Today’s Great Explorers

NEW FRONTIERS IN STRATEGIC RESEARCH AT LUND UNIVERSITY
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EDITOR
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Introduction
How come a university may all of a sudden rack up one major success after the other? As chairman of the board of Lund University in 2004–2012, I have basked in the reflected glory of the great achievements attained by the university’s researchers, first in the context of the Linnaeus Centres and then in that of the Strategic Research Areas.

When sitting on a board, one is tempted to believe that such successes follow from decisions the board has made. However, successful research projects are never initiated by a board; and to the extent that the board is involved in determining a research agenda, its task is to confirm issues where researchers and the university management are already in accord. The board simply finalises a long process of preparations and decisions.

Should the vice-chancellor and the other members of the university’s management team be given credit for the successes, then? Yes, they should, but only up to a point. Good organisation is an important prerequisite for success, and I would like to give recognition for a job well done to the management teams I have had the privilege of working with over the years.

The Mystery of Success
The task of the vice-chancellor of a university has been compared to directing an orchestra consisting entirely of soloists. This requires a great deal of sensitivity, but also the ability to make decisions and to distinguish projects with a high likelihood of success, ensuring that they are given the support they need.

The vice-chancellor and his or her team are thus important, but only to a certain extent. How, then, can the rest of the success achieved by Lund University be explained? I believe that part of the explanation resides in the fact that it is a comprehensive university, spanning across the huge field of knowledge in its entirety. It is easier for the vice-chancellor of Lund University to build trans-boundary research projects than it is for vice-chancellors in Stockholm or Gothenburg, where there are no comprehensive universities and hence many administrative boundaries. The ability to collaborate across the traditional boundaries between faculties and departments is becoming increasingly important in a time when many major breakthroughs take place on the borderland between established disciplines. Furthermore, Lund University has built a coherent campus with short distances between departments and between researchers. The university is known for its ability to interact across boundaries – what matters most is research, not administrative affiliations.

However, this is not enough to fully explain the achievements of Lund University over the past decade. The successful initiation of research builds on curiosity, enterprise and entrepreneurship. What are the mechanisms and driving forces that set the spirit of enterprise free? That is something I would dearly like to know. What explains the ‘mystery of success’? Is it a matter of chance? Or is chance no coincidence?

This book describes successful research projects and great achievements by individual researchers and research teams. Taken together, this creates an image of a very successful university that attracts the next generation of students and researchers, and indeed the large numbers of young people who apply for an opportunity to become students at Lund University testify to the truthfulness of that image. What remains to be done is to launch a research project to identify the success factors, so that we will find out how to make this period of success permanent. That, however, may well turn out to be the most challenging research effort of all.

ALLAN LARSSON

Chairman of the Board of Lund University in 2004–2012, the Swedish Government’s Chief Negotiator for the European Spallation Source (ESS) project in 2007–2009, at present member of the Board of the Mats Paulsson Foundation/Medicon Village from 2012.
01: Pieces of the puzzle

Strategic research and the University

SARA NAURIN
'Encouraging cross-disciplinary collaborations is one of the most difficult, but also one of the most wonderful, tasks that we have as a university.'

PER ERIKSSON
/ VICE-CHANCELLOR

'The researchers who were successful at securing this funding were the ones who showed enough courage to reach across disciplinary boundaries and combine cutting-edge competences from more than one field of research.'

SVEN STRÖMQVIST
/ PRO VICE-CHANCELLOR FOR RESEARCH

OUTSIDE THE WINDOWS, the early-morning air is filled with mist – the kind that leaves heavy droplets of water behind and bejewels the many spider webs in the Lundagård park now that autumn has come. The large fountain just in front of the main university building (aptly nick-named 'the White House') is still surrounded by flowers, the last of the season.

Per Eriksson, the vice-chancellor of Lund University, and Sven Strömqvist, the pro vice-chancellor for research, are seated next to each other at the conference table in the vice-chancellor's beautiful office, talking calmly over coffee and chocolate biscuits. The rooks in the park outside are also having conversations, but of a louder and more insistent kind. Their calls are drifting through the tolling of the cathedral's bells. Together, this sounds unmistakably like Lund. Which is suitable, in this house, in this office, and in the presence of these two men – and as a backdrop to the discussion they are having.

They have come to this early-morning interview for a specific reason. In 2008, the Swedish Government designated 20 'Strategic Research Areas' (SRAs) in its research-policy bill. Within these 20 areas, 43 research environments were chosen for specific funding in a special evaluation in 2009. They were all conducting research of the highest international quality, but just as importantly their research was of strategic value to society – and to business – in that it helped to meet major needs of society and to solve important problems that society was facing.

This effort represented a significant investment on the part of Swedish taxpayers. In all, 5,270 million Swedish kronor (SEK) was allocated to the 43 research environments. Researchers at Lund University were extraordinarily successful: Lund now hosts a total of twelve SRA environments (of which nine are co-ordinated from Lund while three are co-ordinated at other universities with Lund as a partner). The SRA environme-
nts in Lund were allocated SEK 714.8 million in 2010–2014 – the highest figure for any Swedish university. The researchers chosen are grappling with complex questions in a variety of different fields: climate change, nanoscience, ecosystem services, cancer, diabetes, stem-cell therapy, Parkinson’s disease, mobile communications, sustainable production, Middle Eastern studies and patterns of disease distribution as well as computing and e-science.

Per Eriksson takes a sip from his coffee and reminisces about how it all started. He began his work as vice-chancellor just as the Swedish Government announced its intention to fund the SRAs. Now, five years on, his tenure is coming to an end and the SRA environments are about to face a comprehensive evaluation of their efforts.

In 2014, the SRA environments and their host universities were told to report on their progress to the Swedish Government and the Swedish Research Council. These reports show that the environments in Lund have been incredibly successful. Not only have they produced research findings of the highest international standard, but they have also built important infrastructure for continued excellence, in particular by recruiting outstanding researchers and by creating new inter-disciplinary collaborations. They have also built important links with the business sector as well as generating spin-off companies and patents. They have actively engaged in societal outreach, many of them to an extraordinary extent. They have advised decision-makers, given interviews and contributed to international reports such as those of the Intergovernmental Panel on Climate Change (IPCC), they have hosted many conferences and workshops and held panels during the Almedalen Week (Sweden’s largest annual political get-together), and they have striven to improve health-care by actively working with local authorities and regions. Further, they have engaged in improving education – at the university as well as in society at large. They have made scientific breakthroughs and written countless articles not only in specialised journals of international repute but also in popular-science contexts. They are in a good position to do extraordinarily well internationally and to compete for opportunities within Horizon 2020, the largest European Union research and innovation programme ever initiated.

In the 2014 evaluation process, the Government called for twelve separate reports from Lund – one from each environment – intended for the panel of experts overseeing the Government’s evaluation. The university’s ‘guardianship’ of the SRAs was also documented in twelve separate reports to the experts. This book was born out of a wish to illustrate the big picture – the total scope of research, the combined achievements – and to make sure that it is clearly communicated to the wider society. Since the research involved will be important in shaping our future, knowledge about it should be more widely available. The two men seated at the table in the vice-chancellor’s office and the twelve SRA environments are now working together in this effort to illustrate the significance of this research to society. There is a simple enough rationale for their work: the general public is the true owner of this progress and so has a right to be told about it.

‘In 2008,’ says Per Eriksson, ‘when the time came to apply for the SRAs, I was just leaving a position at Vinnova (Sweden’s innovation agency) to become vice-chancellor here in Lund. I knew what type of innovative research would be singled out for this – it had to be research with an impact on society.’

Sven Strömqvist nods next to him and drinks from his cup. The rooks outside are still calling noisily but the cathedral bells have fallen quiet.
'We made a lot of decisions right there at the start,’ Per Eriksson recalls, ‘strategic decisions in dialogue with the faculties and the researchers. In what areas was Lund particularly strong – where could we compete?’ Looking at Sven Strömqvist, he adds: ‘Do you remember? The Ministry of Education and Research had this vision: they wanted all the universities to compete with each other for this funding until one group of researchers at one university would be crowned the winner. But we felt that’s not the way research works, that it wouldn’t be good to take that approach. The best researchers and collaborations are often found in networks among the universities. This was something that we felt quite strongly about. So we embraced it, and I suppose we built our applications on collaborations with others more than any other university did. And in the end this was a very successful approach: we built networks with complementary strengths and that worked out very well for many of these research groups. We actually ended up being the university that got the biggest share in terms of allocated funding.’

‘And now,’ I ask him while accepting one of the chocolate biscuits that he offers me, ‘five years on? You must have had visions in the beginning, about what this funding would entail for the university – not just for these particular research groups, but for the university as a whole. What has been the largest gain, do you think – for Lund?’

He reflects for a moment, sips at his coffee again. ‘Well, you know, I think we are probably the university – nationally I mean – that has placed the most emphasis on our strong research environments in our profile. We have presented them as the prime examples of our culture, as the ones who carry our culture on their shoulders. With all due respect to single individuals and to the leadership, it is the strong environments that set the tone at a university. And these research environments, the SRAs, they are not just good – they are brilliant.’

‘Yes,’ Sven Strömqvist agrees.

‘When you want to develop a university,’ Per Eriksson continues, ‘and are part of its leadership, there are different approaches to take when it comes to finding a competitive edge. We made a choice there: to highlight our strong environments and to do our best to help them excel, help them renew themselves and their leadership, and help them work actively with society and with business. If we can help them be successful, they will inevitably move the entire university forwards.’ Another pause for reflection, and then he adds, ‘And I think that has happened. These environments are on a completely different level of excellence than most others, and they pull the rest along with them as they develop.’

Sven Strömqvist is still nodding next to him, the light from the windows reflecting in his glasses. ‘There’s another dimension as well’, he points out, ‘to why these particular research groups are important, why we think they are special. They are dealing with challenge-driven research, aimed at solving problems with a large impact on society, and it is very rare for a single researcher or a single discipline to be able to be successful at that. So what we are seeing is that in these environments, Lund University’s potential as a comprehensive university is bearing fruit. The researchers who were successful at securing this funding were the ones who showed enough courage to reach across disciplinary boundaries and combine cutting-edge competences from more than one field of research, in order to address highly complex questions such as climate change or healthy ageing. And this is a very positive indication of what Lund University will be capable of in the future.’

‘When the Government allocated this funding, they were aiming to make Swedish research competitive,’ I point out –
because international competitiveness was indeed one of the Government’s three main criteria. ‘Do you think that has happened – is Lund more visible internationally now that five years have passed?’

