact is mainly a signal of dominance. With dogs for example, eye contact is a way of expressing dominance or aggression," says Dr Anne Böckler-Raettig, Professor of Psychology at the University of Wurzburg. In humans however, eye contact can convey a far wider range of emotional and mental states. "As a default, it signals interest. If I want to start a conversation or an interaction with you, I first have to look at you - to show that I am interested and to check whether you are too," explains Dr Böckler-Raettig. "There are also many complex or subtle things we can communicate with a simple gaze. Like colleagues in a meeting may arch an eyebrow or roll their eyes to exchange views on their boss, while people in a bar use eye contact to silently say 'save me from this conversation', or maybe 'join us'."

Deciphering eye contact

This topic is at the heart of Dr Böckler-Raettig's research, in which she is investigating how

humans process eye contact and the different ways in which we use it to communicate with other people. Context is an important consideration in this respect. "It is always the combination of the context, a given situation, and gaze behaviour that creates meaning. There is no single 'thank you' gaze, 'save me' gaze or 'be quiet' gaze - it's always about the interaction with context," stresses Dr Böckler-Raettig. In her research, Dr BöcklerThe context is critical here, as gaze behaviour is likely to vary according to the nature of the conversation. A participant in a dialogue may be perceived as lacking empathy if they don't maintain eye contact when listening to someone talking about their interests for example, but it's different if the subject matter is more sensitive. "If the other person tells you a sad story, then it is much more acceptable to look

It is always the combination of the **context**, **a given situation**, **and gaze behaviour** that creates meaning. There is no single **'thank you'** gaze, **'save me'** gaze or **'be quiet'** gaze it's always about the **interaction with context**.

Raettig uses conversations recorded on video between two strangers to investigate how we use gaze behaviour to reach social understanding and to assess character. "We wondered how someone's gaze behaviour makes them appear to others," she outlines. "How do people come across who maintain direct gaze all the time, or shift between looking at the other person and looking away, or avert gaze constantly?"

away," explains Dr Böckler-Raettig. In her research Dr Böckler-Raettig also addresses impairments in social functioning where individuals show altered patterns of gaze processing and gaze behaviour. "We're investigating two conditions in particular – one is social anxiety, and the other is conduct disorder," she says. "We're looking at the degree to which people's attention is captured by direct gaze, as well as how they use eye contact when listening to others telling a story and whether it supports their social understanding."

All of us are very sensitive to gaze duration. If other people avert their gaze from ours because they are anxious, we might perceive them as shy, or even as untrustworthy. There is some evidence suggesting that people experiencing social anxiety tend to avoid direct gaze. The question is what underlies this tendency. "We want to know whether people with social anxiety are particularly sensitive to being looked at, and whether they typically perceive eye contact as a sign of threat," outlines Dr Böckler-Raettig. Researchers are using sophisticated experimental frameworks to gain deeper insights in this respect. "We're investigating how gaze is integrated with other cues that we are sensitive to, like motion, or emotional expressions," says Dr Böckler-Raettig. "We have found that different social cues are integrated and shape our attention in concert. So when I look at you, this captures your attention – but when I suddenly look at you, this is even more powerful. Similarly with emotional expressions such as anger. They can really boost the effect that eyes have on our attention."

An individual's gaze behaviour may open a window into other aspects of their current states, another topic of interest to Dr Böckler-Raettig. "How can we use gaze behaviour to understand other people, for example to empathise with them or to draw inferences about their mental state?" she continues. "We've used a task, in which participants watch short video clips of others speaking about certain episodes in their lives. These can be sad episodes, like experiences of loss, or neutral episodes, like work or sports routines."

Social understanding

The person who watched the video is then asked how they feel immediately afterwards, which gives researchers an indication of their tendency to empathise, to 'feel with' the other. "People with strong inclinations to empathize may tend to look at the eyes of the narrator less during emotional stories. If you're very empathetic, you may want to down-regulate your own emotions by looking away," says Dr Böckler-Raettig. One of the aims in this research is to assess the extent to which differences in gaze processing affect social understanding and social interaction. "This is why we also test clinical populations. If we find that differences in the gaze behaviour of participants, while listening to somebody, actually relate to their social understanding - for example, in terms of empathy - then this would strengthen the case that 'eye contact is crucial for social understanding'," outlines Dr Böckler-Raettig.

By contrast, if researchers find that the amount of eye contact is not particularly important in these terms, then this could indicate that we use different signals for social understanding flexibly and interchangeably. There is a lot of flexibility in human behaviour, and there is no single golden rule that every person can apply to every social situation to help them fit in. "It really depends on context," stresses Dr Böckler-Raettig. This is a topic Dr Böckler-Raettig plans to investigate further in the future, while she also intends to dig deeper into what actually constitutes 'good' gaze behaviour. "We know that it's perceived as more empathetic to look at the other person when they tell you something neutral, and that it's ok to look away when they tell you something sad," she continues. "This could be extended to many other situations. How much eye contact is ok in what kind of relationship? And how does this shape the quality of our conversations?"



MORE THAN MEETS THE EYE

More than meets the eye: Integration, influences and impairments of direct gaze processing

Project Objectives

Anne aims to understand the basic mechanisms that support social understanding and interaction. She investigates gaze processing and gaze behaviour, socio-affective processes such as empathy and compassion and socio-cognitive processes like perspective taking, also in clinical and developmental contexts. In addition, Anne is interested in interpersonal behaviour, from social exclusion to prosocial decision-making.

Project Funding

Anne received an Emmy Noether Grant from the DFG (German Science Foundation, Deutsche Forschungsgemeinschaft) in 2017. (Grant number: BO4962; volume approximately 850 000 Euros).

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Anne Böckler-Raettig is a Professor for Research Methods and Social Cognition at Würzburg University. She studied Psychology in Berlin, received her PhD from Radboud University Nijmegen and investigated social attention, cognition and behaviour at Princeton University, at the Max-Planck-Institute for Cognitive and Brain Sciences in Leipzig and at Leibniz University Hannover.







Getting to the heart of cardiovascular disease risk

Cardiovascular diseases are estimated to cause around 17.9 million deaths every year, affecting people in low-, middle and high-income countries. We spoke to **Professor Hilde Bastiaens**, and **Dr. Geofrey Musinguzi**, about their work in the SPICES project in implementing and evaluating prevention and control programmes, which could help reduce the burden on healthcare services.

The prevalence of cardiovascular diseases (CVD) is increasing globally placing a heavy burden on healthcare systems. A number of conditions come under the umbrella of CVD, including stroke and myocardial infarction (or heart attack) and they are generally caused by a complex interplay of factors. "CVD is caused by a combination of hereditary and lifestyle factors, such as stress levels, smoking & eating/drinking habits and levels of physical activity," explains Hilde Bastiaens, Associate Professor in the Department of Family Medicine and Population Health at the University of Antwerp. Early identification and follow up of those at an increased risk of developing CVD is crucial, an issue at the heart of Professor Bastiaens' work as the coordinator of the SPICES project. "The specific focus of SPICES is on the prevention of CVD, meaning that we profile people so that they can know their risk," outlines Dr. Geofrey Musinguzi from the Makerere University School of Public Health in Uganda and project manager of SPICES.



SPICES project

SPICES is an acronym for scaling up packages of intervention for cardiovascular disease prevention in selected sites in Europe and sub-Saharan Africa. The project is implemented in five different settings, including locations in low (Uganda)-, middle (South Africa)- and high-income (Belgium, France and the United Kingdom) countries. "In the global north, the project is targeted primarily at vulnerable populations," outlines Professor Bastiaens. "We are reaching people in deprived areas and working collaboratively with different partners for sustainability". For example, the UK Sussex SPICES team has been building links with the Sussex Health and Care Partnership, a local NHS clinical commissioning group in Brighton. SPICES-Sussex partly operates within this network. SPICES Nottingham works in the Nottingham conurbation and works to supplement the NHS Health Check programme for the over 40s with communitybased screening of CVD risk for all consenting adults. In France, the project is implemented in the "Pays Centre Ouest Bretagne" (COB),

a rural setting of 100,000 inhabitants located in the center of the Brittany region with no maritime border. The region has several phone and web access issues due to isolation.

In Antwerp, Belgium, the programme is implemented both via existing community organisations and in GP (general practitioners) practices. In these GP practices nurses play a prominent role in profiling and coaching. In Uganda and South Africa, the focus of SPICES is on both community and primary healthcare settings, Dr Musinguzi says. In Uganda, the project trains community health workers (also called village health teams) who conduct health education on CVD prevention at household level. In addition, the project trains healthcare workers at the primary healthcare facilities and equips the facilities with basic diagnostic and screening tools for CVD. Similarly, in South Africa, the team is focussed on training homebased careers and health workers to improve



their suspicion index and proper screening, diagnosis and management of CVD risk.

In all settings, they conduct a comprehensive cardiovascular risk factor screening (profiling) using the non- lab screening tool, the INTERHEART. Professor Bastiaens says the project aims to work with local communities to reach these populations, so it's important that the instruments used to assess CVD risk are fairly accessible. "We wanted non-medical people to be involved in risk profiling," she continues. The INTERHEART tool has been validated in 52 countries in all regions of the World. It is not invasive and the only measurement that is taken in assessing CVD risk is the waist-hip ratio, with the rest of the assessment based on a short questionnaire. "The INTERHEART includes questions on gender, age and family history, as well as stress levels, diet, exercise habits, and some other aspects," explains Dr. Musinguzi. The INTERHEART tool is a fairly simple risk assessment instrument that is applicable across all settings with fair CVD risk predictability.

In the SPICES project, those individuals identified as being at intermediate risk of developing CVDs are encouraged to take measures to reduce that risk. This is the core of the SPICES project. While it's clearly not possible to change the hereditary factors that may leave an individual more susceptible, certain lifestyle issues can be addressed. "In the



SPICES

Scaling-up Packages of Interventions for Cardiovascular disease prevention in selected sites in Europe and Sub-Saharan Africa: An implementation research (SPICES Project)

Project Objectives

• To implement and evaluate the impact of a comprehensive CVD prevention and control program on patients at high risk of cardiovascular disease in five settings: a rural & semi-urban community in a low-income country (Uganda), middle income (South Africa) and vulnerable groups in three high-income countries (Belgium, France and United Kingdom).

• To identify and compare the contextual barriers and facilitators across study sites that influences the scale-up of the comprehensive CVD prevention and control intervention.

Project Funding

Scaling-up Packages of Interventions for Cardiovascular disease prevention In selected sites in Europe and Sub-Saharan Africa – A Horizon 2020 funded project

Project Partners

See SPICES website for partner information.

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Prof. dr. Hilde Bastiaens Dr. Geofrey Musinguzi



Prof. dr. Hilde Bastiaens is the SPICES coordinator and she is an associate professor at the department of Family medicine and Population health at the University of Antwerp. Her research is mostly oriented towards implementation science in primary care both in high and middle Income countries. Her interest lies in prevention of chronic conditions and person centered care. Besides being an academic, she works as a general practitioner in the province of Antwerp.

Dr. Geofrey Musinguzi is the SPICES Consortium Project Manager and Principal Investigator at Makerere University School of Public Health in Uganda. His research interest is cardiovascular disease risk factor epidemiology, prevention and health systems strengthening.



European Commission

Horizon 2020 European Union funding for Research & Innovatio project we really focus on supporting people to change their lifestyle," outlines Professor Bastiaens. This approach was selected based on analysis of the literature, with some core underlying principles that are applied in every setting, while some other aspects are adapted to the local context. "We adapt to local cultural values, and consider feasibility and the availability of resources against the understanding that healthcare is also organised very differently in different settings where we are implementing the SPICES project," acknowledges Professor Bastiaens. Across all settings, what is common is the use of a motivational approach to communicate the risk to participants. "Analysis of the literature shows that conveying information on risk is very important in terms of people's willingness to take action" explains Dr. Musinguzi. "The

Evaluation

The most important thing is to evaluate the implementation process. "What were the facilitators? What were the barriers? How did it go?" Professor Bastiaens says. Two implementation frameworks are being used in the project – the Consolidated Framework for Implementation Research (CFIR) and RE-AIM. "CFIR is a determinant framework, so that from the beginning you know what kinds of determinants might influence your implementation, and then they can be followed up." continues Professor Bastiaens. "RE-AIM is a framework to evaluate the reach, effectiveness, adoption, implementation and maintenance. So it also focusses on what things are in place that might support continued prevention and control when the SPICES project stops."

Cardiovascular disease is caused by a combination of hereditary factors and lifestyle issues, such as stress levels, eating habits and levels of physical activity.

lifestyle coaching in all setting is also based on motivational interviewing and in addition, we use goal setting and problem solving to support people in their efforts to change. All settings are committed to training the profilers and coaches."

Both Prof Bastiaens and Dr Musinguzi noted the differences in health capacity across the settings. They noted that an individual at high risk of developing CVD in high-income countries may already have an appointment with their GP or a specialist, in which case the priority is to make sure that they follow up on any advice that has been offered. On the other hand, this may not always be the case for low- and middle-income countries but also for vulnerable populations in the high-income settings. The information and reports from the different countries will all be brought together following implementation. Due to the pandemic, the project was extended for six months. "We aim to finalise the country-specific analysis this year, and at the same time we're continuing with the cross-country analysis," Dr. Musinguzi outlines. "We're also looking to identify which topics merit further investigation and which we could investigate in future with a few partners."

One possibility is to look in more depth at coaching of people to reduce CVD risk. Another point of interest is the possibility of targeting younger people. If you want to really work on prevention, you should start earlier," stresses Professor Bastiaens.



Modelling the mechanics of the brain

Researchers in the BRAINIACS group are combining experiments, modelling and simulations to build a fuller picture of how mechanics and different forces affect brain function. This could ultimately help clinicians diagnose neurological disorders at an earlier stage and also treat them more effectively, as **Dr Silvia Budday** explains.

The human brain is enormously complex and research into its function by nature crosses disciplinary boundaries, so it's important to bring scientists from different areas together to build a deeper understanding. Based at the Friedrich-Alexander-University Erlangen-Nürnberg in Germany, Dr Silvia Budday is Research Group Leader of the BRAINIACS project, an initiative looking at the mechanics of the brain. "We bring our mechanics knowledge to this topic," she says. The mechanics of brain tissue has been relatively neglected in historical terms, with most research attention devoted to other topics like neuroscience and biology, yet Dr Budday says awareness of its wider relevance is growing. "When we talk with clinicians or neuroscientists we find that there are certain phenomena they cannot explain. Some of those phenomena can then be explained from a physical or mechanical point of view," she outlines. "The field of brain mechanics is growing."

Brain mechanics

Research in this area involves looking not only at the stiffness of the brain, but also the forces that act on it and which may then affect its functioning. During brain development, folds emerge in the neocortex, a process that researchers in the project are now working to model. "We use continuum mechanics modelling to predict the folding process, which happens on the tissue or organ scale," says Dr Budday. Alongside the largerscale processes, Dr Budday and her colleagues are also considering processes that occur on the micro or cellular scale. "There are cells that divide, migrate and interconnect. We include those processes, in connection with the folding process, through growth and diffusion models," she explains. "We also develop models to predict brain stiffness and investigate how micro-structural parameters determine the macroscopic stiffness."

The different models developed in the project are built on the basic laws of physics. These models are designed to provide an

insight into the impact of mechanical forces on brain tissue, for example how a specific deformation or displacement is related to stress on the brain. "How much force do I need to deform the tissue to a certain extent?" outlines Dr Budday. These models build on experimental data; both human and animal tissue have been characterised, while researchers have also used data from other sources. "We not only use the mechanical data that we can generate ourselves, but also This research holds wider relevance to the diagnosis and treatment of certain neurological disorders related to malformations in the brain. When brain mechanics go wrong during development then folds do not emerge correctly and these neural connections cannot form, leading to health problems later on. "Children who suffer from this have neurological disorders, such as epilepsy," outlines Dr Budday. The models developed by the project are

When we talk with **clinicians** or **neuroscientists** we find that there are **certain phenomena they cannot explain.** Some of those phenomena can then be explained from a **physical or mechanical point of view**.

data from images. We use microstructural analyses, which can be histology or immunohistochemistry, as well as data from MRI scans to assess the macroscopic structure," continues Dr Budday. "We have also analysed evidence of brains in the foetus, to determine cell density at different stages of development." designed to give researchers a deeper picture of the processes that lead to these malformations in the brain, which could eventually lead to improved treatment of neurological disorders. "Children with epilepsy can be treated more effectively if you know more precisely where in the neocortex neurons are firing when they





shouldn't," says Dr Budday. "It can be really difficult to identify or see these regions on an MRI scan. We can simulate this folding process and use our models to understand what has gone wrong."

Reverse-engineer

The ability to connect genetic or cellular disruptions with the more easily observable effects of larger scale malformations is a key strength of the models. Typically, clinicians only see the end result, the malformed cortex of the child with a neurological disorder, but it's difficult to understand the events that have led up to that point; Dr Budday says the project's models are highly valuable in this context. "They enable us to basically reverse-engineer the process. It's possible to go back and investigate what process could have led to that malformation," she explains. In a patient with epilepsy, this would ultimately help researchers identify



the region of the neocortex responsible for bursts of electrical activity, which could then be removed. "Eventually, physics-based modelling could help diagnose and treat epilepsy," says Dr Budday.

A further topic of interest in the project is the relationship between the structure of tissue and its properties. Many different diseases lead to changes in the mechanical properties of tissue, and those are always related to changes in the microstructure, which Dr Budday says can be an important indicator of disease. "For example, if a surgeon removes a tumour, the tumour has a different stiffness to the surrounding tissue, and this is also the case for other diseases. So the surgeon, without knowing about mechanics, is already using this concept," she explains. This could represent an alternative method of diagnosing disease, while it may also open up new possibilities in terms of treatment. "If you change the mechanical environment and, like this, affect the cells in such a way that they will do what they should instead of pathological behaviour, then that would be another treatment target," says Dr Budday.

Further research into the mechanics of brain tissue could uncover new biomarkers and strategies to diagnose or treat disease, a topic that Dr Budday plans to explore further over the coming years. The BRAINIACS team are in close contact with researchers from different Exploring mechanical aspects of cortical folding from early stages of brain development (right) through birth (middle) and adulthood (left) by combining mechanical testing of specimens extracted from human brains (bottom left) and corresponding microstructural analyses (top left), continuum mechanics modeling and finite element simulations (middle).



disciplines, including neuropathology and anatomy, reflecting the overall complexity of the topic. "Some scientists have looked at the mechanics of the brain from the perspective of biophysics, or through using magnetic resonance elastography," outlines Dr Budday. It is difficult to define the stiffness of the brain, as there are many different factors to consider, underlining the wider importance of Dr Budday's work. "We've shown in recent years that you need to consider all these different factors when you model the brain and do simulations. So you have to consider not only the different length scales, but also time scales," she says.