Per Eriksson nods thoughtfully. ‘It’s a bit more complicated than that, though,’ he says, ‘because these kinds of efforts need to be complemented with recruitment of the best international researchers. But yes, this funding has reinforced the most excellent groups we have, ensured that they have long-term opportunities, and that does have an effect. Because such environments attract top-class researchers. We have seen that happen, particularly in some environments, where they have managed to recruit outstandingly skilled people.’

‘When we try to recruit the best people,’ Sven Strömqvist adds, ‘junior as well as senior researchers, they inevitably consider the kind of environment that we offer. And of course it matters how successful the research group in question is, but it also matters how open it is: how inclined it is to take on new ideas and start new collaborations. To me, that’s one of the most exciting aspects of these particular research groups – that they are so open. They have initiated so many collaborations during these past five years, not least among each other.’

‘You know,’ Per Eriksson says, ‘we have actually put some effort into planning for that, building the campus in a way that encourages cross-disciplinary collaborations. I believe that making this happen is one of the most difficult, but also one of the most wonderful, tasks that we have as a university. But we could be much better at it; we can develop it much further. Specifically, the task is to make sure that people meet, so that we encourage the cross-fertilisation of different thoughts. Those things don’t happen by themselves. We need to make a continuous effort to ensure that we become better at promoting them.’

‘We designed a leadership programme specifically for these environments,’ Sven Strömqvist adds, ‘a two-year programme that they all took part in. It was designed to help them become even better leaders, not just brilliant researchers – they’re all brilliant researchers. However, I think another thing that came out of that programme was just as valuable: new collaborations between them. There is a new type of network now, one where it’s more natural to exchange ideas and take on collaborative efforts. We see them do that, the nanoscience group working with the diabetes group – just to take one example – and that’s very, very positive.’

‘The effort involving the SRA environments,’ I say, looking from one of them to the other, ‘it began while you held the reins of this university. What are your visions for them in the future?’

‘Like I said,’ Per replies, ‘they carry our culture on their shoulders, and that will continue to be true. They will go on setting the standard. We have strong research environments of many different types at this university – the SRA environments are not the only ones, and not the only good ones – but we do think they are special, because of this combination they have of scientific excellence and the potential to have a large impact on society and business. Still, as regards specific steps that we would like to take, our ambition now, for this next phase, is to help them make sure that their excellence is also put to good use in the curriculum, that it starts permeating the education we offer.’

‘What kind of position will they have in the next five years, then,’ I ask him, ‘compared with those five that have now come to an end?’

‘My firm belief’, he replies, ‘is that after this ongoing evaluation they will carry on as they have until now, at most with a slight adjustment to the level of funding. I will certainly fight to make that happen. It would be a disastrous waste of resour-
cesses and potential if they were to be wound up; during these five years they have built research and infrastructure of great value. Having said that, I don’t think we as members of the university’s leadership should be the ones to evaluate these environments. What is needed to do that objectively, in a way that our researchers can feel confident about, are thorough international evaluations, independent of this university. But there’s another good thing: this cross-fertilisation between the Government’s evaluation of this effort and our own strategies ensures continued quality.

‘But you’re leaving your position as vice-chancellor by the end of this year,’ I point out. ‘Do you believe that the new leadership here in Lund will carry on managing these environments like you have during the first five years of their existence?’

‘Yes, I do,’ he replies confidently. ‘For the very simple reason that they are the best environments we have. And they know that themselves. They are very well aware that when it comes to competing for external money, when it comes to research excellence, they deserve the position they hold at this university. Still, we will listen to the suggestions offered by the Government, we will study their evaluation of our environments and we will use their conclusions in our future management – that’s the right way to proceed.’

‘You have followed these environments closely in your capacity as pro vice-chancellor for research,’ I remark to Sven Strömqvist a while later once we are seated at the table in his office instead – Per Eriksson has hurried on to his next appointment, leaving us to finish our coffee. ‘In your opinion,’ I continue, ‘how has the extra funding they have received over these past five years changed them?’

He considers the question, letting the silence draw out. ‘A very important aspect of the Government’s strategy for these research areas is that the funding is very long-term in nature,’ he replies at last. ‘That allows the researchers to take greater risks, to take on more difficult issues of the kind that will not necessarily bear fruit in the immediate future. I think we are now starting to see the real benefits and value of that. And I also think they have clearly developed in terms of leadership – from something that started out as more traditional research projects into something that I would say helps the entire university change into something more modern.’

‘As I understand it, you are currently considering how the university can best capitalise on the strengths of these environments in the future?’

“That’s right,’ he says. ‘We have started to develop guidelines for the next leadership on how the university should handle our strong environments in the long term. What strategic value do they hold? In what ways can the SRAs be strengthened and developed?’ He nods as he thinks about this issue: ‘It’s going to be very important to keep an open mind – the ability of the environments to renew themselves must be one important criterion in these discussions. We must look at things like how the relevant fields of research develop over time, how society’s grand challenges evolve. We must be open to adapting these environments to a changing reality, open to helping them adapt. It’s a huge jigsaw puzzle, there are so many possibilities.’ He stops to think. ‘It’s like Per said earlier: solving that jigsaw puzzle is the most difficult but also the most wonderful task we have. You have to be flexible. These environments are already good at that – it is among their great strengths – but we need to support them in that process. We should stop thinking in terms of “this is an SRA”, “this is a department”, and “this is a project”. Instead we have to view them all as pieces of the same jigsaw.’ He pauses. ‘I’m happy’, he adds after a moment,
that we have spent as much effort as we have on these issues. We’ve come a long way since we started. For example, there’s the report we made in 2012.’ What he is referring to is a report on the strong research environments at Lund University, which specifically included an assessment of the current strengths and continued development of the SRAs.

‘And there’s the critical-friends report we commissioned in 2011,’ he continues, ‘where we invited top people from Stanford, the Max Planck Institute for Psycholinguistics and University College London to evaluate our management of the SRAs. They wrote something brilliant in their conclusions – they said that, as a university, we need to facilitate this kind of inter-disciplinary research if we want to remain at the cutting edge of human knowledge and innovation.’

‘What lies at a university’s core then,’ I ask him, ‘excellent research – or excellent education?’

‘Well,’ he replies immediately, ‘that’s something we need to consolidate now as these environments continue, we need to make sure that their excellence is reflected in the curriculum. That’s a slower process – ensuring that the students come to benefit. It takes longer than consolidating the research, and like Per said earlier we must focus on helping the environments achieve that during the next period. We are seeing progress when it comes to the implementation of their findings in undergraduate education, but we can help them do even better.’

‘The SRAs are the best research environments Lund has,’ I put to him, ‘in terms of combining great science and a strong impact on society.’

‘Exactly,’ he agrees. ‘But the main impact of our university on society is through education. And to make sure we give our students a top-class education, so that they can do wonders when they leave here, there has to be a strong and vibrant link between our research and the curriculum. And that is why we believe that these research environments – with their modern, challenge-driven research – should take part not only in the education of graduate students, but in undergraduate education as well. These research groups are special: they are an effective way to reach a new generation of students who are interested in the great challenges of society.’

Outside his window it is early morning. Lund is just waking up, and the students he just spoke so emphatically about are everywhere to be seen. Their bikes are drawing lines in the gravel on the paths criss-crossing the park and the rooks take flight to give way. There they are, the new generation of students interested in the great challenges of society. Right at this moment they are busy pedalling past Lundagård’s distinctive features: the old buildings, the splashing fountain, the grand old cathedral.

Let that be another purpose of this book, then – showing them where to steer those bikes. Flip through the pages ahead and find out where you can make a difference. In cancer research perhaps? Stem cells? Climate change or the Middle East? The list goes on: how about mobile communications or sustainable production? Take your pick. The brilliant researchers in this collection of texts have already built a foundation, and now they are offering their shoulders as a place to stand when you reach for that future, beyond the scattering rooks. □
“We bring to this review process the firm conviction that cross-disciplinary and interdisciplinary research and education must be a major feature of any university that aspires to be world class. Progress depends on combining the expertise of individuals coming from diverse disciplines, and thus the modern university has to facilitate these cross-disciplinary connections and collaborations if it is to remain at the cutting edge of human knowledge and innovation.”

– Quote from a Critical Friends Report on Lund University’s management of the Strategic Research Areas (SRAs). Colleagues from Stanford, the Max Planck Institute for Psycholinguistics and University College London were invited in 2011 by Lund to take part in workshops and interviews with the SRAs.

RESEARCH GROUPS
/ IN ORDER OF APPEARANCE >

MERGE – ModElling the Regional and Global Earth system

MECW – The Middle East in the Contemporary World

BECC – Biodiversity and Ecosystem services in a Changing Climate

MultiPark – Multidisciplinary research focused on Parkinson’s disease

EXODIAB – Excellence Of Diabetes Research in Sweden

STEMTHERAPY – National Initiative in Stem Cells and Regenerative Therapy

EpiHealth – Epidemiology for Health

BioCARE – Biomarkers in Cancer Medicine

eSSENCE – The e-Science Collaboration

Nanoscience at Lund University

ELLIIT – Excellence Center at Linköping – Lund in Information Technology

SPI – Sustainable Production Initiative
Exploring our Changing Planet
Climate models go green

MARKKU RUMMUKAINEN
ERIK SWIETLICKI
The use of coal, oil and gas, and land use change, has caused emissions of carbon dioxide which equals to about 550 billion tons of carbon. Half of these have accumulated in the atmosphere, which warms our climate with profound effects on natural and human systems. The other half has been absorbed by the oceans and the biosphere.

Climate change affects the strength of these ‘carbon sinks’. Knowledge about their future capacity is important for informed action on climate stabilisation. MERGE’s research on a new generation of climate models aims for a greater understanding of vegetation, climate and climate change.

MERGE addresses the climate system and its feedbacks, a fundamental concern of our society as we face the challenge of climate change. Climate models are key tools that encapsulate our understanding of the climate system and how it responds to carbon dioxide emissions. Climate models enable us to explain the causes of observed climate change and make predictions for the future. Until recently, climate models focused almost exclusively on physical aspects of the climate system – in the atmosphere, the oceans, the land surface, and at the interfaces between these. However, living systems – ecosystems on land and in water – are also part of the climate system, responding to and impacting climate change. Under the guiding theme “The biosphere in the climate system”, MERGE strives to develop new and better representations of ecosystems and their responses and feedback to the climate. We incorporate the latest scientific knowledge into the newest generation of climate models (models increasingly referred to as Earth System Models or ESMs). ESMs are the top-of-the-line scientific tools for studying the future climate – used to characterise and quantify climate change, and to underpin mitigation and adaptation strategies.

The earth of today is a habitable place thanks to its favourable climate. We live across a range of climate zones which span from the humid and warm tropics to cold polar regions. We experience the changing of the seasons and variable weather. For the past 10 000 years, since the retreat of the polar ice cap gave way to the milder epoch we now still enjoy (known as the Holocene), the earth’s climate has been relatively stable, with comparatively minor variations in temperature and circulation patterns at the global scale. It has not always been so, and it will not always be so. The climate has varied greatly during the history of the earth, due to various natural factors. Thanks to
research on past climates, we know that the climate system is sensitive to forcing and we understand a lot about how it has responded to past variations in the earth’s orbit around the sun, solar variability and other natural forces.

It is clear that the climate is now changing again. Since the beginning of the industrial era, and particularly in the past few decades, temperatures have been rising on every continent, and warmer ocean waters are causing sea levels to rise, together with the melting of retreating glaciers and diminishing ice caps. It is no coincidence that these changes are occurring at the same time as emissions from fossil fuel consumption and forest clearing are rapidly raising concentrations of carbon dioxide and other greenhouse gases in the atmosphere. The greenhouse effect has been understood and accurately quantified for more than a century. Atmospheric carbon dioxide concentration has reached levels over 40% higher than during pre-industrial times. The increase in atmospheric methane is about 150%. These marked increases are enhancing the greenhouse effect, making the world a warmer place. Thus, there is a fundamental difference compared with past climate changes: for the first time in earth’s history, the climate is changing due to the actions of human beings. We have entered the era of the Anthropocene!

Greenhouse gas concentrations will continue to rise as long as our society remains dependent on fossil fuels for its energy needs. The direct effects on climate can be capably described by current climate models. However, there are also substantial indirect effects, known as feedbacks, some of which still have question marks around them. This is especially so for the indirect effects mediated by the responses of living systems – the biosphere – to climate change. While we have learnt a lot over the past few decades of climate modelling science, understanding and characterising feedback mechanisms linking the ‘spheres’ of the earth – the atmosphere, hydrosphere, cryosphere, biosphere and not least the sphere of human influence, the anthoposphere – remains in some ways a grand challenge. Research needs to address and overcome this challenge in order to increase understanding of the climate system, which can lead to improved climate models and better scenarios and solutions for the future, to resolve the problem of climate change. The Strategic Research Area MERGE – short for ‘ModElling the Regional and Global Earth system’ – works on key contributions to the next generation of climate models, which can highlight issues that until now have been labelled as key unknowns, such as how global warming changes the biosphere and how the biospheric response feeds back to climate change. In essence, we are making climate models greener by the incorporation of vegetation into some of the most advanced global and regional climate models in the world.

The basics of climate
The driving force of the climate system is the sun. The earth responds to the energy received from the sun by returning energy as outgoing radiation. This both maintains an overall energy balance, and generates the energy, water and other material cycles of the climate system. How incoming and outgoing energy affects the atmosphere, the oceans and the land surface depends, among other factors, on atmospheric composition (not least water vapour and carbon dioxide) and clouds. This is known as the natural greenhouse effect, which adds some 30ºC to the average surface temperature of the earth. The colour of the earth’s surface also plays a role as light surfaces like snow, ice or agricultural fields reflect more of the sun’s rays than darker surfaces such as deep water bodies and forests.
Excluding anthropogenic factors, the amount of greenhouse gases is regulated by global biogeochemical cycles. The most prominent of these is the carbon cycle, which links atmospheric concentrations of carbon dioxide with the accumulation and loss of living biomass in the world’s ecosystems and with carbon dissolved in water bodies. The amount of carbon in the oceans, soil and living vegetation, as well as in the atmosphere as carbon dioxide, is high. Yet larger amounts are present in sediments and in the form of coal, oil and natural gas deep down in the ground. As these underground deposits are effectively buried away, they normally impact climate only over very long time scales. The carbon cycle is a constant flow of carbon through the atmosphere, ocean surfaces and the biosphere, with exchanges that are in balance. The additional emissions from human activities effectively shortcut the natural cycles and mobilise buried-away carbon. Over the past 10,000 years, until the start of the industrial revolution, atmospheric carbon dioxide levels were stable, around 280 parts per million (ppm), which corresponds to the geologically fairly mild climate phase, the Holocene, we have been experiencing.

**Humankind comes into the picture**

Since the industrial revolution, the growing use of coal, oil and natural gas to power industry, cities, transport, and so on, as well as the clearing of land for agriculture and wood products, have added 120 ppm of fossil carbon dioxide to the atmosphere. This is unprecedented in light of the past 10,000 years, the past 800,000 years and probably also in an even longer perspective, well before human beings emerged as a species.

Global anthropogenic emissions of carbon dioxide to date correspond to around 555 billion tons of carbon. Of these, 375 billion are from the burning of coal, oil and natural gas and 180 billion from land use change – losses of standing biomass from cleared, mainly tropical, forests. Around half of these emissions have accumulated in the atmosphere, enhancing the natural greenhouse effect and forced the earth to respond. Global warming is – purely and simply – a reaction of the physical/chemical/biological system we call our home.

While around half of all emissions have accumulated in the atmosphere, the other half has been taken up by the oceans and ecosystems on land, in roughly equal amounts. This slows down the rate of increase of carbon dioxide concentrations in the atmosphere. The biospheric uptake of carbon involves plants and algae that convert atmospheric carbon dioxide into carbohydrates and biomass through photosynthesis. There is also a return flow of carbon to the atmosphere via respiration which consumes biospheric carbon. Emissions from wildfires also return some carbon dioxide from the biomass to the atmosphere.

In a stable climate, respiration adjusts to balance photosynthesis over time. The current net biospheric uptake of carbon represents an imbalance, or a sink. This is due to the responses of ecosystems across the world to rising temperatures and carbon dioxide concentrations. This cannot be sustained forever; ultimately respiration must catch up with photosynthesis or may even end up overtaking it. The former would reduce the sink effect to zero and the latter would lead to a state where the biosphere became a net source of carbon dioxide to the atmosphere, which would accelerate climate change.

Temperature, winds and precipitation are among the factors that drive ecosystem processes, and regulate the carbon cycle. Climate change thus implies changes to the carbon cycle, which could range from slight weakening of the efficacy of the terrestrial carbon sink to transformation of these systems into carbon sources instead. Clearly, it is of paramount importance...
to be able to account for these interactions as time progresses, in order to both calculate the amount of climate change and determine the emission reductions necessary to stabilise the climate. For example, for a given climate stabilisation target, weaker carbon sinks require larger and faster emissions reductions than in the case of stronger carbon sinks. The more rapidly the emissions reductions need to happen, the greater the need for a faster pace of technological change, consumption change and overall societal transformation.

The future unknown. Climate models to the rescue
We know about the climate of the past and of the present thanks to direct observations and measurements, for example using instrumented weather stations, tide gauges and satellites monitoring vegetation cover, and by learning from such natural climate archives as tree rings and ice cores. The future is unobservable. We cannot measure how much warmer it will be in 2050, for example. Neither can we take the climate into a laboratory and experiment on it. (What we inherently do is to experiment on the real system with emissions.) The only viable option is the use of climate models for the global climate and for regional climates. With their construction based on basic physical principles, expressed in mathematical form, climate models allow for computer simulations on how the climate system responds to continued emissions, as well as reductions in them.

Fundamental physics, chemistry, biology and physical geography provide the basis for numerical models for the climate system, which can be solved on powerful computers. Climate models date back to the 1960s. The first models were very simple constructs by today’s standards, but allowed for basic experiments. Over time, the models developed, and our knowledge of the climate system increased thanks to new measurements and observations. More powerful computers made it possible to do more and more experiments with the models. Today, global climate models are being developed and used in a number of countries, with modelling centres in countries including the UK, Germany, Norway, France, the US, China, Japan, Canada and Australia. Regional climate models are being used in an even larger number of countries.

The latest full generations of global climate models have predominantly consisted of atmospheric and ocean components complemented with representations of the fast physical exchanges of energy and water vapour at the land surface. When performing climate change simulations, atmospheric composition changes have been provided as input to the model. Thus, the feedback between climate change and carbon sinks has not been explicit in the simulations. The same applies for climate-induced changes to vegetation and land cover. In some regions such changes may have appreciable importance through their effects on the reflective properties of land surfaces and on water vapour exchanges, which over land occur largely as evapotranspiration from plants. Also regional climate models as a rule do not carry vegetation components and often do not represent the oceans either. In the last two decades, the vegetation component has gradually been introduced in climate models to study the impact of changes in the carbon cycle, as well as changes in the physical properties of the land surface.

Next generation climate models
MERGE takes the next step with climate models, and thus improves base knowledge for decisions and measures to curb climate change and reduce the risks of impacts. The overarching target is to contribute to developing a new generation of Earth System Models – climate models which go beyond the atmos-
phere and ocean, and also represent the part that ecosystems play in carbon, water and energy cycles and the climate system. This means the incorporation of vegetation, biogeochemical cycles (carbon, nitrogen) and related atmospheric chemistry. In other words, climate models are going green!

The core effort of MERGE deals with the improvement of today’s advanced global and regional climate models by the addition of an interactive terrestrial biosphere. The building blocks are: a global model of vegetation dynamics and biogeochemistry (LPJ-GUESS), the global climate model EC-Earth and the regional climate model RCA-GUESS.

LPJ-GUESS (the Lund-Potsdam-Jena General Ecosystem Simulator) is a model of vegetation dynamics and ecosystem biogeochemistry, a dynamic global vegetation model (DGVM). It is suitable for research on climate impacts on vegetation and ecosystems, global and regional carbon balance, biodiversity, agricultural and forest management, and climate adaptation. Through work carried out in MERGE, it now provides the biosphere component in the regional and global Earth System Models RCA-GUESS and EC-Earth.

EC-Earth is a European global Earth System Model that incorporates LPJ-GUESS to account for the role of vegetation and ecosystem carbon exchange in the climate system. In addition to vegetation itself, it accounts for biogeochemical climate system feedbacks due to ecosystem exchanges of carbon dioxide, other greenhouse gases such as methane and nitrous oxides, reactive atmospheric compounds emitted by plants or wildfires affecting ozone and OH chemistry, and secondary organic aerosols. A climate model that accounts for changes in the climate and the vegetation, accounting for the continuous linkages between them, can capture feedbacks not accounted for by each kind of model on its own.