A lot of fundamental research has been conducted so far in the project, with the aim of understanding where mechanics plays a role in modulating brain function, and in future Dr Budday would like to use that understanding to address clinical questions. In the meantime, the BRAINIACS group is still growing, with researchers branching out in different directions and exploring new avenues of investigation. "We are using the same techniques to characterise hydrogels, with applications in tissue engineering and 3-d biofabrication. We also look at different organs or systems," continues Dr Budday. However, Dr Budday expects that most of her research attention in future will be centred on investigating the brain. "The

BRAINIACS project has another four years to run, and other related projects have also started," she says. "We have more ideas about branching out into new directions. For example, we haven't included brain activity in our models yet."

The BRAINIACS group combines experiments, modelling and simulation, which is a significant advantage in terms of rapid iteration and adapting quickly to emerging findings. Rather than having to wait for the data required to calibrate and validate the models, researchers can quickly respond to experimental findings, while the broad scope of the group also helps in terms of developing accurate simulations. "It's a huge advantage to have each of those three aspects in the same group," stresses Dr Budday.

Microstructure of white matter brain tissue at 63x magnification, visualized through histological staining (Klüver-Barrera).



BRAINIACS

BRAIn MechaNIcs ACross Scales

Project Objectives

The BRAINIACS project aims to establish novel computational tools that can facilitate early diagnosis of neurological diseases and advance modern treatment strategies by closely integrating biomechanical experiments, microstructural analyses, continuum mechanics modeling, and simulation. The developed computational models bridge the scales from known biological processes on the cellular level to macroscopic pathologies apparent through modern imaging techniques on the organ level.

Project Funding

Funded through the Emmy Noether Programme by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG), grant BU 3728/1

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Silvia Budday



Silvia Budday studied Mechanical Engineering at

Karlsruhe Institute of Technology (KIT), Germany, with a one year stay at Purdue University, Indiana, USA. She received her PhD in 2017 from Friedrich-Alexander-University Erlangen-Nürnberg, Germany, with research stays at Stanford University, USA, and Graz University of Technology, Austria. For her work on experimental and computational soft tissue biomechanics with special emphasis on brain mechanics she has received several prizes and awards.









How is human brain development regulated?

The neocortex is central to humans' cognitive abilities, and it has grown significantly over the course of evolutionary history. **Doctor Mareike Albert Ph.D** is investigating how the development of the neocortex is regulated, research which could uncover more details about the mechanisms behind certain neurodevelopmental diseases.

The human neocortex is fairly large in comparison to other mammals, while we also have a very high number of neurons in this area of the brain, both features which are associated with our species' advanced cognitive abilities. Essentially all neurons are generated during gestation, so that by the time of birth neurogenesis is largely complete. "Neurogenesis starts during the first trimester of development. The first and second terms are the time when most neurons are born," explains Doctor Mareike Albert, Research Group Leader at the Centre for Regenerative Therapies in Dresden. During the second half of development folds start to emerge in the human brain, which greatly increases the surface area of the brain. "Humans have a highly folded brain. Other primates also have a folded brain, but it's particularly extensive in humans," says Dr Albert. "Many species don't have any folding in the neocortex at all, like mice or rats."

Neocortex development

As the Principal Investigator of a research project based in Dresden, Dr Albert is now investigating how the human neocortex develops, and specifically how this development is regulated. This involves looking at neural stem and progenitor cells, with Dr Albert and her colleagues using several different models to probe deeper. "On the one hand we use mice as an *in vivo* system, but as I've described, some things are specific to humans, so mice are not always the best model system," she outlines. Over the last few years a type of miniature organ called brain organoids has been developed, which offers exciting opportunities to stem cell researchers. "These organoids are sometimes called mini-brains," continues Dr Albert. "They're derived from induced pluripotent stem cells. They allow you, in cell culture, to make 3-d structures that – in their organisation – resemble the developing human brain."

rare in a mouse, but they are more highly abundant in species that have a folded brain, like humans or other primates. That's why these organoids are so exciting for stem cell researchers. They allow us – for the first time – to study human neurogenesis, not just model organisms," says Dr Albert. The main area of interest for Dr Albert is the epigenetic regulation of development, which is crucial to understanding the diversity of human cell populations. "Each cell in our body has the same genetic information, each cell has the same DNA, yet you have many different cell types," she says.

Humans have a highly folded brain. Other primates also have a folded brain, but it's **particularly extensive in humans**. Many species don't have any folding in the brain at all, like mice or rats.

A good example is the organisation of the ventricles, the fluid-filled cavities that are present during development, around which stem cells organise. The same thing happens when these organoids are grown in the lab, with similar organisation of the different neural progenitor types around ventricle-like structures, opening up new possibilities in research. "The human brain has some neural progenitor types that are This is where epigenetics comes into play, with researchers looking at the different factors that may affect gene expression. Histone modifications and DNA methylation are known to affect gene expression for example, an issue that Dr Albert is exploring. "We're specifically interested in this process in brain development. It's known that these epigenetic mechanisms contribute to the proliferation and differentiation of progenitor



cells," she explains. The amount of times stem cells divide before they start to differentiate is what ultimately determines how many neurons they make. "Stem cells need to divide more times in order to develop a large brain, so that there is then a bigger pool to ultimately make more neurons," continues Dr Albert. "We're looking into this regulation. What affects proliferation and differentiation? How does that vary between species?"

Researchers are using brain organoids to investigate these questions, both observing them in tissue and also isolating cells to study their epigenetics. This could ultimately help uncover how humans developed a larger brain than other species, a topic of great interest to Dr Albert. "There was a surge in brain size a few million years ago, before our split from the neanderthals," she says. By investigating novel gene regulatory regions, and essentially turning on genes linked to proliferation, Dr Albert hopes to gain deeper insights into how the neocortex has evolved. "There may be a gene that plays a role in a different tissue, and that maybe now evolutionarily is newly used in the brain, and that can contribute to the emergence of new properties," she outlines. "We're looking into the epigenetics and the non-coding portion of the genome, to understand how and if these regulatory changes contributed to this increase in brain size."

Intellectual impairments

This research also holds wider relevance in terms of understanding the root causes of certain intellectual impairments. In most cases babies born with a disorder called microcephaly - with a brain that is too small - have reduced intellectual abilities, while a brain that is too large also leads to problems. "If you have macrocephaly - too large a brain - then this can also lead to cognitive impairments," explains Dr Albert. In some cases the underlying genetic mutations are known while in others they are not, now Dr Albert aims to build a fuller picture. "We want to look into how these disorders develop, and which factors are involved in causing them. In particular, we are focusing on epigenetic alterations," she says. "The idea is that you can derive induced pluripotent stem cell lines from patients. That allows you to have patient-specific models, and to generate organoids that are built up with these mutations. That then helps us to develop a deeper understanding of the mechanisms involved."

The project itself is in the second year of a six-year funding term, and Dr Albert says several interesting strands of research are being pursued in both stem cell regulation and epigenetic regulation. Over the next four years, Dr Albert hopes to gain some interesting results in both the evolutionary side of the group's research, and also the development of disease. "These are our two main interests, and the gene regulatory code can be relevant to both," she says.

INTERROGATING THE GENE REGULATORY CODE

Interrogating the gene regulatory code – unraveling human neocortex expansion

Project Objectives

The scientific objective of this project is to decode gene regulatory mechanisms orchestrating cell type-specific gene expression programs during neocortex development and evolution. Epigenetic mechanisms are key for neural stem and progenitor cell behavior. The project will make use of novel epigenome editing tools and human 3D brain organoid models.

Project Funding

Emmy Noether program of the German Research Foundation (DFG) running from November 1, 2019 until October 31, 2025 in two 3-year-funding phases.

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Schram-Stiftung

Technology that reads your thoughts

It's the stuff of science-fiction movies, a device you wear on your head that effectively reads your mind's intentions, allowing you to operate machinery, communicate without talking or move connected devices, even to drive cars. **Brain-to-Computer Interfaces (BCIs)** are now a reality, albeit not on the shelves yet. How will this technology develop? Will it become part of our every day, and should we celebrate it or fear it?

By Richard Forsyth

Representation of the second s

The rate of development for BCIs means that it's not so much a matter of 'if', but 'when' they will become an accessible technology for consumers and industries. So how do BCIs work and are they a good idea?

Reading your mind

When we think, feel or recall memories, neurons in our brain go to work, using biochemical and electric signals. Detecting and understanding the patterns associated with this brain activity is possible using electroencephalography (EEG), or functional magnetic resonance imaging (fMRI), near-infrared spectroscopy (NIRS), or electrocorticography (ECoG) technology.

The signals are amplified and interpreted by a program to a level where they can be linked to software and even a device that you can manipulate purely with thought power.

Our brains contain hundreds of templates or 'brain maps' of activity that represent physical sensations or actions and intentions. These patterns, which are found in identified sections of the brain, are similar for everyone which makes BCIs feasible. Research with this kind of technology has revealed that gender, age, if we are left or right-handed, our attentional control, or even the vividness of visual imagery we can achieve, have no bearing on the accuracy of detection. We do, however, have personal variations in the patterns, so scientists have developed software that looks for the identifiable, understood markers of brain maps to decipher intentions. For the highest accuracy to detect such signals in the brain it is an advantage for strength of signal to place electrodes under the scalp, directly on the brain, which is clearly an invasive surgery that does not suit commercialisation. However, with non-invasive BCIs, the user can wear specially adapted headgear, like a swimming cap or a helmet, with electrodes connecting with the head to pick up brain signals.

Applications to think on

The most obvious applications for BCIs are in healthcare, for when patients cannot use their limbs, and suffer from disabilities with speech or mobility. In 2006, a man who had suffered complete paralysis of his four limbs and the trunk of his body after an accident, had a microelectrode array implanted in his primary motor cortex. The BCI system enabled him to open simulated emails, operate a TV and use the basic functions in a prosthetic hand. Further research in 2011 discovered it was possible to record from the cortical surface to spell words on a screen. The startling potential of BCIs used for healthcare have been mushrooming ever since. A BCI can be used in many ways, to help a patient think words and operate all kinds of remote and robotic devices. BCIs enable everything from moving a cursor, to steering a wheelchair or controlling prostheses.

Recently researchers have, for the first time, managed to control a robotic arm with thoughts in real time with a noninvasive technique using an EEG cap. This is a major advance. Normally for moving robotic arms for people with spinal injury the control could be awkward and time consuming because the thought patterns had to be repeatedly imagined for success. Via the ERC Consolidator Grant project 'Feel your Reach', the head of the Institute of Neural Engineering at Graz University of Technology (TU Graz) in Austria, Gernot Müller-Putz, together with his team, has developed a system that allows natural and continuous movement in real time.

"The contribution of the eyes is essential..." explained Müller-Putz. "It is important that users are allowed to use their eyes to follow the trajectory of the robotic arm."

A clever part of the system is that it specifically recognises goaloriented movement. The brain's error response can be read from an EEG. If the movement was not intended the arm resets. The team also integrated kinaesthetic feedback, so the patients could feel the movements of the prosthesis as well as observe them. This was done with vibration sensors attached to the shoulder blade although there may be new applications considered for people where the sensors need to be attached to the neck, in more extreme cases. BCIs have potential to help rehabilitate patients with neurological conditions by effectively retraining the brain. BCIs have for the first time, provided hope for people suffering from spinal cord injury as well as people who have suffered a stroke or cerebral palsy.

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What we must be prepared for, is that such innovations, whilst serving our needs, have the potential to change not only the way we do things, but our identity.

Incredibly, BCIs have potential to help rehabilitate patients with neurological conditions by effectively retraining the brain. BCIs have for the first time, provided hope for people suffering from spinal cord injury as well as people who have suffered a stroke or cerebral palsy. New innovations in this field can be seen across the world.

In the US, researchers at Brown University have developed a system, they are testing on rodents, using a scattering of grain sized microchips over the brain to record and transmit brain activity to a computer. Dubbed 'neurograins', they access parts of the brain implants can't reach.

"Each grain has enough micro-electronics stuffed into it so that, when embedded in neural tissue, it can listen to neuronal activity on the one hand, and then can also transmit it as a tiny little radio to the outside world," said Arto Nurmikko, a neuroengineer on the team.

The neurograins stimulate neurons with electrical pulses which could be advantageous in tackling brain disorders like epilepsy and Parkinson's disease or other brain injuries.

It should be noted that despite the remarkable success stories thus far and clear potential, BCIs are still a developing and experimental technology, so there is a way to go till you see these devices in your local hospital.



BCIs are being explored in many industries. A more frivolous application but with an enormous marketplace, is videogaming. Why hold a joypad when you can think the controls to your onscreen characters? Gabe Newell, boss of US gaming company Valve Corporation is working on an open source BCI software project involving modified Virtual Reality hardware, a headset design called Galea. Newell told a reporter for 1 News: "If you're a software developer in 2022 who doesn't have one of these in your test lab, you're making a silly mistake."

The software will pick up signals to interpret the player's mood, whether they are sad, afraid or bored for instance. This can make the game respond, so if a player is bored – this emotion could trigger more challenges to be included in the game. There is also the literally mind-boggling potential to 'write signals into minds' to influence how players are feeling or to deliver better visual and auditory experiences during gameplay.

There are many examples of mind-controlled gaming in the lab. Recently, in a remarkable video that has trended online, Elon Musk demonstrated the power of such devices by teaching a macaque monkey, named Pager, to play a video game, Pong, with his mind only, with the reward of a fruit smoothie as an incentive.

Of course, if you can control video game agents with your mind in simulated battles, why not do it for real in a real battlefield? DARPA, the US defence Advanced Research Projects Agency has been involved in BCI projects since the 1970s. Controlling robots is one goal but an even more fascinating and strange project being explored by DARPA is project 'Silent Talk' which is aiming to allow front-line soldiers to communicate telepathically. It would 'allow user-to-user communication on the battlefield without the use of vocalised speech through analysis of neural signals'. The initial investment for this research is \$4m USD, with the aim of identifying the neural activity that occurs in the brain when people talk to themselves.

And it may not be just shady military uses for this kind of mind conversation technology. Consider that in 2017, Facebook declared it had at least 60 engineers working on building a BCI with the goal to allow mobile device and computer users to communicate at a speed of at least 100 words per minute.



The car had no pedals and no steering wheel, the driver was essentially simply driving with his mind.

A drive in the mind

Controlling vehicles with BCIs has produced positive results. The University of Minnesota demonstrated a thought-controlled minihelicopter could be piloted through obstacles with about 90% accuracy. On the tarmac, Roberto Hubner Mendes, a quadriplegic drove an F1 car with mind control with the EMOTIV BCI. It was possible by combining EEG brain powered technology with steering algorithms and track mapping. The car had no pedals and no steering wheel, the driver was essentially simply driving with his mind.

For in-car applications, there are already concepts circulating for commercial usages that could roll out sooner. Mercedes-Benz is working on BCI capabilities for inside cars, with a concept car known as VISION AVTR.

"BCI technology has the potential to further enhance driving comfort in the future...," said Britta Seeger, member of the Board of Management of Daimler AG and Mercedes-Benz AG. The focus in this application is on in-car adjustments. The hypothetical thoughtcontrolled in-car features mean that drivers could switch on the radio station and change the interior lighting with a BCI. The proposed process starts with a 'short calibration' of the BCI unit around a driver's head and the device analyses 'the measured brain waves and triggers a defined function.'

It's clear how such technology could evolve. Imagine a time when we could talk to each other just with our minds, rather than phone or chat, or operate machinery without moving, or touching controls. A truly bizarre futurescape, but one that has the seeds of development growing today.

Do we need to think again?

With technology that directly links to our minds, we would be foolish not to examine the ethics and the potential for abuse or harm. Is it safe, how does it affect privacy, what are the risks and are they worth it for the benefits?

Data from your brain could be considered highly personal and so how is it stored safely? When a computer effectively reads your emotional states, and reactions to stimuli, such as with the prior example where video games are influenced by your moods, imagine if this was used for marketing or government intelligence. The ability for insertion of thoughts too could have truly sinister implications and be open to abuse from industry and state. Could it be developed for a new kind of interrogation? BCIs could have new applications for employee monitoring that may be of concern. This branch of technology is developing at speed and so regulatory agreements would ideally need to keep pace. Informed consent should be a pre-requisite for usage. Neuro-hacking, where users seek to better their reflexes, or learn faster could create a new divide in 'have' and 'have-nots' and like any truly disruptive technology, there will undoubtedly be unforeseen challenges and ethical concerns that will emerge as it advances.

The ethical considerations and the fact so many tech firms are examining and developing BCIs has led to a number of neuroscientists to recommend the United Nations examine BCIs to consider protections and limits around how neural data is collected and used.

To be at this remarkable juncture where minds can be mapped, machines obey our thoughts and we may have a shot at a form of telepathy, is hard to fathom. What we must be prepared for, is that such innovations, whilst serving our needs, have the potential to change not only the way we do things, but our identity, our understanding of self and what that means, in very profound and fundamental ways.



Models to help contain and control disease in pigs

* * * Diseases like African Swine Fever (ASF) represent a major threat to the health of pig populations, and can spread rapidly through a variety of different pathways. We spoke to **Dr Salome Dürr** about her work in exploring the different pathways through which disease can be transmitted between pigs, which can then be added to epidemiological models.

An outbreak of infectious disease can have highly adverse effects on the agricultural sector, and so it's important to monitor farms and trade networks so that any cases can be detected quickly and the wider impact contained. As Assistant Professor in Veterinary Epidemiology at the University of Berne, Dr Salome Dürr is the head of a research project investigating disease transmission in the Swiss pig population. "We have developed an epidemiological model that we want to use for diseases that spread through different pathways," she says. The focus here is on three specific diseases, namely African Swine Fever (ASF), Porcine Reproductive and Respiratory Syndrome

(PRSS) and Enzootic Pneumonia, all of which can be spread through direct contact. "When you transport a pig from one premises to another, an infected pig will certainly spread the disease. A disease can also be spread by indirect contact, depending on how it is shed and how tenacious it is," outlines Dr Dürr.

A batch of pigs may be transported from one farm to another for example, and then another batch is transported in the same truck from a third farm to a fourth. A disease can be transmitted between different batches of pigs in the course of these journeys, via fomites for example, although Dr Dürr says not a lot of data is available on this. "These types of indirect contacts are not recorded in the official Swiss animal transport database," she explains. It is mandatory in Switzerland to record all livestock transports, representing an important source of data, while Dr Dürr and her colleagues in the project are also considering other potential disease pathways that are not officially recorded.