RCA-GUESS is a regional Earth System Model coupling LPJ-GUESS to the regional climate model RCA from the Rossby Centre at the Swedish Meteorological and Hydrological Institute (SMHI). It is being used to probe climate feedback mechanisms mediated by changes in vegetation patterns, species composition and land use on regional climate patterns and trends, for example in Europe, the Arctic and Africa.

What does a tree do?
Vegetation is green and covers the ground. However, there is a lot more to a tree or a plant. From the climate’s point of view, the colour of the vegetation is important as it affects the reflectance or albedo of the surface – how much of the incoming sunlight is reflected and how much is absorbed. Forested areas tend to appear dark when the earth is viewed from space. This is because the leaves of a tree tend to be oriented differently relative to the angle of the sun, and shade each other. Trees also mask underlying, much brighter, snow in winter and spring. Deciduous trees may appear lighter in winter because they cast less shade without their leafy summer canopy.

The structure of vegetation is also important as it affects the wind by forming obstacles and causing friction. This, in turn, affects mixing between the surface and the atmosphere and thus the flows of energy, water and gases such as carbon dioxide. Vegetation also transfers water from the soil into the atmosphere and many plants can regulate the evaporation from their leaves in order to conserve water during dry periods. In this way, plants actively control soil moisture, atmospheric humidity and, because energy is absorbed when water is converted from liquid to gaseous form, near-surface temperatures.

In addition, trees emit different hydrocarbon compounds as gaseous emissions. These cause reactions that change green-
house gas concentrations, but can also be transformed in the atmosphere into small particles, which contribute to the planetary albedo and can change some cloud properties. Vegetation may be said to be ‘deeply rooted’ in the climate system.

**Climate change and vegetation**

As the climate changes, vegetation and its functions are affected. This causes ecosystem impacts as such, and also affects forestry and agriculture. As well as having a considerable effect on the temperature and precipitation conditions locally, changes in vegetation may in some cases propagate to influence climate features on a regional scale and on yet larger scales.

A burning global issue is the future efficacy of the carbon cycle sinks in the biosphere and oceans. The oceans will continue taking up carbon dioxide as long as atmospheric concentrations increase. The prospects are somewhat less clear for the terrestrial biosphere, i.e. vegetation. Different regions will experience different amounts of warming and changes to precipitation, for example. Some ecosystems will benefit from more carbon dioxide in the air, a milder climate and improved water availability. Others are less affected. And some ecosystems will be increasingly stressed by intolerable temperature increases, decreased precipitation and outbreaks of pests, forest fires and suchlike – as may be expected in a warmer climate. Furthermore, the decomposition of organic material in the soil speeds up with the warming, which decreases the carbon dioxide sink.

The climate/vegetation connection is not only about carbon dioxide. The biosphere also contributes to the flow of nitrogen, the already mentioned hydrocarbon compounds and their resultant small particles, and methane. Nitrous oxide and methane are both powerful greenhouse gases. One key unknown in climate change science concerns the large amounts of methane locked away by permafrost in the Arctic. Thawing soils and changes to the water landscape (for example, meltwater lakes) have the potential to release significant amounts of this methane. The present estimates are that decisive releases are unlikely, but it has been notoriously difficult to put a number on them. Climate models also have scope for improvement in this regard.

**We need to know!**

It is difficult to imagine what our future world will be like. Indeed, if we were living at the start of the 20th century, and pictured to ourselves what the world would look like in 2014, we would probably get it wrong. Similarly, one could question why we now attempt to think ahead to 2100 (and beyond), as things will occur which we cannot possibly foresee. However, we do know what we are doing now and we know what lies ahead of us – for at least some time ahead. The trouble with carbon dioxide emissions is that they stay with us for a very long time. Of the additional carbon dioxide which we compound in the atmosphere today, some 20–30% will still be in the atmosphere in 1000 years’ time. Major ecosystem shifts may well be irreversible and losses of species absolutely so. Along the road, many peoples’ livelihoods will suffer, as regional agricultural prospects worsen. Should we cross the threshold to large methane releases or ice sheet disintegration, things will be even worse.

The science tells us, however, that we can curb climate change. This requires reduced net emissions, and fundamental changes – over time – to the world’s energy, transport, agricultural, industrial and building solutions. In order to limit long-term global warming to below two degrees Celsius, which is the international target, global emissions need to start decreasing now and do so on a rather steep path towards net zero or
below zero sometime after 2050. This is a grand undertaking, but is nonetheless achievable. The issue of the carbon cycle raises its ugly head, however. If the natural carbon sinks weaken, it follows that the anthropogenic emissions over time will have to be even lower. The same applies if methane becomes mobile in Arctic systems. We quite simply need to know how sensitive these systems are. This does not mean that we should wait for yet more information before dealing with climate change. Rather, it means that we may need to do even more to tackle the problem.

Coordinator – Markku Rummukainen is Professor in Climatology at Lund University. He is also Climate Advisor at the Swedish Meteorological and Hydrological Institute (SMHI). His background is in research on climate models and on atmospheric chemistry.

Deputy Coordinator – Erik Swietlicki is Professor in Nuclear Physics, and leads the Aerosol Group at the Division of Nuclear Physics. He has more than 30 years of experience in atmospheric aerosol science. His research is motivated by the effects of atmospheric aerosols on climate, environment and human health.

About MERGE

MERGE stands for ModEling the Regional and Global Earth system. It engages in advanced research on climate models. MERGE is hosted by Lund University, and is a collaboration between Lund University, University of Gothenburg, Rossby Centre/SMHI, Linnaeus University, Chalmers University of Technology and Royal Institute of Technology. MERGE engages more than 100 researchers and doctoral students from across several scientific disciplines, and some 20 additional staff.

Reliable modelling of the climate system is of utmost importance for the society facing the challenges brought about by climate change. Even though climate science is robust enough to support mitigation and adaptation measures, the need to develop relevant scientific understanding persists. The interplay of physical and biological climate system components is such a key aspect as it can both compound and slow down climate change due to emissions, and it modulates how ecosystems and ecosystem services are affected.

www.merge.lu.se
03:

The latest thinking on the Middle East

LEIF STENBERG
ANNA HELLGREN
The Middle East in the Contemporary World (MECW) is a cross-disciplinary research milieu engaging scholars from a variety of academic disciplines, all working in one physical environment.

Our aim is to coordinate, redirect and expand research on the Middle East, and we have successfully pursued this goal. We have been able to place MECW firmly on the map and are well known among scholars working on the Middle East. In addition to excellent results in research, scholars within MECW have been committed to extensive outreach, providing information about the Middle East to businesses, governmental organisations and the general public.

MECW – The Middle East in the Contemporary World

A THREE-HOUR flight away from Sweden lies the Middle East, a fascinating region rich in history, culture, religions and languages. Lund University’s interest in what today is called the Middle East goes back to its founding in 1666 with a main focus on Semitic languages and religious studies. Since then interest in the region has increased and research concerning the Middle East is today conducted across all faculties at Lund University.

Many factors play into why the Middle East is an important region to study and comprehend: its significance in the history of human civilization; its conflict-ridden recent history which is a pressing global matter; its important role as a strategic trade partner; scarce water resources in the region, which are one of the future’s greatest environmental challenges; its richness in oil and gas resources and general role in the world economy; its closeness to Europe and the migration between the regions. All of these issues are at the core of the research conducted at MECW.

In order to address the reasons for studying the Middle East mentioned above, and to coordinate research at Lund University, the Centre for Middle Eastern Studies (CMES) was inaugurated in 2007. The funding of a Strategic Research Area (SRA), entitled the Middle East in the Contemporary World (MECW), in 2009 made it possible for scholars at Lund University to develop a new and dynamic research environment that was merged with CMES, physically as well as academically. Through these first five years, MECW has been able to take a leading role in coordinating, redirecting and expanding research on the Middle East at Lund University and nationally. Moreover, in a short period of time we have become a leading research institution in Europe. The directive for the SRA funding, specifically to create strong research environments, enabled us to create a common, unified and cross-disciplinary milieu.
in one physical building. This evolution has been strengthened throughout the five years with strong support from the management of Lund University. This organisation of MECW in one physical environment has been immensely important for the productivity of ideas and outputs – and it is our strong intention to preserve and develop this structure. From a national and international perspective the funding has enabled us to conduct research, organise conferences, do fieldwork, and also to organise a network in the Middle East and support scholars at other universities. MECW creates a platform for Middle Eastern studies that pushes the quality of the field forward, and it has created competition and increased interest in Middle Eastern studies at Swedish universities.

Our research profile has gradually moved towards the strengthening of a unique cross-disciplinary approach. The contact between scholars from a variety of disciplines in one environment has contributed immensely to creative thinking on method and theory among scholars within MECW, but has also been an empirical learning experience. The idea to coordinate, redirect and expand research on the Middle East has improved the overall quality of research. The creation of an SRA has been tremendously important for scholars participating in MECW. Without the SRA funding we would not have been able to create this new and cross-disciplinary research environment. Currently, we are one of the leading centres in Europe and with another five years’ worth of funding we will be one of the leading centres in the field of Middle Eastern studies – not just in Europe, but in the world.

Examples of cutting-edge research – responding to changing realities

The drastic changes in the political situation in the Middle East over recent years have raised the demands on academia to be reactive and provide relevant analysis. It is a challenge to every academic discipline to produce and disseminate “real-time” knowledge and analysis. Research results produced today usually take at least a year to get published in conventional scientific journals. To have a real societal impact, researchers have to work with many different tools designed for outreach. There are several options at hand, e.g. commenting on events in the media, using social media channels, writing reports and publishing special editions of journals. Here follow a few examples of how MECW has reacted to new realities.

SYRIA The anti-authoritarian uprising that began in March 2011 and successively evolved into a civil war has brought contemporary Syria to global awareness. Today the war has driven millions of people from their homes. The situation has been described as the worst humanitarian disaster of our era, to which an end is yet to be seen. The conflict has consequences for Europe and Sweden and the exceptional situation needs to be analysed and explained from different academic angles. Within MECW, Syria has been a focus area. A large conference in 2010 and several workshops on issues in relation to developments in Syria after 2011 have given rise to several important publications such as a special edition of the journal *Middle East Critique* and two edited volumes on Syria during the presidency of Bashar al-Assad. The coordinator of MECW, Leif Stenberg, has also frequently been interviewed in media about the developments, and has written numerous articles since the start of the uprisings in the country.
This conflict, and the often blurring, ill-informed news coverage of it, has exposed the absence of expert writing on Syria. The need for scholarly perspectives has been imperative. The contributions of MECW researchers to the journal and edited volumes mentioned above offer a unique body of research that examines Syria beneath its puzzling surface. These unique scholarly contributions reveal how Bashar al-Asad’s decisive first decade of rule generated changes in power relations, economic, religious, cultural and social circumstances and public discourse that fed the 2011 protest movement. Thus, research within MECW has also explored the complex and intersecting social, political, economic and religious fault lines that obstructed and still obstruct a peaceful development of the Syrian society.