"We wanted to explore - together with experts from the pig disease and epidemiology field, as well as farmers - what types of pathways exist. We also wanted to investigate how important and relevant they are in regard to these three diseases as well," she continues. "We were able to identify 24 pathways. Now the question is; how can we put them into a model?"


Disease transmission model

The baseline of the model is in place, built on a farm contact network constructed from official transport data, so essentially how often farms are in contact with each other, which is an important consideration in terms of disease transmission. There is also scope to put in additional pathways to the epidemiological model; researchers have rated each of the 24 different potential pathways of transmission in terms of their relevance to the spread of disease amongst the pig population. "We wanted to rate them according to the frequency of the contact and the likelihood of disease transmission when a contact happens. Both are important considerations in rating a contact. If they happen often, and there was a high likelihood of disease transmission via that pathway, for example transport between farms, then we would give a very high rating," she outlines. It is not possible to include all 24 pathways in the model, as in some cases data is not available, yet researchers plan to use further data sources. "We plan to add data about indirect contacts due to pigs being transported in the same lorry, as well as data about veterinarians, as they often go from farm to farm," says Dr Dürr.

Further information is available on different types of indirect contacts, such as data from transport companies. The idea is to use this data to build a deeper picture of the situation across the whole of Switzerland, using machine-learning algorithms. "We are working with a company which stores a lot of information from farms as well as from different clients. They gathered information on veterinarians going from farm to farm, and the health status of the farms," outlines Dr Dürr. While veterinarians take precautions, Dr Dürr says there is still a possibility that they could be bringing a disease from farm to farm as they travel around. "The professional, often larger farms have clear biosecurity rules, where you have to change clothes, wash or change the boots, and go through disinfectant," she continues. "But there are also these types of farms that for example have mainly dairy cattle and just a few pigs in another barn. In those farms, or in cases where pigs are raised outdoor, access to the pigs from visitors is much easier - this is also another type of contact that could be considered."

Management strategies

There are a wide variety of highly specialised farm types along the pork production chain in Switzerland. While some farms are quite industrialised, others are smaller in scale and



less professionalised, with all farms having to meet clear regulatory standards. "In the main, our animal welfare regulations are a bit more advanced than those in the EU," continues Dr Dürr. The Swiss pig population is currently free from a lot of diseases, a position that the authorities are keen to it's clear to most people that it's a question of when it enters Switzerland and not if, because it's now very close from the German border, so the priority is then to detect it early. After you've detected the first case, you can then stop all movements and close these transmission pathways."

The focus here is on three specific diseases, namely African Swine Fever (ASF), Porcine Reproductive and Respiratory Syndrome (PRSS) and Enzootic Pneumonia, all of which can be spread through direct contact.

maintain, so one important goal for Dr Dürr in the project is to develop more effective surveillance strategies. "It's really about this early phase, between the disease coming into the population and it being detected. How can we detect it as rapidly as possible?" she asks. "ASF is not yet in Switzerland. However, This type of measure can be implemented relatively quickly, for example banning the movement of pigs anywhere in Switzerland for a week. Most of the pork produced in Switzerland is consumed in the domestic market, and Dr Dürr says the authorities are keen to minimise exposure to these

SwineNet

The effect of network accuracy and risk categorization on dynamic disease transmission models

Project Objectives

SwineNet project aims at identifying optimized surveillance strategies for rapid detection of diseases in the domestic pig population, such as emerging African Swine Fever. Strategies will be tested by an epidemiological network model that is based on animal movement data and further complemented by additional links between holdings of different types, generated by quantitative and qualitative approaches.

Project Funding

Funded by the Swiss National Science Foundation (SNSF)

Project Partners

- Friedrich Loeffler Institute, Germany
- Free University of Berlin, Germany
- Connecticut University, USA
- SUISAG, **Switzerland** • ETH Zurich, **Switzerland**

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Professor Salome Dűrr



Salome Dűrr is an Assistant Professor of Veterinary Epidemiology at the University of Berne, where she gained her degree and has held several research positions. She is diplomate of the European College of Veterinary Public Health (ECVPH), the Swiss Forum for Epidemiology and Animal Health (EpiForum) and several other organisations.



b UNIVERSITÄT BERN

FNSNF Fonds national suisse Schweizerischer Nationalfonds Fondo nazionale svizzero Swiss National Science Foundation diseases, which would dramatically impact the domestic and international pork market. "There is a very big effort to keep these diseases out of the Swiss pig population," she stresses. The project's work represents an important contribution in this respect, while Dr Dürr says in future it could also be applied to other diseases, besides the three that are the specific focus of attention. "The idea is to develop a model that is sufficiently generic that it can be adapted for other diseases," she continues. For example, the infectious period may be different between different diseases – if we modify the value of this parameter, then the model can be adapted. It could also exchange with the Federal Food Safety and Veterinary Office, and we're collaborating closely on how surveillance strategies should be implemented and conducted," says Dr Dürr. The aim is to develop a model which can be used to improve these strategies, and identify which farms should be targeted for surveillance in which circumstances. "It may be that certain types of farms are known to have a lot of contacts but cannot be identified easily by the authorities, because some other data has to be compiled," continues Dr Dürr. "We have come up with some fresh insights about how you could identify those farms that have more contacts than others."

We wanted to explore - together with **experts** from the **pig disease** and **epidemiology field**, as well as **farmers** - what **types of pathways exist**. We also wanted to **investigate how important** and **relevant** they are in regard to these three diseases.

be used to monitor how bacteria resistant to antibiotics spreads from farm to farm, which is highly relevant to the wider food chain."

The primary focus in the project at this stage however is ASF, which is present in wild boar populations in a few European countries, while Germany has also had some cases in domestic pigs. Given this close proximity it is expected that there will be cases in Switzerland in future, at which point it will be important to quickly identify the farms affected. "It is important to us being in regular The project is set to conclude in May of next year, and there are plans to both publish papers and present research findings in scientific conferences. In terms of practical application, Dr Dürr hopes to present the project's findings to national authorities, which will help in the wider goal of monitoring disease effectively and rapidly identifying the presence of new cases. "The Federal Food Safety and Veterinary Office, as well as our partners from the pig industry, are interested in using the model further," she says.





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Getting the whole picture of emergency situations

* * * Research and industry partners in the ResponDrone project are developing an integrated solution designed to give first responders a fuller picture of a disaster situation or emergency like a forest fire or flood, which can then guide operational decisions, as the coordinators of the project, **Max Friedrich** and **Joonas Lieb** of the German Aerospace Center (DLR) explain.

A first response team arriving at the scene of a disaster or an emergency needs to understand the nature of the situation they face if they are to respond effectively. The use of drones can provide first responders with a detailed picture of the situation without putting human lives at unnecessary risk, a topic at the heart of the ResponDrone project. "We are developing an integrated system to be used in first response missions during disasters or emergencies, such as large forest fires, floods, or search and rescue missions," explains Joonas Lieb. Often first responders do not know what to expect when facing a large forest fire or flood, an issue the project aims to address. "The ResponDrone system will rapidly provide an initial overview of the situation," says Lieb.

ResponDrone project

The system is designed to enable the operation of multiple drones simultaneously, so that large areas can be covered and relevant, real-time information provided to any first responder with access to the



system. The information gathered can then inform decisions on the ground. "The first responders have two possibilities to interact with the system. A desktop interface is meant to be used as an on-site command centre and a mobile application for the first response units in the field. The desktop interface will basically be a map on which you can see where your drones and the in-field first responders are. You can then supervise and manage the mission," Friedrich outlines. "The first responders out in the field will have the for flying the drones. "The system itself essentially identifies the trajectory that a drone should take. The operator says that they want to have a drone at a given point, but they don't have to specify how it gets there," says Lieb. While drones are already used to some extent in emergency response, they may need to operate closely alongside each other, underlining the importance of this work in de-conflicting flight trajectories. "You definitely don't want to have a mid-air collision," stresses Lieb. "I would expect the

We are developing an **integrated system** to be used in the response to disasters and emergencies, such as **large forest fires**, **floods**, or **search and rescue missions**.

mobile app installed on their cell-phone or tablet, and they can have a live video feed from the camera mounted on the drone. They can also direct the drone to a certain point, for example if they want to know what's on the other side of a house or river."

A single operator can fly multiple drones under the ResponDrone system, which Lieb views as one of the major benefits. The drones provide their information to a single system which can de-conflict their flight trajectories, so less people are required use of drones to increase significantly in the future, as they are easier and faster to deploy, and not as expensive as manned helicopters."

The system also enhances communications resilience in what can be extremely challenging environments. In a large wildfire, communication infrastructures may break down for example, an issue the ResponDrone project is working to address. "Our system is able to extend the communication network by providing an on-demand wi-fi coverage to the first responders and potential victims in the

Mobile application for first response units in the field.





disaster area," Lieb explains. The system also has a decision support capability, which gives first responders a picture of how a situation is developing, for example a fire. "You can then identify which areas are likely to be affected in the near future, and which buildings may need to be evacuated," continues Lieb.

The project consortium includes a number of emergency response organisations, operating in different environments, who have provided extensive feedback on the system and helped guide its design and development. "We have first responders from various European countries as well as Israel and Armenia. Several first response organizations in our consortium are in fact looking at bigger and rural areas, which are currently quite difficult to reach with their units," says Lieb.

Emergency response

The ultimate aim here is to provide a system that is useful for first responders and helps them to respond more effectively to emergency situations. A trial is planned soon, at which Friedrich says the performance of the ResponDrone system will be compared to the systems currently used by first responders. "We will compare what worked well and what didn't, and we will also check the response times. How quickly did they

find a certain victim?" he outlines. The core question here is how rapidly first responders are able to assess the true reality of the situation they're facing. "If they get it faster with our ResponDrone system, then we see the benefit of it," continues Friedrich. "We want to basically figure out how quickly and accurately they get the overall picture of the situation with our platform, and to compare that to the existing equipment."

This information will then be fed back into the development of the system, and in the future, there is the possibility of bringing it to the commercial market. If the system proves effective, then Friedrich expects there may be interest from first response organisations. "If they see that the system brings benefits, that they are able to get the important information quickly and easily, and are reassured that the drones will not crash, then these organisations may be interested in buying it," he says. There is a work package in the project dedicated to innovation and commercialisation, and the project partners are now exploring wider opportunities. "We are looking at translating the project into a real product. We need to identify what is missing and what has to be improved," outlines Friedrich. "We are in the process of finding who would be interested and how this could be arranged."

Desktop interface for the on-site command centre.



ResponDrone

NOVEL INTEGRATED SOLUTION OF OPERATING A FLEET OF DRONES WITH MULTIPLE SYNCHRONIZED MISSIONS FOR DISASTER RESPONSES

Project Objectives

The ResponDrone system will accelerate situation assessment, support decision making and simplify operations management during crisis situations by delivering high quality information (incl. live video feed from airborne unmanned aerial vehicles) to any involved control center as well as in-flied first responders through a web-based system. In addition, it will serve as an on-demand airborne communications network to allow first responders in the disaster area to communicate with the command center in case of a breakdown in communication infrastructure.

Project Funding

€ 8.3 Million from the European Union's H2020 Research and Innovation Programme and South Korean Government under Grant Agreement No. 833717.

Project Partners

There are a total of 20 project partners from 13 different countries • https://respondroneproject.com/partners/

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Joonas Lieb is a scientific associate for the German Aerospace Center (DLR) in Braunschweig in the UAS group of the Institute of Flight Guidance within the department of Pilot Assistance. Currently he is working in a variety of international projects for DLR, including the integration of Unmanned Aircraft Systems into the existing airspace.



European Commission Horizon 2020 European Union funding for Research & Innovation Rio de la Plata estuary (Brazil). Source: https://en.wikipedia.org/wiki/Estuary#/ media/File:Rio_de_la_Plata_BA_2.JPG (accessed September 27, 2021).





Simulating sediment transport

Researchers in the PRO-MUD project are working to simulating the transport of sediment in surface waters and coastal areas. Through these simulations researchers can track the position and velocity of each particle, as well as the forces acting upon them, and gain new insights into how nutrients and pollutants are dispersed, as **Dr Bernhard Vowinckel** explains.

There is enormous scope for sediments in the world's oceans to interact and form different kinds of interesting flocs and aggregates through thousands of metres of water column. This occurs in a process called flocculation through which silt and clay particles come together to form larger structures like flocs, building on the smallest possible entity, called the primary particle. "This is not an individual clay particle - in fact it can already be an assembly of particles. Those primary particles are platelets that are bonded together so strongly through van der Waals forces that the shear conditions, provided by the flow of the current, would not be enough to tear them apart," outlines Dr Bernhard Vowinckel. The primary particles, as the building blocks of larger particles, have a fairly uniform size distribution. "These primary particles come together to form larger aggregates or flocs. These flocs of cohesive sediment remain cohesive even at larger sizes, but they may be torn apart more easily by shear forces because of this larger size," continues Dr Vowinckel.

PRO-MUD project

As the Principal Investigator of the PRO-MUD project, Dr Vowinckel is now working to simulate how these sediments are transported in shallow waters and coastal areas. This project has its roots in research Dr Vowinckel conducted earlier in his career



Flocculation in isotropic turbulence. Source: Zhao, K., Pomes, F., Vowinckel, B., Hsu, T., Bai, B., & Meiburg, E. (2021). Flocculation of suspended cohesive particles in homogeneous isotropic turbulence. Journal of Fluid Mechanics, 921.

in the US, when he was part of a group which sent material to the international space station (ISS). "I proposed that we should look at fine-grained sediments, and look at how they form flocs together in micro-gravity," he says. On earth, a suspension of fine-grain sediments typically falls to the ground due to gravity, but the environment on the ISS opened up new research opportunities. "The idea was that if we turned off gravity then we could look at flocculation over long periods of time within a tiny container," explains Dr Vowinckel. "Containers were then flown to the ISS, and they were stirred to homogenous suspension. Then we observed flocs emerge over time with a camera."

The aim now in the project is to build on earlier findings to simulate sediment

transport, which is affected by gravitational, hydrodynamic and electrostatic forces. In this research, Dr Vowinckel and his colleagues in the project are using computational fluid dynamics to solve a partial differential equation called the Navier-Stokes equation numerically. "This equation is impossible to solve analytically, apart from a few exceptions with heavy simplifications," he says. This equation is solved on what researchers call a computational grid. "There is a large domain that you want to simulate, and you sub-divide that into smaller and smaller pieces, in which you can then look to solve the Navier-Stokes equation numerically," explains Dr Vowinckel. "With a partial differential equation there are gradients of a certain quantity as a function of space and time."

Researchers can then look at discrete timesteps, which is how a continuous fluid flow is discretized, essentially transferred into a form in which it can be analysed more easily. The tiny boxes that the domain is sub-divided in – the grid – must also reflect the Kolmogorov length scale for turbulent flow, the smallest scale over which an eddy can form. "We want to resolve this kind of motion. If we don't have a grid capable of resolving this kind of motion then we won't be able to capture that. This is how we compute the fluid motion" says Dr Vowinckel. It is possible to go to ever finer grids, although Dr Vowinckel says there are some practical limitations. "If



Settling of sediment grains over time. Particles are cohesive and colored by their vertical velocity component. Source: Vowinckel, B., Withers, J., Luzzatto-Fegiz, P., & Meiburg, E. (2019). Settling of cohesive sediment: particleresolved simulations. Journal of Fluid Mechanics, 858, 5-44.

you go to finer and finer grids you will have more grid cells, then everything becomes more expensive," he points out. "You would need a big supercomputer to do this. In fact, these types of simulations are typically run on supercomputers with hundreds or even thousands of processors that work in parallel."

The particles are submerged within that domain, and researchers can then follow their position in space and time. The position and the velocities of every particle can be followed at every point in time throughout the simulation, as well as the forces acting on them. "We can essentially track their progress, and that's how we couple particle and fluid motion," explains Dr Vowinckel. project's research also holds relevance to our understanding of hydrocarbon fields. "Hydrocarbon reservoirs in the oceans are simply made of organic material that has been deposited and then sequestrated by additional layers of sediment that went on top. Over the years it then became oil," he explains. Understanding the flow conditions under which these types of sediment are deposited opens up the possibility of predicting where those deposits will be formed in future. "If you reconstruct the flow conditions of a landscape, you could then estimate the types of flow conditions that are beneficial in terms of the formation of such reservoirs," says Dr Vowinckel.

We can vary the volume of water, the number of particles and the turbulence intensity for example. We can also vary how strongly our primary particles are glued together and how heavy they are.

Researchers can change certain parameters in the simulation to gain deeper insights into the factors that affect sediment transport. "We can vary the volume of water, the number of particles and the turbulence intensity for example. We can also vary how strongly our primary particles are glued together and how heavy they are," continues Dr Vowinckel. "This gluey force is called van der Waals force. It's cohesive and it combines certain properties so that when particles touch, they effectively stick together."

Transport mechanisms

This force binds particles into larger flocs, which can then transport certain nutrients or pollutants in coastal areas and shallow waters. Feeding this information into larger global circulation models could help scientists identify how pollutants and nutrients are circulated, while Dr Vowinckel says the

The reservoir could then be exploited in a much more precise way that minimises ecological damage, yet this type of application is still a distant prospect. At this stage, the priority in the project is to understand how those transport mechanisms work, which could then be applied in larger models. "Eventually we would like to see this knowledge incorporated into models that can handle an entire estuary for example," outlines Dr Vowinckel. Larger scale models always rely on assumptions, as it's not possible to incorporate every given process; Dr Vowinckel's research will help put these models on a firmer basis. "We're trying to give better information about how those processes work and how they should be accounted for," he explains. "We can achieve a better predictive capability when we have described all relevant physical mechanisms properly."

PRO-MUD

Particle-Resolving Simulations of Cohesive Sediment Dynamics

Project Objectives

The aim of the PRO-MUD project is to carry out particle-resolved simulations to better understand the transport of finegrained sediments in surface waters and coastal areas. The focus of this project is on flocculation, settling behavior, and erosion to create a better understanding of predicting the dispersal of nutrients and pollutants that bind to these sediments.

Project Funding

Project funded by the German Research Foundation (DFG) via the Emmy-Noether Programme, grant-no. VO2413/2-1.