**TURKEY** On May 28, 2013 what started out as a peaceful sit-in to counter government plans to raze Istanbul’s Gezi Park turned into a countrywide protest movement. The Gezi protests were arguably the most serious political crisis Turkey – a country often hailed as a “model” in the Middle East – has faced in the last decade. Triggered by a violent police crackdown and precipitated by the then Prime Minister Recep Tayyip Erdoğan’s defiant and polarising rhetoric, the demonstrations quickly spread to other cities. There had been more than 200 demonstrations in 67 cities across the country by 3 June according to Interior Minister Muammer Güler, turning Gezi into a hub of diverse grievances directed at what was widely perceived as the ruling Justice and Development Party’s (AKP) growing “authoritarian” tendencies.

Much ink has been spilled since June 2013 to explain Gezi in the media, most of it based on hasty analogies and banal platitudes, speaking of a “Turkish Spring” or portraying the events as the latest manifestation of the global occupy movements. Yet no academic analyses of the protests had been published before *The Making of a Protest Movement in Turkey: #occupygezi – the first academic book on the topic in English* – was produced at MECW. The aim of the book was to offer a preliminary analysis of the Gezi protests and address the following questions: How can we account for the protests? Who were the protesters? Why did the AKP government choose to suppress the protests instead of meeting the demands of the protesters? Were the Gezi protests in any way connected to protest movements in other parts of the world?

Gezi constitutes a landmark in recent Turkish history. The legacy of the protests is far from certain. It remains to be seen if a new durable form of politics and citizenship will emerge out of this rather unique moment. Still, one thing is certain. The seed has been sown, and a generation that had been taught to shy away from politics has been caught up in the maelstrom of political contention, and has gained/reclaimed its voice. The book, even though it hit the shelves only three months ago, has already contributed to this process by sparking debates in Turkish media and academic circles, leading to several interviews with Umut Ozkirimli, editor and senior researcher at MECW. A good example of the impact of the book is the speed at which the rights for the Turkish edition of the book have been sold just a month after its publication in English. When the Turkish edition is published, the book will have a greater societal impact as the current hardback edition is too expensive to reach wider audiences.

**ISRAEL/PALESTINE** The Parallel States Project (PSP) explored new avenues in regard to the relationship between Israel and Palestine. In this project scholars and practitioners analysed the idea of having two parallel state structures, one Israeli and one Palestinian. These parallel states would be built on ex-
isting institutions and frameworks – such as the Government of Israel and the Palestinian Authority – and extend the jurisdiction of both to all citizens living in the whole area between the Mediterranean and the River Jordan. Barriers could be lifted, introducing a joint security and defence policy, a common economic policy and a common labour market. Civil and family law could largely follow religious affiliation, as is already the case in many places.

The Israeli-Palestinian conflict in no way lends itself to a "quick fix". However, new ideas have to be explored to seek ways out of the present deadlock. The primary objective of the Parallel States Project is to introduce new ideas, rather than build a ready model.

The Parallel States Project was an attempt to study the questions and issues that would arise in a structure of two parallel states, “superimposed” upon each other. The project was a joint venture between Israeli and Palestinian thinkers, academics and policy makers, as well as a number of international academic institutions and think tanks. The project was conducted within the framework of MECW at Lund University, and was funded by the Swedish Ministry for Foreign Affairs and MECW. As a result of the project, the edited volume *One Land, Two States – Israel and Palestine as Parallel States* (M. Levine & M. Mossberg, California University Press) was published in May 2014.

**Conclusion**

In MECW, scholars sometimes study the contemporary Middle East in collaboration with practitioners. MECW researchers come from a variety of academic disciplines and they are established scholars within their own fields. MECW has favoured cross-disciplinary research, but research builds on the scholars’ capacity within a particular field. The critical approach within MECW research supports a positive development of democracy and human rights in the Middle East. Moreover, the examples of projects above demonstrate how MECW scholars take Lund University’s ambition to understand, explain and improve our world seriously.

**Life on the Nile – Transgressing disciplinary borders**

Water management is one of the biggest challenges the Middle East will face in the future. Scarce water resources affect economic development as well as political stability in the region. In 2012 MECW researchers from the humanities and natural and social sciences were involved in a project called “Hydrosolidarity in the Nile Basin” with the ambition to approach the challenge of water management from different academic perspectives. An essential research problem addressed in the hydrosolidarity project was how to improve the communication and understanding of the need to find global as well as local solutions to the water scarcity problems in Middle Eastern countries. Important questions in this project were related to solving water infrastructure problems in view of demands that are in excess of existing supplies – as well as finding new solutions regarding how national and international collaboration can improve water use efficiency. Solving these issues will have immense positive societal effects and spin-offs with regard to water security and economic development in water scarce countries.

Results of the project have led to improved recognition of MECW nationally as well as internationally – as an outspoken and truly cross-disciplinary research centre. The collaboration has also resulted in a joint policy report written with several consultant companies and NGOs (Glaumann, K., et al., (2014), *Measuring Results in Transboundary Water Management. Swedish...*
**Water House Policy Brief (SIWI)**. This policy report has been distributed internationally and will have implications on views of water management in internationally shared river basins.

Through the project, a strategic alliance with the Oxford University research cluster “Transformations: Economy, Society and Place” has been formed. This research cluster focuses on the roles that water insecurity plays in poverty, environmental degradation and dispute, as well as the role water security plays in growth and stability. The continued work strives to further initiate research through co-founding with research allies.

The hydrosolidarity project has helped to highlight the need for sincerely cross-disciplinary research at Lund University. The project has enhanced research and created added value not only for the university, but potentially also on a national and international level.

**Outreach**

MECW has an ambitious outreach programme. We believe that reaching out to people and organisations outside academia is of utmost importance in order to achieve real societal impact. Since the beginning of MECW, lunch seminars, public lectures, conferences, concerts and cultural events have been an integral part of our organisation’s activities. Some of our research projects directly involve civil society in Sweden and elsewhere in the world. Here are some examples of research projects and activities that connect to civil society and target groups outside academia.

**PODCAST** Together with Anton Berg (P3 dokumentär) a podcast on Syria was released at the beginning of 2014. Anton applied his unique storytelling techniques to explain the conflict in Syria and its consequences for people in Syria and Sweden. The podcast can be listened to and downloaded from the collection “Mellanöstern idag” on ItunesU.

**48H OF SYRIA** During a time span of 48 hours (5–7 December 2013) twenty-four events on Syria were organised in the city of Lund. Events included lectures, seminars, theatre workshops, concerts and poetry readings. 48H of Syria was a non-political event with the aim of spreading knowledge about the current situation in Syria, but also about the history of the country.

**STREETPOSIA** Researchers at MECW work with and do research on different NGOs. We work with the Unite Lebanon Youth Project (ULYP) on empowering and including Palestinian youth in Lebanese society and with Streetposia, linking academics, activists and artists through cross-national conferences engaging youth from marginalised backgrounds in discussions on social justice.

**FOOTBALL** We have received two grants (Åke Wiberg & Magnus Bergwall foundations) to study Swedish football clubs such as the Assyrian/Syriac, Kurdish and Palestinian teams, and their Middle Eastern links. One ambition within the project is to study migration to Europe through the lens of football. Another is to analyse the identity politics related to football clubs. The case of Sweden is of particular interest through the success of clubs like Assyriska FF, Syrianska FC and Dalkurd FF, which are built on strong link to a religious and/or ethnic identity. A third ambition is to discuss the role of clubs in regard to integration processes in Swedish society.
SYSTEMBOLAGET (the state owned company that has a monopoly on selling alcohol) has given a grant to MECW scholars (one theologian and one from the discipline of medicine) to carry out a study on the Swedish Temperance Movement, where the International Order of Good Templars (IOGT) is a partner. Research results produced within the project on alcohol consumption among teenagers have been utilised by national policy makers as well as the Swedish Temperance Movement.

MIDDLE EAST IN OUR NEIGHBOURHOOD Every spring MECW arranges a “fieldweek” in which scholars and students at MECW spend a week working together to map the Middle East in the local and regional area (Malmö/Lund, Skåne). The main purpose is to document activities in Malmö and Lund in order to ease contacts between researchers, students and wider society, but also to obtain knowledge about local environments with a connection to the Middle East that could be of interest to the general public. This is all in accordance with MECW’s ambition to reach out to various groups within as well as outside academia. Thereby this documentation constitutes a part of the third-stream activities of the university, which are to interact with, inform and explain research and projects to the general public. One additional positive outcome has been that our students gain their first experience of doing fieldwork. Our hope is that this material can provide information and inspiration for a wide range of people interested in the Middle East in Sweden.

ALMEDALEN During Almedalen Week 2013 and 2014, MECW arranged lectures, debates and seminars with staff and scholars. Panels were a mix of MECW staff and practitioners, and in one panel representatives from Swedish companies dealing with water management in arid areas participated. Another panel focused on Muslims in Sweden, during which MECW scholars engaged in discussions with several politicians. Other panels concerned updates and discussions on the developments in several countries in the Middle East. All seminars arranged by MECW in Almedalen were full and people were standing in order to be able to listen to the panel members.

TRAINING PROGRAMMES MECW scholars have given lectures and provided full days of training for staff at schools, businesses, NGOs and governmental organisations. For example, scholars have participated in seminars at the Foreign Ministry, trained schoolteachers, lectured to political parties, prepared Swedish companies and relief organisations for activities in the Middle East, and trained employees of municipalities and the Swedish Migration Board working with migrants from the Middle East.

MECW in the media MECW scholars appeared in the Swedish media well over 700 times in 2012 and more than 500 times in 2013 (newspapers, television and radio). Since MECW started, we estimate that there have been more than 2 000 references to MECW scholars in the media. Hence, the public impact of research in regard to MECW is very strong and the demand for knowledge of the present situation in the Middle East is extremely high in society in general. NGOs, employment offices, the Swedish Migration Board, the Swedish Foreign Ministry, private businesses, schools, municipalities, political parties and media agencies have all requested MECW scholars for lectures, workshops, panel discussions, expert opinions, policy papers and training courses.
Summing up

The original Centre for Middle Eastern Studies (CMES) was inaugurated in spring 2007. The funding of the Strategic Research Area MECW in 2009 made it possible for scholars at LU to develop a totally new research environment that was merged with the previous centre, physically as well as academically. With the support of the funding, we have been able to take a leading role in coordinating, redirecting and expanding research on the Middle East at Lund University and nationally. The directive for the SRA funding to create strong research environments enabled us to create a common, unified and cross-disciplinary coherent milieu. This evolution has been strengthened throughout the five years with strong support from the management of Lund University. The organisation of MECW in one physical environment has been very important for research productivity – and it is our strong intention to preserve and develop this structure. From a national perspective the funding has enabled us to organise conferences, support scholars at other universities and create a platform for Middle Eastern studies that pushes the quality of the field forward, and it has created competition and increased interest in Middle Eastern studies at Swedish universities.

The research profile has gradually moved towards a strengthening of a cross-disciplinary approach. The contact between scholars from a variety of disciplines in one environment has strongly contributed to creative thinking on method and theory among scholars within MECW, but has also been an empirical learning experience. Hence, the idea to coordinate, redirect and expand research on the Middle East has been fulfilled and has improved the quality of research.

On the level of the individual scholar, the SRA funding has been of tremendous importance for participants in MECW.

Without the funding we would not have been able to create this new and cross-disciplinary research environment. Today we are one of the leading centres in Europe and in another five years with continued funding we will be one of the leading centres in the world. We have been able to place MECW firmly on the map and we are now well known among scholars working on the Middle East. The next step is to develop a School of Middle Eastern Studies – Lund University and MECW is the place to be!
Nature’s services at risk in a changing climate

HENRIK SMITH

About MECW

The Middle East in the Contemporary World (MECW) is a dynamic and cross-disciplinary research environment (with 32 staff members) that provides a platform for researchers with different academic backgrounds and experiences. In collaboration with the Centre for Middle Eastern Studies (CMES), MECW fosters projects where researchers from humanities, engineering, theology, and natural and social sciences merge their knowledge and expertise in problem solving-oriented projects. A focus is on cross-disciplinary projects that concern current interpretations of Islam, water resource management, security, migration and mobility and Middle Eastern communities in Sweden and Europe. In order to coordinate, redirect and expand research on the Middle East, MECW is today developing new research themes to meet ongoing challenges. These include research on developments in regard to democracy-building and human rights implementation. Hence, the aim of MECW is to produce the latest thinking about the Middle East with high potential for scholarly and societal impact.

www.cmes.lu.se

Coordinator – Professor LEIF STENBERG.
Stenberg received a PhD in Islamic Studies from Lund University in 1996 with his award-winning thesis The Islamization of Science: Four Muslim Positions Developing an Islamic Modernity. He has been a visiting scholar at CMES, Harvard University and at the Institut Français d’Études Arabes de Damas (IFEAD) in Damascus, Syria.

Vice-coordinator – Associate Professor LORY JANELLE DANCE.
Dance received a BA from Georgetown University in 1985, a Master’s Degree from Harvard University, and a PhD from Harvard University. Recent article: “Performativity Pressures at Urban Schools in Sweden & New York,” (Ethnography & Education 2014). Book-in-progress: Minority Teens, School Reform, & Urban Change in Sweden & the U.S.
Climate change is increasingly posing a threat to biodiversity, both through its direct effects on organisms and through indirect effects resulting from changes in land use. Preserving biodiversity is an ethical obligation, but it is also increasingly being realised that biodiversity contributes to ecosystem services, i.e. ecosystem processes important for human needs and prosperity.

In order to answer the complex questions surrounding ecosystems and the services they provide us with, as well as to inform land management and policymaking, there is a need for a concerted effort from several scientific disciplines. BECC builds on research essential for understanding the impact of climate change on biodiversity and ecosystem services, and integrates such knowledge to provide a scientific basis for sustainable management.

CLIMATE CHANGE impacts the abundance and distribution of organisms around the globe. In addition to direct impacts on the biology and ecology of species, climate change-driven transformation of land use, agriculture and forestry may have additional effects on species and communities, exacerbating direct climate effects on ecosystems. The conservation of biodiversity in the face of climate change is an ethical obligation, but is also increasingly perceived as a key to preserving ecosystem functions important for basic human needs and prosperity. It is a familiar contention that biodiversity is essential for the direct and indirect contributions of ecosystems to human well-being. Improved scientific knowledge is needed to systematically account for the value of biodiversity and ecosystem processes when making decisions about ecosystem management.

The concept of ecosystem services elucidates the dependency of human society on ecosystem structures, functions and products. Ecosystems provide us with provisioning services, e.g. food and fibre; regulating services, e.g. climate and water regulation; and cultural services, i.e. the non-material benefits we obtain from nature. Behind these types of ecosystem services are processes carried out or affected by the functions of living organisms, i.e. supporting services, such as soil formation (e.g. for crop production), carbon sequestration (e.g. for climate regulation), and habitat provisioning (e.g. for recreation). Lack of awareness or consideration of ecosystem services, in particular supporting services, in the management of ecosystems may result in harm and services being reduced. For example, farmers not appreciating the value of wild pollinators may fail to preserve necessary habitats, resulting in reduced productivity of their crops.

Ecological knowledge is vital for the sustainable management of ecosystems. Yet knowledge of natural processes alone is not sufficient, since ecosystems are affected by complex interac-
tions between humans and living organisms that take place at a wide range of different scales in time and space. To account for the value of biodiversity and ecosystem services in decision-making, we thus need to understand both ecological processes and human decision-making. What is the direct impact of climate change on organisms and ecosystem processes? Will the preservation of biodiversity help to maintain ecosystem services under global change? How can the value of biodiversity be integrated into farmers’ and forest owners’ decision-making? Should management target the landscape level rather than a single farm or property in order to safeguard ecosystem processes? Are there synergies and conflicts between policies and institutions that address climate change, biodiversity threats and ecosystem resilience? To answer these questions, informing management and policy, there is a need to create an integrated scientific understanding that cuts across traditional academic disciplines.

The strategic research area Biodiversity and Ecosystem Services in a Changing Climate (BECC) brings together research on climate-ecosystem-biodiversity relationships from natural and societal perspectives at Lund University and the University of Gothenburg. We build on research essential for understanding impacts on and of biodiversity and ecosystem services under climate change, and integrate such knowledge to provide a scientific basis for the sustainable management of ecosystems and biodiversity. We address the direct impacts of climate change but also the indirect impacts that may result from climate adaptation or mitigation measures. Our core focus is on biodiversity and ecosystem services in Sweden.

Global change affects biodiversity and ecosystem services
In BECC we try to understand and predict how biodiversity and ecosystem services may be affected by climate and land use changes in the future. We do this by learning from the past using historical records, museum specimens and monitoring data. Sometimes this is straightforward, for example when using monitoring data to investigate how organisms have been affected by recent climate change. In other cases there is a need for sophisticated methods to infer the conditions of the past from available data, for example when developing landscape models to interpret pollen deposits in soil sediments in terms of vegetation and land cover patterns of the distant past.

Our efforts to understand the impacts of climate change on the distributions of organisms demonstrate how we make use of historical records. Capitalising on bird and butterfly data primarily collected by Swedish and European volunteers, for example in the Swedish bird and butterfly surveys hosted by Lund University, we have shown how many species have acquired a more northerly distribution over recent decades. This has had positive consequences for bird populations with southerly distributions but, due to competition, has tended to have a negative impact on northern species. Historical records show that permafrost has warmed, the length of the annual vegetative period has increased, and treelines have moved upwards, and this may help to explain why many bird species in the Fennoscandian mountain range have declined. Different species of birds and butterflies are not affected equally. Generalists often respond more strongly to climate change, resulting in changes in the composition of ecological communities with long-term consequences for ecological functions that are hard to predict. Furthermore, bird and butterfly populations do not keep up with the pace of climate change, colonising only certain areas predicted to become accessible as a result of climate change alone. This climatic debt may be caused by dispersal being constrained by non-climatological factors such as land use, or may
result from shifting distributions of plant species affecting the habitat of animals feeding on them. Issues of this kind may be explored using vegetation models to simulate habitat changes in response to climate change.

Detailed historical records of biodiversity and ecosystem services are often hard to obtain or reconstruct. A poorer but necessary alternative is then to use space-for-time substitution studies. Such studies compare present-day ecosystems in places characterised by different climatic or management conditions to infer how ecosystems may have changed in response to changes in such conditions over time, for example the direct or indirect effects of climate change over recent decades, or shifts in the intensity of landscape management since pre-industrial times. Using such approaches we have, for example, demonstrated that intensive agriculture may have a negative impact on pollinating insects, leading to negative consequences not only for the yield of crops that depend on pollination but also for wild pollinated flowers.

**Understanding biodiversity – ecosystem service – climate links**

To make plausible projections of how climate change will impact biodiversity and ecosystem services in the future, we cannot rely solely on statistical evaluations of past relationships. Instead we need to understand the specific mechanisms through which climate factors like temperature and rainfall control ecosystem processes. We expect this mechanistic understanding to hold beyond the range of historical experience, allowing us to make predictions of what may happen in a changed climate. Hence, an important part of our research is to understand whether and how species populations respond to global change in general – and climate change in particular – by acclimation, by adaption, or via changing distributions – or if they ultimately may become extinct. To this end, BECC researchers combine theoretical modelling, laboratory studies, studies of controlled ecosystems (mesocosms) and field studies in natural ecosystems.

**Theoretical modelling generates new insights**

Theoretical models may contain simplified assumptions and descriptions of how ecosystems work, but by virtue of their simplicity may reveal non-intuitive relationships among ecosystem components, or between processes and their drivers (such as climate variables). In other words, the models help us to think clearly about how the machinery of an ecosystem may be affected in a changing world. Theoretical models have, for example, helped us to increase our understanding of climate impacts on phenology, the timing of seasonal cycles in the activities of organisms – such as annual migration, breeding or flowering – and how these may change in response to a shift in temperature, precipitation or some other driver. Phenological change has been demonstrated for a range of organisms, for example in flowering time of plants and breeding times of birds. It has been argued that unequal shifts in phenology across trophic (feeding) levels, such as that of a predator compared with that of their prey, may result in a mismatch, with negative consequences for the population of one or both species. For example, some birds may breed earlier in response to climate warming with the result they fall out of phase with the annual population cycle of prey such as moths used to feed nestlings. However, BECC modelling demonstrates that a mismatch between the timing of highest food requirement and food availability may be compensated by other advantages, when the full range of costs that vary over the seasons are taken into account.
BECC research on the consequences of phenological timing across different levels in the food chain has shed new light on how to interpret historical phenological records.