Project Partners

Funded institutes: Leichtweiß-Institute for Hydraulic Engineering and Water Resources, TU Braunschweig (Germany)

Unfunded project partners: University of California Santa Barbara (USA), University of Delaware (USA), Xi'an Jiaotong University (China), University of Plymouth (UK), Friedrich-Alexander-Universität Erlangen-Nürnberg (Germany), Aix Marseille Université (France), Université de Paris (France)

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Dr. Bernhard Vowinckel Photograph by Juliane Vowinckel

Dr. Vowinckel studied Hydrology in Germany (2003-2009) and obtained his doctorate at the Institute of Fluid Mechanics at TU Dresden in 2015. Afterwards, he was a postdoctoral scholar at the University of California, Santa Barbara, USA and a research associate at the German Federal Institute for Geosciences and Natural Resources. He currently holds a position as a research group leader at TU Braunschweig (Germany).



Protecting against the oomycete threat

* * * Oomycetes cause serious disease in ecosystems, agriculture and aquaculture, and represent a major threat to food security. Researchers in the PROTECTA project are investigating how oomycetes interact with their hosts while also looking to apply this knowledge to improve plant and crop resilience, as **Professor Laura Grenville-Briggs** and **PhD student Christian Andersen** explain.

A group of eukaryotic microbes, oomycetes were historically thought to be fungi, but now are recognised as being more closely related to brown algae. From an evolutionary perspective, oomycetes arose as pathogens of marine algae before evolving to interact with land plants and animals, and certain species can cause serious disease. "For example, an oomycete called Aphanomyces euteiches is a pathogen of legume plants, like peas and beans. It causes major problems when present in the soil as essentially you can't grow peas for around 8-10 years, and there are no fully resistant varieties," says Laura Grenville-Briggs, Professor of Integrated Plant Protection at the Swedish University of Agricultural Sciences (SLU). Another type of oomcyete called Phytophthora infestans causes potato late blight, a disease which was a factor in the Irish potato famine and remains an issue today. "It's a big problem for potato growers here in Sweden, as growers typically have to spray fungicides weekly throughout the growing season," explains Professor Grenville-Briggs. "More durable resistance, and biological control options will reduce our reliance on synthetic (chemical) fungicides, which will be welcomed by both farmers and the wider society as a move to make potato production more environmentally sustainable."

PROTECTA project

As the lead of the PROTECTA project, Professor Grenville-Briggs is both pursuing fundamental research into different species of oomycetes and also looking to apply this knowledge to improve plant protection. The project is an ITN training programme in which 15 Early-Stage Researchers (ESRs) are conducting research into oomycetes affecting various plants, crops and animals,



and Professor Grenville-Briggs believes it's important to share ideas across different sectors. "These different sectors are facing similar problems, and we can learn a lot by comparing approaches. Learning about something that's being done in a particular sector may stimulate innovation in another," she says. Researchers in the forestry sector are typically quite advanced in their ecological understanding in comparison to those in agriculture for example, while Professor Grenville-Briggs says valuable insights can also be drawn from the aquaculture sector. "In aquaculture researchers are often highly advanced in immunology and the identification of antibodies. There are sort of analogues to antibodies that we could potentially use in agricultural settings," she outlines.

The ESRs in the project are conducting research into a variety of different oomycetes, with a lot of attention focused on effector proteins. Some of these effector proteins can manipulate the host and help pathogenic oomycetes cause infection. "In *P. infestans* for example, there could be as many as 400 different effector proteins with different roles, and they may come into play in different environmental conditions," explains Professor Grenville-Briggs. These effector proteins effectively infiltrate the cells of a host plant

when an infection occurs, and prevent its normal immune response. "They interfere in molecular, plant-based signalling, and they effectively stop signals being sent to other parts of the plant," says Professor Grenville-Briggs. "The plant will respond by trying to make the cell as toxic as possible – it will sacrifice individual cells which are under attack, in a leaf or a stem or a root, to try and preserve the health of the whole plant. The effectors then try to stop that process. So, there's a kind of arms race that goes on between the plant – or fish – and the pathogen."

This topic is at the heart of the project's overall agenda, with some ESRs quantifying specific effector proteins, some characterising specific responses of the host plant, or fish, to effectors, while others are looking at the ecology. Based at SLU, Christian Andersen's PhD project sits somewhere between ecology and molecular biology. "I'm researching how an oomycete called Pythium oligandrum uses these effector proteins. What is the role of these effectors when P. oligandrum parasitises other oomycetes in agriculture?" he says. This particular oomycete can be used to help strengthen a plant's defences against infection, and can directly kill plant pathogenic oomycetes and fungi, so now researchers are exploring the potential of using P. oligandrum as a biological control agent against crop pathogens. "I will spend some time at a sugar beet breeding company, DLF Beet Seed, where I will try to help them combat one of the major diseases which affects sugar beet, using this biological control agent P. oligandrum," continues Andersen. "The initial idea is to coat the seed in the spore solution of P. oligandrum, and then it will hopefully colonise the plant root and provide enhanced protection against the disease."

A field trial carried out by ESR Murilo Sandroni to evaluate resistance to potato late blight under future climate scenarios (high atmospheric CO₂) at the EPPN research station, Julich, Germany July 2021.

Salmon eggs infected with Saprolegniosis caused by a species of Saprolegnia.

Sustainable resistance to oomycete diseases

The use of mycoparasites, such as *P. oliqandrum* could represent an effective way of enhancing the resilience of crops and plants against disease, while researchers in the project are also working to identify which effector proteins are particularly important in different pathogens. Researchers are also looking at how these can be utilised in new resistance breeding programs, or for better ecological management of oomycete diseases. This research holds important implications for the commercial sector, as crop productivity can be badly affected by oomycetes like P. infestans. "Quite a lot of people in the project are working on P. infestans, which is probably the most devastating of the oomycete pathogens," outlines Professor Grenville-Briggs. Max Ossenbrink, an ESR in PROTECTA is working

genes from wild crop relatives. "You can take genes that are very good at resisting *P. infestans* for example, and engineer those into potatoes," she explains. Further research and trials are required before these ideas can be widely applied in the commercial sector. "You would need to conduct trials over a longer period of time to evaluate how something might work commercially, and how sustainable or durable your crop with the new armour would be," says Professor Grenville-Briggs. "This line that Solynta developed has shown good resistance for example. But they will then need to take that forward in some more field trials before it's fully released commercially."

The wider backdrop to this research is the need to feed a growing global population, and Professor Grenville-Briggs believes collaborations between academia and industry

An oomycete called **Aphanomyces euteiches** is a **pathogen of legume plants**, like peas and beans. It causes major problems when present in the soil as essentially you **can't grow peas for around 8-10 years**, and **there are no fully resistant varieties**.

at Solynta, a hybrid potato breeding company on a project aiming to develop more durable resistance to *P. infestans.* "They have bred a diploid potato. A potato is normally tetraploid, so it has four copies of every gene, which is part of the reason why it normally takes 20 years to breed resistance into a potato," says Professor Grenville-Briggs. "With a diploid potato, it's much faster to do crosses by conventional breeding, to effectively add different components to its armoury. Stacking multiple resistances in one plant is an effective strategy, it will reduce the need for chemical protection agents drastically."

Several students in the project are working on certain plants, to try and identify whether there is a core set of genes that are important components of immunity, while Professor Grenville-Briggs says it's also possible to take can play an important role in this respect. The combination of rigorous academic training and an understanding of how that knowledge can be applied can help address major societal challenges. "We need to have those kinds of connections," stresses Professor Grenville-Briggs. The Covid-19 pandemic has unavoidably limited the students' opportunities to spend time in industry and at institutions abroad, yet Professor Grenville-Briggs says they have still been able to collaborate online and share ideas. "The students have been working in groups where they have been examining the literature and writing review articles on different topics related to PROTECTA, such as how oomycetes spread around the world," she says. "All of the review articles will be published before the end of this year in the journal Fungal Biology Reviews."

ESR Murilo Sandroni in a field trial in Germany, where he is testing how resistance to *P. infestans* will function under future climate scenarios (high atmospheric CO₂).

PROTECTA

Pathogen-Informed Resistance to Oomycete Diseases in Ecosystems, Agriculture and Aquaculture

Project Objectives

To train the next generation of scientific innovators and future European Research Leaders - 15 Early Stage Researchers (most of whom are also PhD students) in oomycete-host biology, biochemistry, ecology and translational research that will:

Advance our basic understanding of the diversity, environmental impact, genetics, biochemistry and molecular and cellular biology of oomycetes and their effectors, pathogenicity determinants and host resistance. We will further exploit our data for the development of new, environmentally sustainable and durable control or management measures against oomycete diseases in ecosystems, agriculture, horticulture and aquaculture.

Project Funding

An H2020 Marie Skłodowska-Curie Actions Innovation Training Network (MSCA-ITN)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 766048

Project Partners

10 Academic and 7 Industry Institutions across Europe - hosting, mentoring, supporting and training 15 PhD students.

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Laura Grenville-Briggs is Professor of Integrated Plant Protection at the Swedish University of Agricultural Sciences (SLU), a position she has held since 2018. Her research group focuses on the molecular and genetic determinants of disease in oomycete and fungal phytopathogens and their interactions with microbial biocontrol agents and the plant microbiome.



European Commission Horizon 2020 European Union funding for Research & Innovation

Massive Attack on Emissions: A Roadmap for Sustainable Live Music Events

In the UK, the popular band Massive Attack commissioned the Tyndall Centre for Climate Change Research to produce a Roadmap to Super Low Carbon Live Music. The findings and recommendations are open to all the music and events industry, to promote effective methods which can sustain a low carbon future to help prevent escalating climate impacts. The inspiring planner is showing how industries can take the lead rather than rely alone on government intervention for carbon free initiatives.

By Richard Forsyth

he Bristol based band, Massive Attack are a worldwide success story in music. Since their debut album, Blue Lines was launched in 1991, with iconic tracks such as Unfinished Sympathy voted in polls as one of the greatest songs of all time, they have enjoyed a sustained role as a high-profile, respected group in the music scene. The band, made up of Robert '3D' Del Naja, Adrian 'Tricky' Thaws, Andrew 'Mushroom' Vowles and Grant 'Daddy G' Marshall, also have a conscience, and have been unafraid to challenge political agendas. Robert Del Naja specifically has been vocal in politics, for example, he once helped to fund a full-page advert against the war in Iraq in the NME magazine.

The group has now leveraged their influence in another way, working with scientists and engineers at the Tyndall Centre, a

partnership of universities with a shared aim to develop sustainable responses to climate change.

Professor Carly McLachlan, Director of Tyndall Centre, explained how the unusual pairing developed: "They asked around their networks for recommendations of who to approach and a few people suggested us. We haven't done work on music before but we are approached by various sectors and organisations to help them think more about how they could transform to significantly reduce carbon emissions."

Massive Attack commissioned the Tyndall Centre in 2019, just before the pandemic spread and disrupted the world. The pandemic, arguably, presented a period of reflection for the industry as it halted live music activities in a collective pause. The band requested a roadmap, specifically to be delivered from the University of Manchester, a

"We're grateful to Tyndall Centre analysts for providing our industry with a comprehensive, independent, scientifically produced formula to facilitate industry compatibility with the Paris/1.5 degrees climate targets – but what matters now is implementation." roadmap for achieving more sustainable live music events, which has now been produced and is currently available in the public domain.

"This is a time to reassemble practices across various aspects of our organisations and lives. From our interviews in the sector, we found that there was a lot of enthusiasm to take this moment to fundamentally address the emissions from the sector. However, the sector has been really hard hit by COVID – and so it about working collaboratively to make sure smaller venues, festivals, crew and artists can be supported in adopting new practices and approaches," said McLachlan.

Researchers scrutinised Massive Attack's own touring practices before developing this roadmap for the wider live music sector for cutting emissions in line with the UN Paris Agreement. The roadmap reveals ways the music industry can change major live events to support sustainability and minimise often sizeable carbon footprints in the production of concerts and band tours.

The report produced, drew from discussions and interviews with people across the sector and 'found widespread commitment to reassembling practices post Covid-19 so that they are fundamentally more sustainable'. The document segments advisory action for artists, managers, tour managers, venues, equipment manufacturers, suppliers, local and national Government. There is a palpable drive and enthusiasm amongst those closely involved in the industry to create a new, greener format of live event, post Covid-19 lockdowns, to make carbon emissions reduction a clear priority.

Greener food and travel

As well as the Tyndall Centre, the band has been working closely with industrialist, Dale Vince and Ecotricity, to craft partnerships with music arenas and events, with the aim to increase renewable energy capacity for the UK Grid. Important aspects of the plan include training staff to run sustainable operations and to also introduce vegan food options during concerts, as veganism is seen as the least carbon reliant food lifestyle.

Dale Vince commented: "The partnership we've designed will allow venues and arenas to create and contribute more renewable energy to the grid every time they switch on their lights, or power an amp. The staff training element can hard wire sustainability into every area of operations, and the vegan food option for back and front of house can make an immediate difference to our carbon impact."

Including vegan dishes for catering is on the roadmap's recommendations list. This is based on findings that indicate if the majority of people converted to plant-based diets there would be a huge impact on reducing emissions. For instance, researchers at Oxford Martin School, stated in the report, Analysis and valuation of the health and climate change co-benefits of dietary change, published in the Proceedings of the National Academy of Sciences, that a widespread adoption of a meat free diet could lead to a 64% drop in greenhouse emissions as the population expands.

Carbon savings can be made on transport around events too. Whilst touring inevitably involves a degree of air travel, the reliance on private jets for convenience, schedule keeping and security should be considered too costly an environmental burden and alternatives sought. Limiting total sector aviation emissions to a maximum of 80% of 2019 levels is one priority.

"It is about planning from the inception," explained McLachlan. "It is only likely to be really impractical if you try to fit it to a tour that wasn't designed for low carbon travel. In some of our scenario work we could get emissions from band and crew travel down by around 80% on a European tour, so there is a lot that can be done between how we do things now and the lowest options."

Massive Attack say they know from experience of band travel via rail that immediate action is possible. Rail travel would achieve an instant 31% reduction overall in the most carbon intensive band activity. What's more, biogas HGV technology can offer up to 95% GHG emissions reductions.

"I do believe that the leaders in the space will adopt these types of approaches and some already are – and I think that will catalyse change across the sector as new approaches are shown to be effective. I think it is super feasible if there is will and leadership – but it has to be a central part of how tours are developed and planned."



Even more savings can be made with higher reliance on virtual rather than face to face meetings when organising, a practice now engrained into society from working through the pandemic remotely.

On the ground, there should be a push on improving public transport links and services, adding cycle parking options and electric vehicle charging points at the venue, reducing the amount of equipment shipped, renting staging rather than bringing it – all these options have potential to squash emissions levels. It would be necessary to form close collaborations between artists, managers, venues, local authorities, transport operators and all stakeholders, investing time and budgets into transforming the way gigs are run. In the UK, several local authorities have declared Climate Emergencies and can incorporate some of the findings into climate action strategies to reduce emissions for local music events.

Cec.

The report recommendations would require leans towards greener travel services, and the facilitation of improved public transport as an efficient and convenient way to travel to events and reduce traffic. It has been suggested that individually chartered trains and coaches would be an attractive pull and good idea for emission reduction when running major events.

Efficiencies that cut emissions

There is ultimately a benefit of cost savings with careful planning.

"There are many ways this could save money and there is the potential for business models to adapt and develop to facilitate lower carbon practices like plug and play," concluded McLachlan.

Having a plug and play style set up for indoors events would allow bands to minimise transportation of equipment which would also lessen carbon impacts. Buildings can play a key role in carbon offsets in other ways and the report describes an aim for zero emissions by 2035 within the live music sector for energy emissions in venues, offices and other premises it uses. Current outlooks on electricity supply emissions and available heating, cooling, ventilation and catering technologies and energy efficient AV equipment suggests that this target is technically feasible.

On the wish list of changes, generating renewable electricity onsite is made possible with solar PV. There should also be an increase in data sharing and awareness of electricity used in productions to all stakeholders and there is always the option of switching to energy tariffs that directly support renewable energy projects.

Dancing to a different beat

It became clear in consultations with the industry that diesel is wasted and not eco-friendly, often running generators for peak load throughout the events. Therefore, better scheduling of generator use would be a cost saving that could be redirected into low carbon investment. There is a milestone to completely phase out diesel generators as soon as 2025. It is important to engage with venues to switch their power supplies to genuinely renewable sources.

"We're grateful to Tyndall Centre analysts for providing our industry with a comprehensive, independent, scientifically produced formula to facilitate industry compatibility with the Paris/1.5 degrees climate targets – but what matters now is implementation," said Robert del Naja. "The major promotors simply must do more – it can't be left to artists to continually make these public appeals. But our sector is operating in a government void."

He adds: "Fossil fuel companies seem to have no problem at all getting huge subsidies from government, but where is the plan for investment in clean battery technology, clean infrastructure or decarbonised food supply for a live music sector that generates \pounds .6 billion for the economy every year and employs more than 200k dedicated people? It simply doesn't exist."

Massive Attack say they are committed, with immediate effect, to working with all stakeholders who are focused on actioning the recommendations their roadmap highlights. Will it work? It will take sizable efforts and commitments from artists and all those around who organise their live events, but the idea is a popular one in the industry and catching on fast.

Indeed, the band Coldplay have recently pledged to slash CO2 emissions for their new world tour by 50 percent compared to their 2016-17 world tour with a reliance on renewable energy to power their stage. This will include initiatives like a kinetic floor to harvest energy from fans during the gig, and a stage built from sustainable materials, like bamboo and recycled steel.

The reality is that this kind of industry-wide initiative will need a high level of collaboration and investment of time and resources from all stakeholders. As Professor Carly McLachlan puts it: "I don't think it is about bands alone – it is about the whole sector. This is a conversation happening across all actors in the sector. I do believe that the leaders in the space will adopt these types of approaches and some already are – and I think that will catalyse change across the sector as new approaches are shown to be effective. I think it is super feasible if there is will and leadership – but it has to be a central part of how tours and developed and planned."

Special thanks to Carly McLachlan and Amrita Sidhu with this feature.



Find the report here:

pre: https://documents.manchester.ac.uk/display.aspx?DocID=56701

Building a picture of transition metal oxides

Novel electronic and magnetic properties can emerge in low-dimensional systems, where electrons are confined to a narrow area. We spoke to **Professor Milan Radovic** about his research into titanates, and how their properties can be tailored and controlled in low-dimensional systems, which could then open up wider possibilities in oxide electronics.

The modern electronics industry uses large quantities of silicon in device production embedded in the current technology. However, transition metal oxides (TMOs) also have a range of interesting properties which are way more versatile than silicon. "Transition metal oxides can be insulating, metallic, magnetic, super-conducting, etc., and can also be used for optoelectronics," says Professor Milan Radovic, a scientist in the Spectroscopy of Novel Materials Group at the Paul Scherrer Institute (PSI) in Switzerland. The main problem in terms of using transition metal oxides for industrial applications is that they are essentially very expensive as raw materials. "Silicon can be found pretty much everywhere and its big crystal can be grown easily," points out Professor Radovic. "The transition metal oxides, however, include some rare earth elements which are "rare" and therefore very expensive and it will be hard to imagine that devices based on such elements will be produced on a large industrial scale. They are however very relevant for certain special needs and purposes, perhaps in novel quantum computing technology."

Stronthium titanate

As the Principal Investigator of several research projects based at the PSI, Professor Radovic and his team are now investigating how to control electron behaviour in titanates such as strontium titanate (SrTiO3), which is among the most widely used of the transition metal oxides. Strontium titanate has some very interesting electrical properties, now Professor Radovic aims to gain deeper



insights into this compound, which will help lay the foundations for further development in oxide electronics. "We want to understand it in order to control and further improve its properties," he says. The electronic structure is the key consideration in terms of understanding the properties and behaviour of the system. "If the system is metallic than it is usually simple, while if there is a gap between conduction and valence bands, then you may aim to modify system to generate more exotic properties."

This research includes investigation into titanium dioxide (TiO2), which can be thought of as the parent compound of the titanates. Professor Radovic's research is largely focused on artificial materials in the form of thin films with a thickness of just a few unit cells. "Strontium is an element that tends to diffuse, segregate or intercalate in the oxide matrix. Therefore we decided to use titanium dioxide, which is a simpler compound, and to investigate the effect of Sr contents, hoping to create a system with novel properties," outlines Professor Radovic.

The focus here is on low-dimensional electron systems, where electrons freely move in the confined area, leading to the emergence of new physics and properties that many scientists are now working to harness. In their research, Professor Radovic and his colleagues are able to transform a 3-dimensional transition metal oxide into a 2-dimensional system. "In this 2-D system the electrons propagate only in plane. This dramatically affects the electronic properties of the system," he outlines. A pulse laser deposition system is used to make a 2-D system (physically, it is an utra- thin film) in what is essentially a bottom-up process, an approach which gives researchers a high degree of freedom. "We have more parameters to play with," explains Professor Radovic. "During the growth of the thin film you can incorporate substitutions or defects which consequently affect a crystal lattice and charge carrier concentration."

Researchers are investigating how they can then control and tune electron behaviour. This essentially involves putting two oxides in close proximity to each other, with a 2-D electron gas at the interface between them, the structure of which is

THE UNITED CONTROL OVER CHARGE DENSITY AND SPIN STATE OF LOW DIMENSIONAL ELECTRON SYSTEM AT TITANATES

Project Objectives

The interplay between orbital ordering, charge correlation, spin–orbit coupling, and lattice distortion in Transition Metal Oxides (TMOs) leads to the complex two-dimensional electron states (2DES) typified with fascinating properties. Understanding, controlling and tailoring electronic properties of TMOs surfaces and interfaces, in general, are mandatory for further development of novel quantum devices.

Project Funding

This research program is supported by the Swiss National Science Foundation (SNSF) through following grants:

1. The United Control over Charge Density and Spin State of Low Dimensional Electron System at Titanates (SNF grant 200021_182695). 2. *In-situ* spectroscopy of oxide heterostructures (SNF grant 206021_177006). 3. Experimental realization of novel quantum materials with MBE/PLD+STM+ARPES (Grant No. IZLCZ2-170075.)

Project Partners

DTU-Denmark supports this research through a staff-exchange collaboration.

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Milan Radovic started his research career at Institute of Nuclear sciences "Vinča"- University of Belgrade in 2000. In 2005 he moved to Italy where he obtained a PhD at Università degli Studi di Napoli Federico II, Naples. In 2009, he was invited to engage a joined position at EPFL- Ecole Polytechnique Fédérale de Lausanne and Paul Scherrer Institute. Since 2013 he has been a staff scientist at Paul Scherrer Institute, Switzerland.



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then affected by changes of the parent materials. "Where two materials are in close proximity to each other, it may be possible to transfer certain properties from one material into the other which you maybe would like to alter," says Professor Radovic. This opens up the possibility of effectively tailoring the electronic and magnetic properties of a system, which is an exciting prospect relevant to a wide range of technological applications. "If, for example, a ferromagnetic material is put in close proximity to a non-magnetic one, then additional properties emerge in the compound of interest. So we're able to

Industrial applications

There are a wide range of potential applications of these transition metal oxides, with researchers investigating how novel quantum materials can be used in the next generation of novel devices. New quantum technology using spin and charge promises a revolutionary advancement in electronics. "Topological TMOs with their resolute electronic states are up-and-coming platforms for quantum computers" says Professor Radovic.

The goal for Professor Radovic and his colleagues will not be to actually produce new devices however, but rather to develop a deeper understanding of these transitional metal oxides

Transition metal oxides can be metalic, insulating, or both. They can be magnetic, superconducting, and can also be used for optoelectronics.

influence the behaviour of the neighbouring compound," explains Professor Radovic.

The main aspects that can be changed or tuned in a system are electronic density, electronic correlations and bandwidth. Electron density relates to how many electrons can cross the fermi layer of a material, yet Professor Radovic says this is not enough in terms of the project's overall agenda. "This gives the electron density, but not the space where electrons can live. The electronic structure is actually important to know because it tells you how many possible states can be in a system, which electrons can jump over, which is a topic we are very interested in," he outlines. and their potential. "If somebody wants to use these titanates as a 2-D electron gas platform, then we can describe what is useful, what are the drawback, and the wider possibilities. When you effectively have a recipe for thin films, then it's easier to produce devices," he says.

The research agenda in Professor Radovic's team also includes investigation into other materials aside from titanates, such as nickelates, manganates, cuprates and iridates with a view to harnessing their technological potential. Many of the concepts that Professor Radovic is investigating are relevant to a variety of different oxides. "Manipulation with these in thin films form can significantly alter the critical properties of the transitional metal oxides," he stresses.



Developing new leaders in engineering

The InDEStruct project (Integrated Design of Engineering Studies) seeks to advance heat exchanger technology by creating novel structural concepts, whilst enabling a new pedigree of engineering leadership. **Prof Atul Bhaskar** of University of Southampton, **Dr Claus Ibsen**, Manager of Research and Development at Vestas aircoil and one of the four Early Stage Researchers (ESRs), **Khandokar Abu Talha**, explain the aims of the project.

With a goal of improving the efficiency and longevity of heat exchangers, which has far-reaching implications for sustainability, the InDEStruct project is entwining the work of four Early Stage Researchers in a collaborative linking of disciplines, aiming to bring new strategies of developing and thinking to industrial applications. This approach to doctoral training in engineering design covers several aspects of mechanical engineering, including structural vibration, stress and thermal analysis, additive manufacturing, multifunctional metamaterials, fatigue and materials development.

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Supervisor of the students, Atul Bhaskar, Professor of Applied Mechanics at University of Southampton said: "This is a Marie Curie programme which is primarily for training networks of PhD students. The theme of this project is integrated design and in my view that is where it is different, in being an applied science. We have this great platform, which is how a real design office works. You have different people working on their research, but they have to work in sync towards a purpose - and the purpose is a product. In general research especially, there is a possibility to focus on solving imaginary problems. So being in industry gives that direction that you are solving industrial problems and scientific questions that have a relevance."

Improvements in the design and materials of the humble heat exchanger could have enormous implications. Heat exchangers are devices that transfer heat between a solid object and a fluid, or two or more fluids, which may be separated by a wall to prevent mixing, or not. Heat exchangers are used in so many applications, including fridge freezers, power stations, air conditioning systems, chemical



plants, for sewage treatment and in combustion engines. Heat exchangers will also inevitably be part of future technologies.

As Dr Claus Ibsen puts it: "Technologies that generate power, all of them use heat exchangers, and we will use heat exchangers in electric vehicles, so you see them in many places. You can use them in all sorts of challenging environments, also fuel cells for example, high temperature fuel cells are also requiring a lot of heat exchanges."

Cooler to be efficient

The project's primary focus is on lowering emissions from engine systems. Heat exchangers in engines have been identified as a key enabling technology for low-emission power systems. If these components could be more efficient and robust, the benefits for carbon reduction would be substantial. Simply put, there is room for improvement in the current designs of such heat exchangers.

"You have this very high temperature heat exchanger and if we put it on a big engine it vibrates, which reduces the lifetime of the heat exchanger," explains lbsen. "When you heat up the materials the component deforms and you create stresses inside it. You have these stress concentrations and vibrations and it reduces the lifetime of the component. Cracks appear. For the researchers, this is the challenge, and they are combining research to be able to design a cooler system."

The project requires the researchers to spend time in both the academic university setting as well as equal time in industry, in this case 18 months at Southampton University in the UK and 18 months at Vestas aircoil in Denmark. Vestas aircoil is a specialist and market leader in air charge coolers for diesel



engines in the marine sector and has developed a comprehensive industrial cooling division, for a range of cooling needs. Indeed, Vestas aircoil manufactured the world's very first charge air cooler with Burmeister & Wain in Copenhagen and have been pioneers of technology and product development in this field. There are additional partners involved who also provide valuable support, and further secondments in the UK and Denmark add value to building experience and knowledge.

To develop high performance heat exchangers is a huge undertaking, with the need of critical thinking and expertise from the academic world, transferred to practical engineering in the private sector. This is the goal of the four researchers, within this project. The researchers are Atul Singh, Kevin Jose, Milena Bavaresco and Khandokar Abu Talha. Each has their own specialism, which they bring to the mix. first collaboration work, which will probably have a real-life application," said Talha.

It was part of the process for the researchers to learn from each other, as well as learn and understand the industry by working within it.

Talha continues: "For the first two years we had to understand the fundamentals with basic training, so we have been working with relevant companies. For example, Milena has been to The University of Southern Denmark where they were developing a new technique, experimenting and learning how to extract the data. In my case, I am taking several courses where they do a particular estimation using an industrial software. We all have this type of training along with our academic modules, to have the fundamentals built in and have the real time application to learn those new techniques. It's a continuous process of learning and trying to also come up with something new.

They can create **complex shapes** that previously they could not make simply because of the **restrictions of manufacturing**. This allows the **creativity** of the **engineer** to **develop**.

Talha, who talked to EU Research, has been working on his PhD thesis, Fatigue evaluations of additively manufactured materials in novel heat exchanger designs. His work has been fuelled and supported by the other three researchers, and vice versa, working closely in parallel, each with their own PhDs in progress. One common aim is to be able to predict failure of a component through fatigue, which can be difficult, traditionally reliant on heavy data, computer modelling and extensive real-life testing. With a team of specialists picking apart the different aspects of the problem it becomes easier to find, use and model the right data.

"Milena is looking into different kinds of experimental methods to extract data from the heat exchanger, Kevin is analysing that data, and he is going to give me that data as an input, then based on that data I will try to come up with techniques suited to calculate the lifetime of the component. So that is our very I am for example generating more data from experiments. That is something new, but I am still learning and perfecting that to collect more and more data. We are continually developing."

Beyond the specific aims of product development, the project's nurturing of collaboration raised the bar in other ways in terms of how the researchers organised together, developing useful transferable and general leadership skills.



ESR1: Atul Singh



Project Title Multi-disciplinary Design Optimization of Cellular Heat-Exchangers.

ESR 2: Kevin Jose



Project Title Computational Modelling of Complex Structures & Structured Materials.

ESR3: Milena W. Bavaresco



Project title Novel experimental characterisation of elastic & acoustic metamaterial as produced using additive manufacturing technology.

ESR4: Khandokar Abu Talha



Project title Fatigue evaluations of additively manufactured materials in novel heat exchanger designs.

InDEStruct

Integrated Design of Engineering Structures

The main driver for the InDEStruct project is training of scientists in the area of multidisciplinary optimisation of engineering systems that involve thermal and mechanical loading. Such scientists can integrate technologies to provide indicators of engineering performance, which can be used in the context of a digital twin. Thereby facilitating the digital transformation inherent in Industry 4.0.

Project Funding

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 765636.

https://indestruct.eu/about-us/partners/

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Claus Hessler Ibsen is Group Research & Development Director at Vestas aircoil and has worked on a number of innovative projects for the company. He is the Project Coordinator for InDEStruct.

Atul Bhaskar is the Professor of Applied Mechanics at the University of Southampton. His research spans structural mechanics, vibration, design, and additive manufacturing. He has published widely, led major research projects, knowledge transfer partnerships, industrial consultancies and patents.

Vestas aircoil Southampton







The progressive collaboration of the four researchers was seen as paramount for success. Whilst the pandemic often prevented the close interaction for the researchers that they would like, frequently two researchers would manage to sit in a room together at least to discuss face-to-face findings and ideas. It was seen as important to bring each researcher involved up to speed with the others' work, always with an eye on where it is headed.

Ibsen observed: "There is a challenge with how to implement this, to use those interesting results because PhD students are going to look very narrowly into the smallest details but still need to look at an end where someone is going to use it in practice, so that is something we are still trying to learn and develop. We need to look at a setup where we use academic findings."

For the researchers, that setup for using findings is being slowly but surely defined. For Talha, the problems were initially with methodologies around data.

"We're looking at the way we collect data," said Talha, "There was this missing link between data they get from heat exchangers and being able to use that data to calculate the fatigue life. If we can correct this, that would be good progress. It would be academically valuable and industrially valuable."

The technology of the future

At Vestas aircoil, there are state of the art technologies and techniques to help in the project's drive to create something new, such as additive manufacturing, where computer aided design in combination with 3D printing can explore design concepts in engineering by producing parts. One focus for this project is pushing, exploring and developing the technology of additive manufacturing. Atul and Talha are embracing this as a focus in research. Additive manufacturing will form part of Vestas aircoil's strategy for innovation, where the designs could lead to scaled up manufacturing of new components in the coming years.

"The additive manufacturing opens up new possibilities in the future," confirms Claus, "you can build in crack arresting properties in 3D printed material or you can change the thermal elongation and you can focus on stress concentrations, so you don't have these kinds of issues. You can have smarter things that you can build into a heat exchanger."

Their academic supervisor, Professor Bhaskar, recognised that by closely working together in an industrial setting, the researchers were exposed to and shared knowledge in ways that were necessary to make progress with toward the design goal.

"The technologies they are working with, like additive manufacturing, are emerging," said



Bhaskar, "They can create complex shapes that previously they could not make simply because of the restrictions of manufacturing. This allows the creativity of the engineer to develop. You can test designs by printing differently with great flexibility. It's unlikely that all the four researchers would learn these kinds of skills outside this type of scheme but all of them are familiar to a basic level with what this technology is all about."

Whilst new insights, greater understanding and improved designs will no doubt reap benefits for heat exchanger efficiency, a legacy of InDEStruct is in the creation of a methodology of working for subsequent Early Stage Researchers with interdisciplinary specialisms, to demonstrate how they can combine and make use of their research and findings together, with a common goal to tackle real world problems in industry.

A driver of the project is not just creating future technology, but creating future technology leaders, who can effectively bridge the divide that often occurs between academia and industry. By weaving together academic structured thinking with a goal to address sector needs, the project could help form a template for researchers and private companies to work toward tangible advances that benefit the world.





Modern vehicles connected to the IoT typically require large numbers of sensors, and these sensors need a reliable supply of power. We spoke to **Professor Ausrine Bartasyte**, **Associate Professor Samuel Margueron** and **Doctor Giacomo Clementi** about European ITN ENHANCE project's work in developing piezoelectric energy harvesters that could reduce the environmental impact of the automotive and information sector.

The autonomous cars, trucks and other vehicles of the future, which are expected to the market after 2025, will require a large number of sensors, for example in speaker systems, parking aids or temperature/pressure sensors. Sensors will also be required for systems in the infrastructure and environment to enable the vehicle to communicate with surrounding objects. All these sensors and systems require energy sources. The different systems inside a car are typically connected by large amounts of wiring, greatly adding to the overall weight and complexity of the vehicle. "There may be more than 2 kilometres of wiring inside a car," says Giacomo Clementi, a researcher at the FEMTO-ST Institute in Besancon, France. After completing his PhD as an early stage researcher (ESR) in the ENHANCE project, an initiative bringing together academic and industrial partners from across Europe, Clementi is now working to develop hybrid energy harvesters which will address these issues and help reduce the environmental impact of the automotive sector. "Our idea in the project is to reduce the wiring cost and the complexity of cars. At the same time, reductions in the weight of the car will also lead to reduced CO₂ emissions," he explains.

The ENHANCE project itself is an Innovative Training Network (ITN), which provides training to ESRs across a range of disciplines, including chemistry, physics and electronics. This reflects the complexity of the project's work in developing a complete energy harvesting



Micro-energy harvesting team at Institute FEMTO-ST: Merieme Ouhabaz, Giacomo Clementi, Mario Constanza, Samuel Margueron, Ausrine Bartasyte and Bernard Dulmet (from left to right).

system. "We are taking a multi-disciplinary approach, starting from the material and finishing with the electronics. We're not focusing on just one part, we're looking at the complete system," says Professor Ausrine Bartasyte, Deputy Director of the FEMTO-ST Institute and the coordinator of the project. The ESRs are also receiving training in 'soft' skills, such as how to write presentations or apply for research funding, which will help prepare them for their future careers, whether in academia or industry. "We organised schools, workshops and conferences covering topics from chemistry and physics, to electronics to micro and nano-technology, as well as soft skills," outlines Professor Bartasyte.

Lead-free Piezoelectric materials

Clementi's primary focus is on vibrational energy harvesting, so converting mechanical energy from the environment into electrical energy, which can then be stored or used to power small wireless sensors inside a vehicle. Piezoelectric materials, which have an internal electric charge, hold great potential in this respect. "When piezoelectric materials are essentially shocked or deformed by mechanical stress, due to their intrinsic atomic structure, they can convert this deformation into an electrical charge. That charge can then be stored in a battery, or used immediately to power a sensor," outlines Clementi. Researchers are seeking to replace commonly used lead-based piezoelectric ceramics, prohibited under EU regulations since 2016, with environmentally-friendly piezoelectric materials offering competitive performance, in particular a piezoelectric material called lithium niobate (LiNbO3). "I am studying the microfabrication of this material and its application in vibrational energy harvesting," says Clementi. "This finds applications not only in transportation, but also in areas like smart buildings, factory automation, internet of things (IoT) and structural health monitoring."

In the frame of ENHANCE project, it was demonstrated that LiNbO3 implemented in vibrational energy harvesters offers







competitive performance in terms of scavenged energy and stability at high operational temperatures with respect to the lead-based ceramics. This opens new avenues to the eco-friendly microenergy sources needed for further development of IoTs and communication systems.