**Laboratory approaches open “black boxes”**

Many ecosystem processes are difficult to observe and require sophisticated laboratory approaches to study. Ecosystem processes in the soil, in particular those governed by the functioning of microorganisms, are critical controls of ecosystem services such as carbon sequestration, greenhouse gas exchange and nutrient mobilisation. However, despite the critical role played by the soil and its fauna, the below-ground part of the ecosystem remains largely a “black box”, where the details of many processes and how they are affected by perturbations such as climate change are yet to be worked out. BECC utilises a variety of advanced methods to open this black box and study how climate and land use affect soil processes. To this end, a range of modern methods are adopted, such as spectroscopic analysis, gene expression profiling, isotope labelling and systems biology approaches. One exciting new finding in BECC is that soil carbon in the humus layer of boreal forest soils is mainly built up from below, being fed from the fine roots of trees associated with mycorrhizal fungi. This finding has spawned follow-up research that may fundamentally change our understanding of how boreal forests sequester carbon and contribute to regulating the climate. A key to gaining new insights is to determine in what forms carbon is actually stored in the soil. To this end, BECC is turning to advanced spectroscopic technologies, such as those represented by the new MAX IV synchrotron light facility in Lund. This essentially functions as a very powerful microscope, able to discern the chemical details of a sample of soil material at sub-molecular level. It will be of great benefit to this line of research in BECC.

**Mesocosms allow controlled ecosystem experiments**

To investigate consequences of climate change for ecosystems and communities, we would ideally like to do experiments. However, full-scale climate change experiments are often prohibitively difficult and expensive to set up. An alternative is to create smaller simulated ecosystems – mesocosms – and perform semi-realistic experimental studies on these. Climate change has a paramount impact on water resources, both by affecting hydrological properties of catchment areas – resulting in changes in the amount and seasonal timing of run-off as well as water chemistry – and by affecting the temperature of water bodies and streams. BECC research combining studies in lakes and ponds with experimental studies in mesocosms, i.e. in large water tanks, has shown that climate warming can cause cyanobacterial (blue-green algal) blooms, including toxic species, to occur several weeks earlier in the spring. Moreover, temperature increases can be expected to give rise to other impacts of concern to humans, such as the brownification (increased humic concentrations) and eutrophication of coastal waters.

**Field studies reveal impacts in and on real landscapes**

While studies in simulated ecosystems are useful for highlighting specific mechanisms of response to climate change, field studies are needed to verify effects in real ecosystems and to capture complex processes at large scales. For example, using space-for-time replacement studies that move beyond the restricted availability of historical data, BECC research investigates how indirect consequences of climate change, such as agricultural intensification, may impact organisms and the ecosystem services they provide. A related line of research strives to evaluate the effectivity of measures designed to mitigate nega-
tive consequences of climate and other associated changes on ecosystems. For example, BECC studies have demonstrated that by simultaneously protecting semi-natural grasslands and reducing agricultural intensity we may benefit organisms, such as pollinators, that provide important ecosystem services for crop production. Such knowledge is useful for informing agricultural policy development at both European and national level (e.g. agri-environmental schemes).

The above examples demonstrate the advantages of adopting and bringing together multiple approaches to examine the impact of climate and land use on organisms and ecosystem processes from alternative perspectives and at different scales. The ability to develop and pursue research of this kind is one great advantage of a large and cross-cutting research environment like BECC. In addition, the formation of BECC has strengthened links between existing research groups, resulting for example in efforts to bridge the terrestrial-aquatic divide in research on ecosystem services, strengthening links between theoretical modelling and empirical research, and resulting in joint efforts to strengthen research infrastructure.

**Modelling**

The processes that govern variations in the species composition, physical structure and functioning of an ecosystem span a remarkable range of scales in time and space. Physiological processes like photosynthesis and leaf gas exchange in plants take place within cells and leaves, and respond quickly to changes in environmental drivers, such as a rise in tissue temperature. By contrast, population processes (birth and death of individual organisms), community interactions such as competition for soil resources by neighbouring plants, interactions between different levels in the food chain such as predation and herbivory, and landscape-level processes such as the movement of insect pollinators between vegetation patches in response to local flowering cycles operate on much larger and longer scales. Whereas small-scale and fast-responding processes can often be studied and accurately characterised by means of measurements and experimentation in the field and the laboratory, long-term and large-scale processes are more difficult, if not impossible, to characterise and understand based solely on direct observations. This is because of the practical hindrances and expense of performing measurements at large scales, and because response times to drivers may extend to years, decades or even centuries (e.g. regarding the generation times of forest trees), longer than funding cycles or even whole careers in academic research!

Ecosystems are highly coupled systems, governed by interactions and feedbacks between processes operating on and mediated by the species populations and matter pools that make up the ecosystem itself. In other words, the response of an ecosystem to a change in external conditions (such as aspects of climate) will vary depending on the state of the ecosystem, and the state of the ecosystem depends on the history of past changes. Consequently, understanding and predicting changes in ecosystems – and their services – as external driving conditions change requires consideration of the full range of governing processes, from small/fast to large/slow scales. This is particularly true in the context of ongoing environmental change. Environmental change has already been impacting ecosystems for a century or more and is expected to have an increasing impact on ecosystems at global scales in the future. This raises societal concerns about impacts and adaptation needs for decades and centuries ahead. Understanding and
predicting responses of ecosystems in this long-term and large-scale context, in the absence of direct measurements of many of the processes involved, and with desirable precision and accuracy, is only possible through the use of models.

**Ecosystem models**

BECC works with a variety of ecosystem models, and emphasises the development and refinement of models based on data and insights from empirical ecosystem research. The goal is to create models that can be applied to particular systems (such as a particular class of ecosystems or a biome such as boreal forest) and that are suitable for addressing questions regarding the responses of that system to perturbations and variations in driving conditions on a certain time scale. A model is suitable for this purpose when it represents the processes, ecosystem components and feedbacks that influence the ecosystem at the target time scale as realistically and accurately as possible. Models may inform us about trends in real-world ecosystems, but just as importantly, the process of developing and testing a model forces researchers to express their understanding of how an ecosystem “works” in explicit terms, and to seek explanations when the predictions of the model differ from what observations would suggest. This raises questions and exposes critical knowledge gaps in need of new research, both empirical and model-based. In global change research, modelling is thus an integral part of the cycle of observation-hypothesis-inference that drives the research forward.

Ecosystem modellers and experimentalists in BECC have worked closely together to improve understanding of how rising ozone levels due to industrial processes and transport may be impacting the productivity of forests and agricultural ecosystems. Tropospheric (near-surface) ozone is a reactive species of oxygen generated by reactions among atmospheric reagents under the influence of light. It is highly toxic for plants, damaging the apparatus for photosynthesis and gas exchange. By introducing an “ozone impact module” to a dynamic ecosystem model, we can now estimate influences on productivity and other aspects of the functioning of the ecosystem.

**Ecological-economic modelling**

Both ecologists and economists use models to handle environmental issues; in BECC we combine these in ecological-economic models known as agent-based models (ABM) that link human behaviour and decision-making to biodiversity and ecosystem services. The decisions of managers (agents) are captured in the economic part of the ABM, whereas the ecological part of the model translates these decisions into ecological impact. In this way we integrate the value of biodiversity and ecosystem services in both land managers’ and society’s decision-making. Using such models we have shown that inorganic fertilisers cannot compensate fully for the ongoing erosion of soil ecosystem services in terms of conserving aspects of soil quality of importance for ecosystem services like carbon sequestration and nutrient retention. Farmers who adapt their management in order to build up soil carbon may expect to see improvements in both the sustainability of food production and farm income. Currently we are extending the scope of this research to encompass additional ecosystem services such as biological control and pollination, and to capture impacts such as increased volatility in prices and changes in growing conditions.

**Governance of ecosystems**

As climate impacts ecosystem processes, these climate-driven changes will feed back to socio-economic systems, for example
by affecting land use decisions via prices for food, forest products and biofuels, as well as transformations in the governance systems that strive to meet such changes. The sustainable management of ecosystem services needs to take into account these interactions between biophysical and socio-economic systems, recognising that climate, agriculture, forestry and biodiversity conservation policies are embedded in systems of governance at different levels – and that these systems increasingly involve collaboration between public and private stakeholders.

BECC researchers critically analyse the changing conditions for policy development and decision-making as well as the implementation and evaluation of new policies in the face of environmental change. This research includes, for instance, examining questions of fairness and legitimacy of environmental politics. It also involves the evaluation of synergies and trade-offs between different environmental policy objectives when addressing climate change, biodiversity protection and ecosystem resilience.

One example is our research on the analytics of carbon accounting. Release of carbon dioxide to the atmosphere is the major reason for human-induced climate change. Carbon dioxide is released when we burn fossil fuels, but carbon is also bound in ecosystems and our management of land therefore impacts climate change. Contemporary climate governance hinges on the ability to account for stocks and flows of carbon and to translate these into stable, quantifiable entities that are conducive to governance. Many policy instruments build on this rationality, for example, carbon emission certificates or incentive-based mechanisms like REDD (‘reducing emissions from deforestation and forest degradation’). This raises questions as to whether it is useful to base policies on the measurement of carbon (for example how much carbon is stored in forests), how different types of stakeholders will respond and what the impact will be on different ecosystems. In BECC we have analysed current approaches to monitoring carbon stocks in forests, finding that vulnerable groups of stakeholders, such as indigenous communities, are often excluded from decision-making or monitoring practices. Current approaches also tend to neglect or undervalue additional ecosystem services beyond carbon, like soil conservation, erosion control or conservation of biological diversity.

In another line of research we investigate whether ecosystem services can be effectively managed based on individual decision-making by landowners alone, or whether, by contrast, collective management is needed. Underlying this research is the recognition of the “tragedy of ecosystem services” which results from the mismatch between those actors that bear the costs of sustainably managing ecosystem services (e.g. local management to benefit carbon sequestration) and those that benefit (global society, which benefits from reduced climate change due to sequestration of carbon dioxide by ecosystems). Using both modelling and empirical studies, we have investigated the effectiveness of environmental policies such as agri-environment schemes in promoting the effective management of ecosystem services. Sadly, the scientific foundation of these policies often seems weak.