The common theme here is the need for a reliable source of energy to power small sensors, with demand set to grow further in the coming years, as more and more physical objects are connected to the IoT. The main expected area of application at this stage however is the automotive sector, with researchers studying vibrations inside cars. "We've looked for instance at acceleration levels and the magnitude of the deformation, and how this relates to different ranges of frequency," says Clementi. A further step in the project involved developing simulations to look at how a device would function in the practical context. "We implemented a very simple structure in the form of very small beams of a few centimetres then we studied them with finite element analysis," continues Clementi. "After that we optimised the structure, then we looked towards fabrication and prototype testing." Researchers are using LiNbO3 in the

development of the harvesters, seeking to

harness its interesting electro-mechanical properties. In particular, Clementi says that LiNbO3 has some very promising performance characteristics in terms of robustness and flexibility. "We are now able to implement such piezoelectric materials on metal foils, which are more reliable," he explains. This means it is possible to achieve power levels comparable to other materials,

Self-powered sensor

The material is also chemically inert and can go to high temperatures, in terms of both processing and application, which is highly valuable in terms of facing different conditions. The aim here is to design a module that essentially functions as a selfpowered sensor. "The harvester can be used already as a vibration sensor, it can

Energy available for free in the environment is sufficient to power up data transmission. Autonomous microsources, based on energy harvesting and eco-friendly materials, will bring the 6th sense to the communication technology.

without any of the toxic effects associated with lead-containing materials. "We can theoretically convert 49 percent of the mechanical energy into electrical energy. That is comparable to both lead-free and and lead-containing materials, and in some cases even higher," continues Clementi. "Moreover, we can lower production costs, because this material comes in the form of very high-quality wafers, which are commercially available." communicate the acceleration of the car. In other cases you may want to measure temperature or humidity, which can be communicated using Bluetooth," says Clementi. The early tests on this device in the lab have shown promising results, with the project's research essentially demonstrating a proof-of-concept, while there is also potential for these harvesters to be applied in areas beyond the automotive sector. "For example they could be used in structural health monitoring, in bridges. Wherever there are vibrations you can use these kinds of devices, so there is a broad range of potential applications," outlines Clementi.

This represents an interesting alternative to existing methods of harvesting microenergy, such as photo-voltaics, which is already widely used. While photo-voltaics is highly efficient in the presence of direct light, it is not really ideal for indoor or enclosed applications and requires regular cleaning, whereas researchers in the project have taken a different approach. "Our approach is about converting every coulomb of energy. This will be achieved thanks to the ultra-low power electronics," says Samuel Margueron, an Associate Professor at the FEMTO-ST Institute who is also closely involved in the project. These sensors do not require any maintenance, and their nontoxic nature means they can be used in the natural world, with only minimal human intervention. "If you are going to distribute these sensors in nature then you cannot use lead-based materials, because they would cause pollution," explains Professor Bartasyte. "LiNbO3 is chemically inert and will not lead to any pollution, as it doesn't contain any toxic elements."

The wider aim here is to develop reliable and efficient energy harvesters that can be adapted to industrial needs. The industrial partners have played an important role in directing research towards the development of products relevant to commercial needs, and Clementi says a lot of progress has been made in the project. "Now we have a device that is at Technology Readiness Level (TRL) 4, with prototypes ready to be tested on the field," he says. The next stage of tests are being prepared, while Clementi has established a start-up company to eventually bring these harvesters to the market. "We are in the maturation stage now, and we are in contact with investors. Our market is vibrational energy harvesting, we are trying to sell our device as an alternative to conventional ceramics," he continues. "Transportation is the obvious market for us at this stage, as we have worked a lot on that, but ultimately we would like to develop a device that endusers can then implement wherever ambient vibrations are present."

An effective energy harvester could have a significant impact in this respect, helping reduce the weight and complexity of vehicles, and so mitigating their environmental impact. This technology could reduce the weight of a vehicle by up to 50 kg, while it would also be significantly easier to maintain. "In many cars sensors are connected by a complex system of wires, and if you have any problems then it can be quite complicated to repair. If the sensor is completely autonomous and battery-free, then it's much easier, as it doesn't require any maintenance," points out Professor Bartasyte. "By taking out the wires, you simplify the system."

ENHANCE

Microenergy sources for autonomous sensors

Project Objectives

The Innovative Training Network (ITN) entitled "Piezoelectric Energy Harvesters for Self-Powered Automotive Sensors: from Advanced Lead-Free Materials to Smart Systems (ENHANCE)" provides thirteen Early Stage Researchers (ESRs) with broad and intensive training within a multidisciplinary research and teaching environment. Key training topics will include development of energy harvesters compatible with MEMS technology and able to power wireless sensor. Applied to automobiles, such technology will allow for 50 kg of weight saving, connection simplification, space reduction, and reduced maintenance costs - all major steps towards creating green vehicles. Other important topics include technology innovation, education and intellectual asset management.

Project Funding

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 722496.

Project Partners https://www.itn-enhance.com/nouvel-accueil

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Ausrine Bartasyte is a full professor at University of Bourgogne Franche-Comté and a deputy director of the Institute FEMTO-ST (Besançon, France). Her research focus on advanced architectures of alcaline niobates for the next generation acoustic filters & sensors, energy harvesters, actuators and integrated photonic devices.





Optimising and storing energy in Europe's homes and buildings

Designing better systems for energy use in buildings will be essential for Europe to meet its target of near zero energy in 2050. Technical Project Coordinator, Pavol Bodis of SCORES explains how new combined technologies can collect renewable energy locally, store it and use it in smarter, more optimised ways to improve efficiency.

The building sector accounts for 40% of the total European energy consumption. It's the big challenge and barrier when forming strategies for the ambitious sustainability goals set by the European Union. The SCORES project sees a solution in renewable energy generated locally and self-consumed by buildings.

A hybrid storage system of electricity and heat could be the answer, bridging gaps in supply and consumption and all at cost effective rates. The project looks at using renewable energy produced by local solar panels and wind farms combined with advanced heat and electricity storage systems and supported by an Energy Management System. This approach allows stored energy to be used when the renewables can no longer provide it because the sun is not shining, or the wind is not blowing. There are a range of solutions and combinations of different technologies on the table and all could play a key role, depending on the needs of the local market in any given country.

"We want to switch to renewable energy, specifically for urban environments where there are houses and buildings. On a global scale, you want to have as much energy generated locally, such as solar panels on the rooftops. But sometimes the sun does not shine and our plan is to store the energy when you have an abundance of it and use it when the sun doesn't shine. This is the whole idea. It can be done with our hybrid energy system," explains Pavol Bodis.

By local, one could mean an individual building or a district consisting of several buildings. The properties are still connected to the Grid and the energy can also sent back to the Grid in some circumstances. The difference is, there is more local, cyclic and



The SCORES concept is based on a hybrid system combining solutions that harvest electricity and heat from the sun, store electricity, convert electricity into heat, store heat, and manage the energy flows in the building.

renewable energy being put to use and in a way that it is not wasteful, rather it is stored and used when and where needed.

There are key technologies that entwine together to make this kind of production, storage and optimisation of energy consumption possible. the market but SCORES has one that has a buffering system which helps households store the energy when they have an excess of it, making it available when there may be a lack of it being collected. Another component part of such a hybrid system is a heat pump. Somewhat more advanced solar-driven technology,

SCORES is actively pursuing involvement in policy for several countries to understand how their solutions can apply in government set frameworks, to their goals and within budget requirements.

Smarter technologies for energy optimisation

An integral component that adds intelligence into energy usage is the Building Energy Management System (BEMS) which relies on clever algorithms to predict all kinds of things, from when the sun is shining, how much energy is used by a building's inhabitants and how to best optimise supply to meet demand. There are many kinds of smart systems available on namely solar thermal technology in the form of PVT tiles on a rooftop can support the functioning of a heat pump in a property.

"The heat pump is a device that converts electricity to heat and provides efficient heating that is driven by green electricity in our case. For optimisation, self-produced electricity comes via these specialised PVT cells put on individual buildings," said Bodis. "Effectively, this produces electricity and

heat which goes into the heat pump, which in turn converts it into the heat that is used for heating up water. The real big chunks of energy at home are hot water and heating of the house, potentially about 80%."

Heat pumps are being looked at seriously as technologies of promise for widespread adoption by some European governments.

There are many innovations that can make up a hybrid storage system. One innovation championed by SCORES is the REDOX heat battery, essentially a battery that stores heat rather than electricity.

"There are technologies where we have basically taken a technology from one industry, for example, the chemical process industry, and we transferred it into the energy storage system, the REDOX heat technologies are an example of that. It is currently in a laboratory testing phase and we are testing the performance for

Demonstration of the integrated hybrid energy system takes place in two real buildings one in Middle/Southern Europe (France).

housing, so it's not technology that is ready for implementation in the commercial world yet.

"We have also adopted a storage technology based on phase change materials. This is material that changes its state from liquid to solid and if you do that you need to put energy in it and when it goes back you release the energy from it. So that means by changing the phase or form of the material you can store energy, we do that as well."

Another key focus of the project, one crucial for emissions targets and green goals in a worldwide perspective, is materials recycling, specifically with batteries. All batteries run down and eventually become inefficient and unusable. Prolonging battery life or finding alternative uses for older batteries needs to be a priority with such a growing industry, so as not to create a new problem around disposal.

Promoting circular use of materials

"We have second hand reused electrical batteries from buses," said Bodis. "For mobility application for a bus, these batteries are no longer optimal, they don't last long or work so well for bus transport, but we can refurbish them and reuse them and give them a second life. We give them a second home in someone's actual home.

"For our society it's not just that energy has to be renewable but also the materials we use should be circular, which means to close the circle of materials and not just unearthing new raw materials. We extend the lifetime of the batteries by years. With our application it is not so important to have the highest energy density. For our purposes the battery can be at 60-70% but on a vehicle that is a real problem as you don't want to have a huge wait to charge it with only 60% capacity, but in a stationary



SCORES

Self Consumption Of Renewable Energy by hybrid Storage systems

Project Objectives

The main goal of SCORES is to demonstrate in the field the integration, optimization and operation of a building energy system including new compact hybrid storage technologies, that optimizes supply, storage and demand of electricity and heat in residential buildings and that increases selfconsumption of local renewable energy in residential buildings at the lowest cost.

Project Funding

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 766464.

Project Partners

You can find information about the project and its partners with the following link: • http://www.scores-project.eu/about.

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Erwin Giling is the coordinator of the SCORES project, working in close cooperation with technical coordinator Pavol Bodis. For well over a decade Giling is developing and managing projects in the field of CO_2 reduction, energy storage, energy conversion and the electrification of the industry.



application it works fine. When we started this, battery life was limited, but we have seen huge developments in lithium-ion batteries in the meantime, so it is a good idea to use these second-hand lithium-ion batteries that have a far longer lifetime now, compared to when we started SCORES. We will also account for that in the business case analysis, as the world changes. When we started SCORES, PV panels were very expensive and now, four years later, they are only 20% of that original price. Costs are going in a positive direction for economic viability."

SCORES is looking at several smart ways to use combinations for optimal benefit from the perspective of self-consumption. An important aspect of SCOREs, is that there is more than one way to create a hybrid energy storage system, this is not focusing on one single configuration. The project is looking into several types to work out how to combine technologies and how they can work together in efficient ways. There is also a cost element for each technology which in the real world, is a very important factor for uptake and use.

Making systems feasible

"Developing these systems for the European market does not mean that you have the same solution for every country, for every climate situation or for the same scale for that matter. We can't test for every variation and country but we do have two implementations. The choice we made was a relatively largescale implementation in the South of France and we've applied our system in two large buildings consisting of 150 apartments, set up for the climate in the Mediterranean. The other one is close to the mountains in Austria, so it is completely different, with a more continental type of climate, where we have a smaller scale system for six houses."

Beyond testing how the system works, there is the broader question around its practicality and feasibility. The question of, can this be rolled-out across Europe and the world? Developers, contractors, governments and existing homeowners would need to be invested and willing. Re-fitting existing housing stock alone could run into big numbers, potentially multiple millions of buildings that have to be refitted, many which are old buildings. This presents an extreme challenge, one which Bodis recognises.

"What we do see from the projects around us is the renovation rate lags behind the needs for the transformation of the building stock. Also, in Germany there are not enough companies to rebuild as quickly as excel sheets tell us. So, what to do? Our approach in this respect is testing in various configurations and modelling how to make the biggest steps with the smallest amounts of resources."

SCORES is actively pursuing involvement in policy for several countries to understand how their solutions can apply in government set frameworks, to their goals and within budget requirements.

"In the SCORES project you have complex systems with so many types of devices, so many functionalities for your home, but you should also see this as the platform for the message, where in certain situations you can apply this or that part of the system. It doesn't mean you can make optimal solutions for every house in every country but, what we are proving that you can find an optimal, minimalistic approach with limited resources."

The research findings will be extremely useful for what comes next in the coming decades, where if Europe does not find workable solutions to the challenges SCORES seeks to tackle, the goals around emissions reductions will surely fail. Optimising energy is one of the greatest challenges for reducing climate impacts and SCORES is demonstrating what can be possible in terms of the changes we all desire.

CDCES consortium meeting and workshops DCDES consortium m

Nurturing

a new generation of mathematicians in Paris

Paris is a city with a reputation for mathematics excellence, which is why the MathInParis2020 Project is championing a new generation of mathematicians in doctoral programmes that give them experience, facilities, networking and most of all opportunities to excel. EU Research talks to Project Coordinator, **Ariela Briani** and **Gael Octavia** in charge of Communications, about supporting the most promising minds in mathematics.

Cultivating, mentoring and supporting a new generation and network of young, ambitious doctoral students is a central goal of the MathInParis2020 project, supported by the Fondation Sciences Mathématiques de Paris (FSMP). Mathematics has profound impacts on other sciences, technology, innovation, economies and society. Developing maths and mathematicians can be a key driver to solving problems and creating opportunity.

Paris has become a highly suitable city for promising mathematicians to thrive. The programme MathInParis2020 seeks to attract talented doctoral students from around the world and provide an environment for a high standard of training and mentoring. Emphasis is placed on ensuring the researchers are internationally oriented, can be open to other scientific disciplines and non-academic issues, in a context of equal opportunities and ethical and societal concerns. "The programme is focused on Paris and the fact is that the Parisian mathematical community is a really exceptional community in the world. It's maybe the biggest community in terms of the mathematical spectrum. In a small area you have all the mathematics you can imagine. In Europe there is nothing comparable to this in scale. It's why the programme is important because we fill this community with young talents, but we also help these talents take benefits from this community," said Gael Octavia.

Indeed, with 1800 mathematicians (1200 permanents researchers out of 4000 in France) in 14 laboratories and 24 Inria teams, the FSMP network comprises the largest concentration of mathematicians worldwide.

The best in maths, together

The programme is looking to attract the best minds in mathematics. There is a high benchmark for selection.

As Ariela Briani puts it, "We are looking for good mathematicians. Part of the programme is to train and help them, but the excellence of the maths students is fundamental to our project."

Under the Marie Skłodowska-Curie COFUND, the project promotes dissemination of a new generation of international mathematicians trained in Paris. The idea is to forge an exciting and vibrant community of like-minded people bonding in a dynamic learning environment that gives them access to everything they need to innovate in their subject. The project looks to develop novel key areas of expertise driving the researchers' ambitions, curiosity, awareness and mobility with an emphasis on innovation and entrepreneurship.

The mobility part is a must. The laureates of the programme live in Paris for three years and the network offers an array of secondment options with financial supports in place. The project has international, interdisciplinary and intersectoral secondment options, the choice of secondment the decision of the fellows – who choose in line with their research.

"With this programme you have facilities and people to work with, rooms to meet to talk about mathematics, conference rooms and seminars, this is what they have, this is opportunity. We have people coming from international places and this international aspect is very important. For us, secondment is compulsory, as it will develop good habits. We are trying to create new habits. They have to learn about talking about mathematics connected with other people and connected with society," said Briani.

In total, 40 PhDs are involved in the programme, from two calls, all selected for their maths skills and potential to become ambassadors of the subject on the international stage.

"We are financing PhDs which are part of our network. The foundation is connecting together all the laboratories for mathematics in Paris. We have three different doctoral schools in our network, so each student is enrolled in a different doctoral school and each doctoral school has got its own seminars and courses and network," adds Briani. "The doctoral schools are quite big, so they do work together, share together but the research in mathematics is quite personal."

Expanding the scope and impact of mathematics

Maths is fundamental to many industrial applications in the private sectors like banking, artificial intelligence, economics and all kinds of business uses, and closer links to industrial research are forged by teams and laboratories in universities. For instance, Simona Etinski's research created cryptographic protocols that could be used for online security.

"Let's imagine that Alice has a password that Bob doesn't know," explains Etinski. "Bob wants to make sure Alice has the password – like your bank when you want to access your accounts online, for example – and Alice wants to confirm that she knows the password, but



Subdivision of the permutahedron.

without telling Bob, because Bob could be a spy or a usurper, not Bob. The solution is to create a protocol where Bob gives Alice a very difficult math problem that Alice can only solve if she has the password. My role is to create these very difficult problems, or to modify existing problems to make them even more difficult in order to make the system safer."

There are many career paths that can develop. Today, maths is evolving, contributing to the world's competitiveness, values and the growth of new technologies. Mathematical modelling is now a standard in key industrial processes like 3D printing, modelling big data, social networks and economic situations. It is essential in financial systems and energy distribution control and new computational and modelling possibilities, like quantum computing. The new generations of mathematicians can apply their research in a vast area of sectors and disciplines to make serious steps of progress, impossible without their research and developing knowledge.

Many fascinating projects have emerged in the programme, from pure mathematics, to applied research relevant to modern world needs. A good example is seen in Guillaume Laplante-Anfossi's research in new developments in algebraic topology.

Guillaume Laplante-Anfossi's elaborates: "Topology is the study of the shape of objects that are preserved under continuous deformations. Topology is only 150 years old, while algebra is 2000. The idea (which was one of Poincaré) is therefore to use algebra to work on topology, associating algebraic invariants, which we know how to calculate, to describe the shape of mathematical objects. To do this, usual algebra had to be extended to adapt to the specific deformable character of topology. New structures have been developed, such as operads, which are a generalisation of the concept of algebra."

Mathematics developments like this offer transformative step changes and advances.

Briani remarks: "Where it's relevant, we try to connect them to R&D but this is not mandatory. Some of the PhDs will work in corporations but most of them will have an



academic career. Some of the applied research is done in the laboratories in the universities which are very useful for industry and R&D. So, a few of them are going to work directly in industry but some of them are going to make good applied maths which will be very useful for industry." MathInParis2020 draws together the cream of the crop for mathematics PhDs. For fellows involved with the programme, it helps with experience, development and career progression, as well as, of course, furthering the vast and important field of mathematics for knowledge and for application in various

Paris has become a highly suitable city for promising mathematicians to thrive. The programme MathInParis2020 seeks to attract talented doctoral students from around the world and provide an environment for a high standard of training and mentoring.

MathInParis2020 utilises the Fondation Sciences Mathématiques de Paris as a platform to improve and promote bridges into companies. In the last 12 years, FSMP has significantly contributed to the scientific landscape in mathematics and strengthened international, interdisciplinary and intersectoral links, specifically with research partnerships in public and private sectors. The foundation finances international programmes (research chairs of excellence, post scholarships, doctoral master positions...) and helps those involved in research in mathematical sciences collaborate directly with industry. MathsInParis2020 is closely aligned with the FSMP's ambitions.

However, whilst some companies enjoy close integration with some of the projects, it is accurate to say the majority of researchers involved in MathInParis2020 pursue a purely academic route, improving knowledge for the benefit of all. related sectors for the benefit of society.

What's more, the researchers involved in the project have given feedback that it was a genuine support to their development. An Impact Assessment found that 81% of the fellows recruited thought the programme was in line with their expectations and there were no unsatisfied respondents recorded. More than 80% of the fellows also considered the training programme very beneficial to their career. Crucially, the scheme has facilitated FSMP to enlarge their transferable skills training.

As a network of mathematics excellence, MathInParis2020 trains, mentors and develops the skilled doctoral students to advance maths in an environment that brings awareness of ethics, internationalism and intersectoral disciplines. It provides a means to develop mathematical skills and projects in arguably, the world's most maths orientated city.



MathinParis

MathInParis - PhD Fellowships for a doctoral training programme in Mathematics

Project Objectives

The MathInParis2020 doctoral programme provides a network or resources and partnerships for brilliant PhD students in mathematics and computer sciences. Making the most of the excellent Math community in Paris, the programme nurtures and networks the most promising minds in Math through doctoral schools and with strong connections to industry.

Project Funding

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 945332.

Project Partners

 https://sciencesmaths-paris.fr/en/fsmp-en/ partenaires

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Ariela Briani works at the FSMP as a project manager. Holder of a PhD in mathematics, she formerly was an assistant professor at the University of Pisa, Italy, and then at the University of Tours, France.

Gaël Octavia is graduated from Telecom Sud Paris. She has formerly been an engineer in telecommunications, then a scientific journalist. She now works as FSMP's communication manager.





Categorifying quantum invariants

The discovery of the Jones polynomial in 1984 marked an important point in the development of the low-dimensional topology, and over the last 37 years many new invariants of knots, links and 3-dimensional manifolds, known as quantum invariants, have been discovered. We spoke to **Professor Anna Beliakova** about her work on categorification of quantum invariants, research which brings together elements of several different fields.

The process of categorification can be broadly thought of as a way of building new mathematical structures, analogous to constructing a house by first laying the foundations, then putting in the walls and subsequently adding more walls between those that are already there. In mathematics, a category is a set of objects, together with a set of morphisms between them, and then further morphisms can be added later on between the existing ones. "For example, think of points as objects, with lines connecting these points as a first layer of morphisms. The so-called 2-morphisms are surfaces between these lines - then we can bring a 3-dimensional object between these 2-dimensional surfaces and so on," explains Anna Beliakova, Professor of Mathematics at the University of Zurich. As the Principal

Investigator of a research project based at her university, Professor Beliakova is working to categorify quantum invariants. "When we categorify, we essentially bring these mathematical objects one categorical level higher," she outlines.

Categorification

This research builds on earlier work in the field of knot theory, in which researchers consider knots which form a closed loop and so cannot be undone by pulling, stretching or other deformations, unlike say a shoelace or a tie for example. Researchers can project a knot onto a plane and so effectively replace this 3-dimensional object by its planar diagram. However, there are infinitely many diagrams representing different projections of the same knot. Hence, diagrams cannot help to tell knots apart. "A knot invariant is a mathematical object (e.g. a polynomial) assigned to a diagram which remains the same under deformations. Such invariants are our main tool to distinguish knots," says Professor Beliakova.

The first knot invariant was discovered in 1923 by Alexander, yet very little progress was made over the following 60 years. The discovery of the Jones polynomial by Vaughan Jones in 1984 led to the establishment of the theory of quantum invariants and ushered in a period of fairly rapid progress. "A large number of new invariants have since been uncovered. The use of a technique called skein relations enables us to compute these link invariants," outlines Professor Beliakova.

Further important progress was made when the Russian-American mathematician Mikhail Khovanov developed what has come to be known as the Khovanov homology in the late '90s, the second recombination of quantum invariants. "A polynomial with positive coefficients can be categorified as a graded vector space. However, the Jones polynomial may have negative coefficients and hence chain complexes are needed to categorify it," explains Professor Beliakova.

A chain complex is a collection of Abelian groups with a differential between them that squares to zero. "For us an important fact is that the homology of the Khovanov chain complex is a knot invariant, which is functorial, which means that surfaces bounded by knots in the 4-ball induce maps between Khovanov homologies of these knots," outlines Professor Beliakova. "This functoriality is essential for the proof that the Khovanov homology detects the unknot, the fact that after almost 40 years of study is still unknown about the Jones polynomial."

Of her own research Professor Beliakova says: "We are revealing new structures in Khovanov type complexes. For example, we discovered an action of some groups on these chain complexes. Surprisingly enough, this purely algebraic action may have deep topological implications."

Annular Khovanov homology and invariants of 4-manifolds

Professor Beliakova is also pursuing several other strands of research. The theory of so-called quantum annular Khovanov homology has been developed by Professor Beliakova and her colleagues, Dr. Krzysztof Putyra and Professor Stephan Wehrli, using so-called horizontal traces in some bicategories. "This provides new functorial invariants for annular links" says Professor Beliakova. The wider aim in Professor Beliakova's research is to essentially uncover new structures in low-dimensional topology and significant progress is being made. "We hope that ultimately our work will help to categorify quantum 3-manifold invariants and reveal their topological properties," she continues.

Recently Professor Beliakova, in collaboration with Dr. Marco De Renzi, discovered a new class of invariants of smooth 4-dimensional manifolds. In dimension four it may happen that the same topological 4-manifold has infinitely many different smooth structures, and hence, sensitive invariants are needed to distinguish between them.

We can consider **3-dimensional manifolds** as maps between **2-dimensional ones**. We can extend this by building **more and more morphisms**, and going into **higher and higher categorical levels**.

In the meantime, many other quantum link invariants have been categorified. A real challenge is the categorification of the 3-manifold invariants. In fact, there is a deep intrinsic relationship between links and 3-dimensional manifolds: every 3-manifold can be obtained by surgery on a link, the surgery consists of taking out a neighbourhood of a link in the 3-sphere and then regluing it back differently. This procedure can also be imitated algebraically resulting in quantum 3-manifold invariants built out of quantum link invariants. During this process the polynomial variable is sent to a p-th root of unity. "A categorification of this construction is probably one of the most challenging open problems in quantum topology," explains Professor Beliakova. "It requires a use of chain complexes in which the p-th power of the differential is zero. We know very little about them".

Aside from that, the work of Professor Beliakova and Dr. Marco De Renzi opens up other research directions. For example, it may now be possible to access the Andrews-Curtis conjecture, a conjecture which is thought to be false, but has not yet been proven to be so. "In order to prove that it's false, a counterexample is required," says Professor Beliakova. With an invariant that has been developed in the course of her research, Professor Beliakova hopes to provide such counterexamples and make tangible progress on this specific conjecture. "The conjecture has been open since 1965 and belongs to the field of combinatorial group theory, but I hope now we will make progress through our approach, bringing together elements from many different fields, including representation theory and lowdimensional topology," she continues.

CATEGORIFICATION OF QUANTUM 3-MANIFOLD INVARIANTS

Project Objectives

The aims of the project are to develop a theory of traces in higher categories, use it for a construction of annular Khovanov homology — a link homology theory that is functorial with respect to the annular link cobordism, define new topological invariants of smooth 4-manifolds and study their properties and finally, push forward categorifications of quantum 3-manifold invariants.

Project Funding

Funded by the Swiss National Science Foundation (SNF) : Grant number: 178767

Project Partners

- Dr. Marco De Renzi
- Dr. Krzysztof Putyra
- Professor Stephan Wehrli

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Anna Beliakova is Professor of Mathematics at the University of Zurich in Switzerland. She graduated from the Belorussian State University in 1990 and has since held positions at universities in France, Germany and Switzerland. She has published many research papers over the course of her career and regularly participates in conferences and events.



FNSNF

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Practical reasons before Kant

* * * The 18th century German philosopher Christian A. Crusius is an important figure in his own right, beyond his influence on the work of Immanuel Kant. Researchers at the University of Würzburg aim to shed new light on the work of Crusius and other pre-Kantian philosophers and bring their ideas to greater prominence, as **Dr Sonja Schierbaum** explains.

The ideas and writings of the 18th century German philosopher and theologian Christian A. Crusius had a major influence on the later work of Immanuel Kant, yet Crusius is also an important historical figure in his own right. With a background in medieval philosophy. Dr Sonja Schierbaum is re-examining Crusius' works not from the perspective of his influence on Kant and later philosophers, but rather from the other way round. "I think we can gain fresh insights if we approach the topic from that direction," she explains. Based at the University of Würzburg in Germany, Dr Schierbaum is the leader of an Emmy Noether Group in which researchers are investigating a number of 18th century pre-Kantian philosophers, including not only Crusius, but also the rationalist Christian Wolff and his disciple Alexander Gottlieb Baumgarten. "The overall aim of the project is to arrive at a more complete 'map' of the theoretical landscape concerning conceptions of practical reasons in 18th century German philosophy before Kant," she says.

A lot of attention in the project is focused on Crusius' philosophical works, of which there are three main texts. "One is about metaphysics, it's called *Entwurf der nothwendigen Vernunftwahrheiten*, then the main text on ethics is *Anweisung*, *vernünftig zu leben*," outlines Dr Schierbaum. "There's also some work on epistemology and logic, which is the *Weg zur Gewißheit und Zuverläßigkeit der menschlichen Erkenntniß.*"

Arbitrariness objection

There are also a series of Latin works to consider, with Dr Schierbaum and her colleagues pursuing several different strands of research, aiming to dig deeper into Crusius' philosophical outlook and bring his ideas to wider prominence. One topic that researchers are investigating is the arbitrariness objection to the libertarian conception of free will, which also implies freedom of indifference



Christianus Augustus⁹ Crusius Philosophiae in Academia Lipsiensi Profesfor 2 ubl.



and so leads to the conclusion that choices can be made without a rational basis. "The rationalist view is that if you have no reason to do something, or to will something, then that leads to irrationality," says Dr Schierbaum. In her research, Dr Schierbaum aims to show that Crusius rejects the arbitrariness objection and validates the voluntarist view by showing that there is no choice without a reason. "He gives an explanation of the conditions that have to be met in order for a choice to be made. So you have to will something," she explains. "An individual is free to choose something or not. If they choose it then they will act on that."

The reason that an individual wants something is because they see some good in it, believes Crusius, whether that's about personal pleasure, health benefits or other perceived positive effects. This does not automatically mean that it's the best possible option at the time, but rather that it is a sufficiently good option to justify the individual's choice. "According to Crusius if you see some good in it, you always have a reason for your choice, even if it might not be the absolute best option," says Dr Schierbaum. Alongside her research into Crusius' work, Dr Schierbaum is also looking at the views of some of his opponents, notably Christian Wolff and Gottfried Leibniz, who held a different position on this specific topic. "Leibniz would say that there's always one best option, even if sometimes we don't know exactly what that is. If you were perfectly rational, then you would always choose the best option," outlines Dr Schierbaum. "Leibniz would say that Crusius was not committed to the principle of sufficient reason."

This principle essentially means that every fact must have a sufficient reason why that is indeed the case. For Crusius, it's not necessary to choose the factually best option in a given scenario. "He would deny that if you are in a position where you need to make a choice between alternatives, that you always have to choose the best option," explains Dr Schierbaum. In some cases a choice may mean rejecting a particular course of action, or choosing inaction." Deciding not to do something is also a choice. But it's a choice that does not lead to an action, but rather to the omission of an action," continues Dr Schierbaum. kinds of contemporary debates. "Crusius' ideas could contribute to certain ethical debates, for example to debate about the divine command theory," she outlines.

This is a meta-ethical theory which states that an action can be considered as morally good if it is commanded by God, and it is still the subject of lively discussion today in many parts of the world. Crusius' work

Crusius would say that we can't do anything that is inconsistent with our own nature, with our basic strivings.

Desires and goals

A further dimension of the group's research involves exploring Crusius' views on what personal desires and goals actually are, and whether they are innate to the individual or if they develop in response to external factors. In some of his works, Crusius expresses the notion that some basic desires are innate, such as general inclinations towards personal progression and development. "Crusius says it's just part of your nature, that you want to become more 'perfect' and better. So you have the inclination to develop," says Dr Schierbaum. While our individual desires may change over time in line with our personal circumstances, Dr Schierbaum says Crusius saw a common thread in terms of our personal motivations. "He would say that we can't do anything that is inconsistent with our own nature, with our basic strivings, like striving for perfection," she says. "There are only a few basic desires."

An individual may develop further desires, maybe around personal or professional aspirations, like the desire to become a pianist, football player, or politician. If this kind of objective is to influence behaviour, maybe motivating the individual concerned to practice the piano, to train harder or sharpen their debating skills, then they need to believe that it is attainable and realistic. "You may be wrong - but it is necessary to first believe it in order for that objective to become action-guiding," says Dr Schierbaum. The nature of desire, motivation and personal goal-setting are still subjects of contention today, and while Crusius' writings may date from the 18th century, Dr Schierbaum hopes to show that they are still relevant to these

on this topic helps to effectively ground the voluntarist position, and represents an important contribution to a debate that has been running for centuries and is set to run for many more, like several of the most fundamental questions in philosophy. "Many of these questions are so fundamental, so basic, that people in every era will be asking similar questions," says Dr Schierbaum. The project's work will help shed new light on the positions that several prominent German philosophers took on these and other questions. "There is a PhD student in the project working on Crusius, and until recently there has been a Postdoc working on Wolff, with whom I am now editing a volume on Wolff's German Ethics that is to be published by Oxford University Press," continues Dr Schierbaum.



IMMANUEL KANT From a pointing

PRACTICAL REASONS BEFORE KANT (1720-1780)

Project Objectives

The project aims at contributing to a fundamental discussion concerning practical reasons in ethics by means of focusing on a historical debate. At the same time, the goal of the project is to interpret a historical debate in light of a contemporary discussion. The primary research questions concern the level of (moral) motivation and the metaphysical level of the source of normativity.

Project Funding

Deutsche Forschungsgemeinschaft German Research Foundation (DFG) – Project number 417359636

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Sonja Schierbaum



Sonja Schierbaum is leader of the Emmy Noether research group "Practical Reasons Before Kant (1720-1780)" at the University of Würzburg, Germany, which is funded by the German Research Foundation. Before turning to early modern philosophy, she earned her PhD with a dissertation on Ockham's assumption of mental speech in 2012 at the University of Hamburg.



Keeping Luxembourg moving

* * *

Around half of Luxembourg city's working population travels in from neighbouring countries, adding to traffic congestion issues in the city. We spoke to **Dr Francesco Viti** about the Merlin project's work in developing new tools designed to help manage transport infrastructure more effectively.

The Grand Duchy of Luxembourg is home to several European institutions and has a thriving economy, attracting many workers from beyond the country's borders. Around 50 percent of Luxembourg city's working population travels in from neighbouring countries, including Belgium, Germany and France, which adds to congestion issues in the city. "We can't limit the discussion about congestion in Luxembourg to the urban areas, it's a national issue, which even extends to the wider region," says Dr Francesco Viti, Associate Professor at MobiLab, the Transport Research Group at the University of Luxembourg. Congestion problems that originated in neighbouring countries can then affect Luxembourg city, and extend further. "We've seen examples of congestion problems that originated with an accident in France, in a queue of commuters, resulting in a crossing of Luxembourg that ended in Belgium," outlines Dr Viti.

Congestion in Luxembourg

This represents a fairly extreme example, but it is nevertheless illustrative of the challenges facing transport planners in the city. As the Principal Investigator of the Merlin project, Dr Viti is working to develop new tools to help manage Luxembourg's transport infrastructure more effectively, which is a pressing issue. "Even during the pandemic, with lower demand, we still observed huge queues and traffic problems. With people beginning to return to their jobs, congestion problems are returning as before," he stresses. One of the main historical reasons behind this congestion is that the transport system has always been responsive rather than forward-looking. "There wasn't a real vision - mobility problems arose and then infrastructure was changed accordingly," explains Dr Viti. "Over the last few years, the government has set new guidelines for developing sustainable mobility plans but the introduction of new emerging mobility services and vehicle technologies makes it difficult to predict the impact of future infrastructure changes. I was part of a group of experts which created a roadmap to set a timeline for new investments towards 2050."



We can use a dynamic set of data to continuously adapt our system towards what we call the digital twin version of reality. This is about reproducing traffic patterns, and then projecting how they could change if you manipulate the system.

The roadmap outlines the different measures that need to be taken in order to meet wider goals around reducing congestion and carbon emissions. One important issue for the Luxembourg government is around the electrification of transport, and Dr Viti says moves are being made in this direction. "For example, the bus fleet is gradually being replaced with electrical and hybrid buses, which contributes to the reduction of carbon emissions," he outlines. "The government is also incentivising people to buy electric cars or bikes. Currently in Luxembourg you can buy a bike

for up to 50 percent of its actual market price, and strong monetary incentives are also given for electric cars. There are really substantial subsidies from the government if you buy any electric or hybrid car. However, these types of measures alone can't solve traffic problems."

A major priority is to encourage a general shift to public transport and more sustainable modes of transport. Rather than building more roads, which are likely to rapidly become congested once they open, the aim is to focus the investments on fostering multi-modal systems. "For example, people travelling into Luxembourg



city from outside could use a dedicated park and ride at the border, then continue their journey using another mode of transport. One is public transport, but there are also other solutions," says Dr Viti. One part of this is a very detailed and fine-grained bicycle network, while Dr Viti says a lot of investment is also being directed at shared mobility services. "There are quite a few car-sharing operators. There's also investment into electrical scooters, electric car charging stations, a very sophisticated tram line, as well as autonomous buses and vehicles that connect the rail system to the city," he outlines.

Merlin project

The emergence of these new technologies means that more sophisticated planning tools are now required, an issue at the heart of the Merlin project. In the past, transportation planning has been focused on calculating the number of trips that take place at the busiest times of day, and so the numbers of vehicles and passengers that the system will have to cope with, but Dr Viti says the picture is now more complex. "With new technologies like electric vehicles, we will have to manage resources in a different way. For example, we will have to understand how many charging points we will need in specific areas - vehicles will arrive at a certain point, be parked, and then will probably be charged. So we need to know how long this vehicle will stay idly in a certain area," he says. "One of our main scientific contributions in this project is the construction of a so-called 24hour mobility model for Luxembourg."

This model is based on several different sources of data, with researchers aiming to ensure that it is a realistic reflection of traffic patterns in Luxembourg. While traditionally traffic models are based on information about where people live and work, and maybe how many cars they own, Dr Viti and his colleagues are considering a wider range of data. "We have access to a lot of data through the national Open Data portal and other sources, which can give us a deeper understanding of why people are travelling," he explains. One important source of data is from mobile phones, while researchers are also exploiting information about how many people might be expected in a certain area at a certain time, for example because of a concert or other events. "We can use a dynamic set of data to continuously adapt our system towards what we call a digital twin version of reality," continues Dr Viti. "This is about reproducing traffic patterns, and then projecting how they could change if you manipulate the system."

A more detailed, realistic model can give planners important insights into not only the peak level of demand, but also how that demand is distributed in time and space over a day. This can then help guide how certain elements of the transport infrastructure should be changed to adapt to evolving mobility patterns, for example by moving electric scooters to areas of the city where demand is high. "It's about learning what is the ideal number of electric cars that should be placed in different areas of the city at different times," explains Dr Viti. Some elements of transport infrastructure cannot be moved around however, like Luxembourg city's new tram line. "Decisions like the number of charging stations and the development of new infrastructure cannot be changed overnight, then there are other decisions like the way buses are synchronised with each other or controlled that can be changed from one day to the next," says Dr Viti.

The long-term planning of a transport system will affect the degree to which it can be adapted to day-to-day changes. The project's research will enable planners to assess the impact of both major infrastructure projects like the new tram line, and also smaller scale changes like moving scooters to a different parts of the city, or how many vehicles will be charging in a certain area. "A tool capable of looking at both planning and management solutions, and assessing them reliably, is pretty unique," stresses Dr Viti. Researchers are essentially building an interactive dashboard to help guide the decisionmaking process. "This dashboard will essentially show the impact of a new solution over a 24hour period. So, not only how beneficial it will be during the busiest times of the day, but also the benefits over a full day, in order to assess the cost-effectiveness of proposed investments," continues Dr Viti. "We want to make sure that government money is spent effectively."

MERLIN

Project Objectives

MERLIN aims at developing a generic approach that leverages different types of traffic and mobility data to estimate daily aggregate activity and mode-specific demand flows that are consistent with individual trip chaining behaviour. This allows to better capture the efficiency and environmental impact of new emerging services such as on-demand and shared modes within a multimodal system.

Project Funding

Funded by Investment in jobs and growth (2014-2020) – European Regional Development Fund, European Union 2017-03-021-18.

Project Team

- Francesco Viti (Principal Investigator)
- Richard Connors (Senior Research Fellow)
- Giulio Giorgione (Post Doc)
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Francesco Viti



Francesco Viti is head of MobiLab at the Department of Engineering at the University of Luxembourg. His research activities range from mobility analysis, travel behavior, Intelligent Transport Systems and network modelling and control. He is author of over 300 journal and conference papers. He is Associate Editor for the Journal of ITS, Transportation Research Part C, Journal of Advanced Transportation and the Journal of Big Data in Transportation.





Adaptable networks for tomorrow's applications

The transmission capacity of an optical link can be increased in different ways, but the presence of dispersion and non-linearities degrades the signal. Researchers in the ALPI project aim to introduce an optical device to mitigate these effects in the optical domain, improving transparency, capacity and energy-efficiency, as **Professor Lorenzo Pavesi** explains.

The transmission capacity of an optical link can be boosted by increasing either the number of channels or the power. Both of those options affect the non-linearities in the fibres however, leading to the degradation or distortion of the optical signal, so the signal then needs to be recovered. "Many people use digital signal processing (DSP) to clean a signal, to remove non-linearities or other sorts of noise," says Lorenzo Pavesi, a Professor of Physics at the University of Trento in Italy. This approach is known to be fairly effective, yet Professor Pavesi says there are two main problems with it. "The first is that it is not transparent – meaning that you need to convert the data from the optical domain to the electrical domain," he explains. "The other problem is that the DSP process is expensive and power-hungry - you consume a lot of electrical power."

ALPI project

As the Principal Investigator of the ERCbacked ALPI project, Professor Pavesi and his team are now further developing the patented technology for an alternative approach to mitigate these non-linearities in the optical domain. The idea is to introduce an optical device, a photonic neural network, which will then be integrated into a transceiver module or along an optical link. "We aim to greatly improve transparency in terms of data outputs. We also aim to speed up mitigation effects, as well as to reduce power consumption," outlines Professor Pavesi. This research builds on concepts from artificial intelligence, with Professor Pavesi and his colleagues integrating neuromorphic photonic circuits in an optical link. "We are





trying to essentially reconfigure a network based on the learning process. In a way we can say that this is neuromorphic, because it is based on how our brains work," he continues.

As optical fibres have been around since the '70s and are very well characterised, the various different kinds of non-linearity which affect optical links are fairly well-known, such as self- and cross-phase modulation, fourwave mixing or raman, chromatic dispersion. However, the relative importance of the different non-linearity effects depends on the data that is being transmitted. "The more power you transmit, the larger one effect is with respect to another. This is something that has to be controlled," explains Professor Pavesi. This means that the type of learning an integrated neural network has to do depends



Photographs by Federico Nardelli. ©UniTrento ph

on the nature of the conflicts caused by the actual traffic along that particular channel. "If you change the pathway - let's say that you activate one or the other non-linearities - then the neural network has to compensate for that," says Professor Pavesi. "Our idea is to effectively teach the network so that it can adapt to different circumstances."

A proper and known sequence (a header) is used to train the network and teach it to adapt to the non-linearities that may be present, then the network can subsequently adapt on demand to the kind of transmission that is being used. Current approaches to error correction are based on similar concepts integrated in electronics, whereas Professor Pavesi and his colleagues in the project are working on an all-optical device, which he believes will



bring significant benefits. "The main benefit is that everything is very transparent. As we are in the optical domain, we can change the data rate or format more easily for example," he outlines. "The second important point is that it will be much more energy-efficient, because it's essentially a passive network. Of course photonic components consume power during the training, but this is still much more efficient than an electronic network."

Research is still at a relatively early stage, yet Professor Pavesi is also looking into its wider commercial potential, with plans to eventually bring the improved transceiver to the commercial market. Potential application areas include metro networks and data centres, where demand is

The project itself is a proof-of-concept grant, with researchers working to demonstrate that the device is viable, which could then provide the foundations for continued improvements and eventually commercial exploitation. The longer-term aim is to scale up the circuit, both in terms of their Technology Readiness Level (TRL), as well in terms of industrialisation, and bring it to the market. "We have laid solid foundations, together with our partners in the region, looking towards the continued development of these optical circuits," continues Professor Pavesi. "The idea here is that we are using artificial intelligence concepts, and implementing neural methods implemented in a photonic circuit to increase transmission capacity."

We aim to greatly improve capacity and transparency in terms of data outputs. We also aim to speed up mitigation effects, as well as to reduce power consumption.

high for efficient, effective and reliable solutions. "Electrical data arrives at a transponder, and is sent into the optical network, or vice-versa. We aim to place our device either at the transponder side, or on the node of the optical network, and that can be used for example in largescale data centres," says Professor Pavesi. The partners in the project are looking to collaborate with system operators or semiconductor companies in the development phase, then in future these optical circuits could be offered to the commercial market. "One possibility is that we could establish a start-up company to industrialise our research," continues Professor Pavesi. ALPI project partner Hub Innovazione Trentino (HIT) supports the technology transfer and the value creation process by drafting a business plan including the commercialization strategy for the ALPI innovative technology.

Photonic integrated circuit

There is still more work to do before the wider potential of these optical circuits can be realised however, with researchers still working to evaluate their performance and assess their effectiveness. Researchers have performed a number of simulations and tests on different passive networks. These will soon be conducted on the all-optical device itself, the photonic integrated circuit. "The chip has been designed by a company called VLC photonics, who are based in Valencia," explains Professor Pavesi. The hope is to have validated the chip in terms of performance by the conclusion of the project, with Professor Pavesi aiming to achieve a competitive 100 Gbps bit rate. "If we can use coherent modulation format on multiplespan network then that will demonstrate the viability of this approach," he says.



ALPI

ALl optical signal recovery by Photonic neural network Integrated in a transceiver module

Project Objectives

The ALPI project aims at the integration of a photonic neural network within an optical transceiver to increase the transmission capacity of the optical link. Based on a deep learning approach, the new compact device provides real time compensation of fiber nonlinearities, which degrade optical signals.

Project Funding

The ALPI project received a total of €150,000 funding from the European Commission.

Project Partners

• HIT Hub Innovazione Trentino https://www.trentinoinnovation.eu/en/home/

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Professor Lorenzo Paves



Lorenzo Pavesi is Professor of Experimental Physics at the University of Trento, where he leads the Nanoscience Laboratory. He founded the research activity in semiconductor optoelectronics at the University and started several photonics laboratories, looking at the growth and advanced treatment of materials. He is interested in integrated classical and quantum photonics. He is fellow of IEEE, SPIE and SIF.











Understanding the value of data and how to share it safely

* * * The SAFE-DEED project examines how to gauge the value of data and share it safely between organisations, so that information can be analysed without compromising privacy. The researchers built a set of technologies and procedures, which aims to provide confidence to businesses and boost innovation for data driven economies. We talked to **Gert Breitfuss, Stefan Gindl, Petr Knoth, Ioannis Markopoulos** and **Mihnea Tufis**.

British Mathematician and data science entrepreneur, Clive Humbly coined the phrase, 'data is the new oil'. Indeed, the data driven economy is set to be worth around 700 billion Euros by 2025 in Europe (Lupu, 2018). In this respect, there are huge opportunities in the digitisation of the economy, for innovation and for knowledge gathering and sharing.

There are also challenges to face in the digital transformation of business. The Safe-DEED (Safe Data-Enabled Economic Development) Project has been investigating how to comprehend and assign value for datasets and is developing a toolkit that can help organisations work out what value their data has, what risk there is in sharing it and how it is possible to share it 'safely' in a digital marketplace. The project also analyses the legal and regulatory framework which governs data exchange.

"Safe-DEED provides tools to assist digital transformation," stated Gert Breitfuss.

A platform to buy and sell data

"Different kinds of companies can benefit from our project," explained Stefan Gindl. "One specific area which the project is focused on is enabling data markets. A data market could be something like Amazon for instance, for buying products. In principle, why can't we have an Amazon-like platform for data? So effectively a data market is just a trading platform, which allows you to buy data. Imagine a world in which companies can trade data on a platform such as Amazon, and other parties are buying the data because, for instance they need to train their models on data. The assumption is that if we could have something like this, it could boost the European digital economy." is that datasets trade is done between professionals and usually not for B2C purposes like Amazon. Nevertheless, Amazon and eBay have the knowledge to create data marketplaces should the opportunity mature."

The project has an interdisciplinary approach, relying on expertise around cryptography, data science, business model innovation, and the law.

A dream goal would be to have an automated, quick and easy way to **assess** and **share** the **value of data without compromising privacy**, to empower Europe with organisations and companies that are fully aware of the **value of the data** they possess and with the **knowledge** to **safely use it**.

Whilst a comparison to the Amazon or eBay platforms is a useful analogy, data are not commodities in the same way as books or T-shirts, for example. Datasets need to correlate with applications for relevance.

"A dataset without a reference to the respective analysis or usage application is probably meaningless," adds loannis Markopoulos, for clarity. "In addition, datasets are used by professionals to create value chains e.g. source the right products for a manufacturing chain. Another point

What's data worth?

Before you can have a trading platform, you need to understand the value of what you are trading.

With this in mind, Petr Knoth summarises one of the project's central challenges: "We are good at understanding and finding ways to understand the value of certain assets. We are able, as a society, to define the value of a property – like real estate, for example. An estate agent will judge the value of a house on bedrooms and bathroom and so on, and


independent valuations will come up with roughly similar values. This is true for any kind of physical assets. We know how much the market sets for the value. Interestingly for digital assets we know very little around how to set the value. We want to make the companies aware of the value of their own data.

"The value depends on many things, there are certain elements that determine the value that are related to the data itself, but in the same way as property there are external factors, related to data, which determine value which are related to, for instance; how many subjects want the data, is it in demand? How much will the data help them? Interestingly, with the physical assets, when you have a lot of buyers, immediately the price will go up because there is more demand but only one buyer can have it, but with digital assets it's very different because all of them can have it, so demand doesn't necessarily increase the value of the data. In fact, it may decrease the value, because if multiple parties can have it it may be possible to charge less per buyer and still make a profit."

Despite this being a developing field of expertise, there exist a number of methodologies established for valuation of datasets. For instance, letting the market dictate value, as companies mine, analyse and exchange data the data will have recognised values in time as the market matures. There is also the Multi-period earnings method (MPEEM), which involves calculating the cash flow attributed to an asset, or the withand-without method, which calculates the impact on cash flows if the datasets needed replacing. You can also estimate how much it would be to license data over a time-period.

The team have been working on what they call The Safe-DEED data valuation component (DVC) aiming to provide companies with a tool which supports decisions on estimating the quality of a particular dataset, which in turn could help define value. Critically, it can help to distinguish between a dataset that has very little value and one that has a huge amount of value.

"What are the characteristics of the datasets that are very valuable and those that are not that valuable?" Mihnea Tufis asks.

Essentially, there needs to be a way of defining data quality. The method used for the component, involves posing a questionnaire to the dataset owner, followed by an automatic data analysis. Questions must be asked such as 'is the data producing money? Is the data shared with partners? Is the data for new business or R&D? For protection of the sensitive information, the answers get homomorphically encrypted before sending them to the DVC.

Data quality is key

Although data valuation is in its infancy, a more mature area of knowledge relevant to understanding this value, is around how to estimate the quality of data, which made a good start point for the research. Also, the context around how to use the data. For instance, is it needed for spreadsheet style calculations or alternatively to generate some infographics, or perhaps to train machine learning algorithms for some specific tasks related to this data? All this builds the context around the dataset. Utility is also important, understanding how beneficial the data is, which needs careful consideration. The value must be characterised by properties such as these. This became the focus for developing the data valuation component for Safe-DEED.

Very specific questions need asking such as 'does the data come from a CRM?', 'Is the data complete?', 'What format is the data?', 'How often is it used?', 'When was it used last?', 'What can you do with it?'

A critical part of understanding the worth of data is understanding the risk to the company it may inherently have if it is shared. Therefore, a risk analysis forms part of the process of the valuation, so if a company has a dataset that contains very personal information, it is essential to understand the risk of sharing the

Safe-DEED

Project Objectives

As privacy and trust remain key in the data sharing debate, privacy enhancing technologies (PET) will play a prominent role by 2025. Safe-DEED takes a highly interdisciplinary approach, bringing together partners from cryptography, data science, business model innovation, and the legal domain to focus on improving security technologies, improving trust as well as diffusion of privacy enhancing technologies to keep up pace with global macrotrends and the data economy, to enable the fastest possible growth.

Project Funding

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825225.

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Stefan Gindl studied Medical Informatics at the Vienna University of Technology and has a PhD in Computer Sciences in the area of machine learning (focus: natural language processing). Stefan has worked in multiple national and international research projects covering such areas as machine learning, interoperability, and text mining.

Gert Breitfuss is a senior researcher at Know-Center embedded in the research group Data-Driven Business with his main research focus on data-driven Business Models. Currently Gert is involved in various EU projects covering the fields of exploitation and sustainable business model development. Gert has a technical background and received a master's degree in business administration from University of Graz, Austria.

Safe-DEED



The developed software library Psittacus allows a GDPR compliant data sharing.

dataset with other entities. If, for example, data includes small quasi-identifiers, it becomes possible that other entities could extract these for a competitive advantage.

However, recent technology is helping overcome this problem, which could have great implications for the growth of the data economy.

State of the art encryption

Data often requires and demands privacy, and it can be vulnerable, especially in the context of business as it can be a competitive element, and for the individual our data is something we all wish to guard from exploitation or abuse, and rightly so. Whilst the first question that Safe-DEED has been asking is: 'how do we know what a dataset is worth?', the naturally following question is, 'how do we share knowledge that is valuable between organisations, without betraying any vital privacy in the data?'

A make-or-break element of developing opportunity in the digital economy is in knowing how to share knowledge without exposing private information. MPCs (Multi Party Computations) are a relatively new discipline in data science but they are a key to unlocking the data economy.

"Our colleagues at the KNOW Center have developed multi-party computations which do the aggregation, basically a sum of all these little components without sharing the individual values of these components and then at the end, what comes back is a data valuator, the global value of the dataset and that is enough," said Mihnea Tufis.

Such a fledgling field means there are not a great deal of experts available to comment on it. Safe-DEED never-the-less sought them out and brought their insights together in their

research. Privacy enhancing technologies will need to become the backbone of the next level digital age that is promised.

MPCs have the remarkable ability to share insights generated from datasets without compromising security or private information in the data. If for example, you wanted to find out if salaries for one gender were less than another across a sector, but you obviously could not divulge the personal salaries of staff in competitive companies, MPCs, with a very intelligent encryption process, could find that answer out without anyone overseeing the personal data, like a name next to a salary, in the datasets. Such a powerful tool means a lot for the future of market intelligence and is incredibly valuable.

With mobile devices, the cloud, the Internet of Things (IoT), Artificial intelligence (AI) – there are clearly a raft of fast-growing technologies that rely on an interchange of data between individuals and organisations. Data is already a valuable commodity but when it comes to trading it, it needs careful handling and a way to understand what it's worth.

"In Safe-DEED we have several components that solve several problems that are attached to a world increasingly more reliant on data. We want to do more and more with data. This generates a set of problems and what we are trying to do in Safe-DEED with the different component tools that we've developed is address some of these problems," said Breitfuss.

A dream goal would be to have an automated, quick and easy way to assess and share the value of data without compromising privacy, to empower Europe with organisations and companies that are fully aware of the value of the data they possess and with the knowledge to safely use it.



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