**Supporting decision-making**

An important aim of BECC is to enhance dialogue with stakeholders, both to inform research on management and policy issues and to support decision-makers in their management decisions and in the formulation of policy. To support BECC researchers in their frequent role as scientific experts, ranging from contributing to the assessments of the Intergovernmen-
economics burden in Swedish forestry. Outcomes can be used to tailor forest management choices such as species composition and rotation time to balance risks against returns from forestry practices.

**BECC – a long-term commitment**

The advent of BECC has resulted in a significant growth and integration of research in the climate-biodiversity-ecosystem service area at Lund University and the University of Gothenburg. In large measure, this is a result of the reorientation of existing research groups, recruitment of new researchers and PhD students, as well as the synergies arising from interactions between research teams. While the development of an integrated research environment equipped to tackle emerging issues in ecosystem service management has come a long way, important challenges still remain when it comes to fostering interactions between the natural and social sciences and bringing together modellers of large-scale processes with experimental scientists focusing on detailed mechanisms at small scales. However, the experience of BECC shows that long-term investment in a common strong research environment helps to overcome challenges like these. BECC has contributed to an increased ability and willingness to contribute to the scientific understanding of adaptation to and mitigation of climate change.

Outcomes are relevant for policy formulation on nitrogen fertilisation of Swedish forests and decisions on increased use of forest for bioenergy with resulting risks for increased acidification. Dynamic vegetation modelling has been combined with modelling of pest dynamics to forecast the consequences of climate-driven changes in forest composition, structure and productivity on the dynamics of spruce bark beetles, a major threat to forest ecosystems.

One example is in the area of forest management. Climate change will affect ecosystem processes in forests, with consequences for the production and costs of forestry, but will also have an impact on ecosystem services that are public goods, such as water supplies and climate regulation. The combined effects of intensified forestry and climate on carbon and nutrient dynamics in the soil can be forecast using dynamic ecosystem modelling (i.e. models that take account of interactions between different parts of the system – such as the soil, trees and understorey vegetation – over time). Such models can therefore be used to guide forest management in a scenario in which we expect the climate to change.

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About BECC

BECC’s vision is to pursue world-leading interdisciplinary research, bringing together ecological modelling with empirical studies and linking this with policy and governance for sustainable management of ecosystems and biodiversity in a rapidly changing world.

In particular, BECC aims to:

> assess climate change impacts on biodiversity and ecosystem services in Sweden, with a particular focus on forest, agricultural and subarctic ecosystems, but also including aquatic systems that are affected by run-off from forest and farmland.

> support regional, national and global policymakers through the scientific evaluation of policy options combining adaptation and mitigation strategies to climate change with conservation of biodiversity and ecosystem resilience.

> create synergies and added value to involved researchers by bringing together modelling, empirical ecology, economics and social science analysis, and by integrating stakeholders in the research process.

> BECC encompasses more than 170 senior researchers and 70 PhD students from some 12 departments at Lund University and the University of Gothenburg.

www.becc.lu.se

Coordinator Henrik Smith

Henrik is Professor of Animal Ecology with a research focus on how agricultural intensification affects meta-communities of interacting organisms and the consequences of this for ecosystem services such as pollination and biological control. The focus is on increasingly cross-disciplinary research to understand consequences of policies for biodiversity and ecosystem services.
Exploring the Human Body
Cell therapy for Parkinson’s disease – the next step

JENS PERSSON
Scientists in Lund have long been global leaders in Parkinson’s disease research. In the past decades they have strived towards nerve cell transplants for large patient populations. Could such a development signal the beginning of a treatment revolution for people with Parkinson’s? The answer – is just around the corner.

Such cell therapy has already been shown to help patients make remarkable recoveries – encouraging scientists to work towards safer and more effective clinical applications. Researchers within MultiPark are now poised to witness the first transplants in over ten years. The scientific community is anxiously awaiting the results.

In the early 1990s, a small group of Lund University researchers found themselves at the centre of the global media spotlight. They had produced a truly pioneering feat, nerve cell transplants in Parkinson’s patients. The news travelled rapidly across continents and soon they graced the cover of the New York Times. The first ever repair of the human nervous system was a fact.

The field of cell therapy for Parkinson’s disease has since hit a number of obstacles, and perhaps one might argue that the setbacks have outnumbered the strides forward towards clinical application. In 2014 the story is set to change yet again as an EU-funded network, with Lund researchers once more at the centre of events, is preparing to perform the first transplants in over ten years. But before we tell that story, let us travel back in time, over half a century, to an extraordinary discovery that would get the proverbial ball rolling.

In 1957 Arvid Carlsson, busy at work in his laboratory in Lund, first identified the neurotransmitter dopamine. Later it would be established that Parkinson’s disease progresses as a result of the withering away of dopamine-producing brain cells. The original discovery, which would eventually be rewarded with a Nobel Prize, laid the foundation for a strong research environment on Parkinson’s disease at Lund University, a legacy that has been carried on to this day.

In the 1970s researchers at Lund University had access to a unique fluorescence colouring technique developed at the university, the Falck-Hillarp method, which allowed for the individual identification of nerve cells based on which neurotransmitters they used to communicate. With Professor Anders Björklund at the helm, one of MultiPark’s original principal investigators, the method was used to identify and isolate dopamine-producing cells that were later used for transplants.
velop Parkinson-like nerve damage. After careful examination, two of them received transplants in Lund using the method that had been practised a couple of years before. The outcome was staggering as the immediate results were clearly evident to the naked eye. Patients who had not been able to get out of a chair six months earlier could now walk, seemingly unhindered by their previous symptoms. The graphic nature of the before-and-after footage created a media circus in the US and the attention helped kick off a global race towards standardising the new treatment for larger patient populations.

Year by year, expectations continued to rise and finally, at the end of the 1990s, two large placebo-controlled studies were launched in the US in the hope of getting the treatment ready for the clinic on a larger scale. Unfortunately, the American trials would fail in a number of ways. They have later been criticised on patient selection, a hasty evaluation process, use of poorly characterised tissue and technical approach. Either way, the bottom line was that the overall reported results were mostly negative. For such an invasive therapy as cell transplants, this news was damaging and the research field became shrouded in a veil of doubt. As a result, immediate plans to bring cell therapy for Parkinson’s disease towards new clinical trials were shelved for the foreseeable future.

A European mobilization
In the wake of the US trials the research field was placed under a voluntary moratorium. Years would pass before researchers on the opposite side of the Atlantic began to mobilise yet again. In 2006 a gathering of European research groups met in London to evaluate the possibilities of breathing new life into what had become a slumbering research field. Under the guidance of Professor Roger Barker of Cambridge University, partnering with a
team from Lund University, the first steps were taken towards an updated blueprint for the future. Using the failed US trials as a stepping off point, the European researchers agreed to launch a broad international study with the goal of strengthening the treatment potential of cell therapy for Parkinson’s disease.

Around this time new reports started emanating from the US suggesting that some of the patients who had taken part in the flawed trials were showing positive results. The news spurred on the European scientists and in 2009, after a laborious collaborative effort, an application for a new European research consortium, TRANSEURO, was submitted. The following year it was rubber-stamped and the painstaking efforts to get another trial off the ground could begin. The goal? To develop an efficient and safe treatment methodology for Parkinson’s disease using foetal cell-based treatments.

The US trials have cast a long shadow over the TRANSEURO project, with concerns still being echoed today by parts of the scientific community. But what if the American studies were designed to fail? Could perhaps more rigorous preparations, more careful selection of patients and ten years of further development in this research area produce completely different results? MultiPark’s Håkan Widner, adjunct professor of neurology and head of patient recruitment at the university hospital in Lund, believes so.

“I believe TRANSEURO is going to be very important in deciding whether cell therapy for Parkinson’s is going to be a clinical treatment in the future, perhaps even deciding if it’s going to be further explored. Still, we have a lot to be excited about. The proof-of-principle we have seen is that some patients can be relieved of their symptoms and can even be taken off medication, so we know this treatment can actually work. The question we’re trying to address now is – how can we make it work for more patients? We are truly hopeful that the results will be different this time.”

To really understand the high expectations put on a research area that has remained partly dormant in the past decade, one must look at the people whose lives have gone through remarkable change after successful transplantations. In a third of the cases, the patients have experienced unprecedented symptomatic relief over a long time, without having to take any medication. In some patients the effect of the treatment has been constant for over 20 years. These results cannot be ignored. For a disease where the typical patient’s everyday life is hampered by demanding medication schedules and where the effects of standard medications begin to decline after only five to ten years, cell therapy still presents hope of a different and better life for many people with Parkinson’s.

The initial clinical trials within TRANSEURO include surgery of about 20 patients in two hospitals in Europe – Lund and Cambridge – planned to begin at the end of 2014. The study will firstly focus on safety issues, to see if patients develop uncontrollable movements, dyskinesias, which were the most disturbing side effects from the trials in the United States. Further on, the therapeutic effects of transplantation will be evaluated. A total of thirty patients have been enrolled in the Lund chapter of the TRANSEURO project. The total number for the six European research sites is 150 patients.

**The next generation of cells**

In parallel with TRANSEURO, the development of the next generation of cells to be used for transplantation has rushed on. Extraordinary advances have been made, not least within MultiPark. Malin Parmar, a former postdoc under Anders Björklund, is one of the world’s leading researchers in develop-
ing stem cell-based alternatives for Parkinson’s disease cell therapy. The scientific community has realised that if this is ever to become a standard treatment we cannot solely rely on foetal cells, for a couple of reasons. Firstly, there is the ethical concern of taking tissue from aborted foetuses. Secondly, there is the issue of availability of foetal cells, which in most cases is scarce. The logistics surrounding the gathering of cells for any specific transplant is partly down to luck and circumstance, and each patient receives a different cell preparation with no possibility to perform extensive quality control of the grafted cell preparation. There simply are not enough available to make this a viable treatment for the global Parkinson’s patient community.

Therefore, as TRANSEURO nears completion, it is vital to develop alternative solutions that can serve larger patient groups in the future. That work is already well underway. Together with her European colleagues, Malin Parmar has helped bring the field forward towards a gold standard of stem cell-derived dopamine cells, ready for transplantation. The pluripotent nature of stem cells means that an evaluated and tested protocol for differentiation towards dopamine cells could produce, in theory, infinite cell populations ready for transplantation. This method of generating nerve cells with specific functions from stem cells, through a set of carefully researched steps of differentiation, will therefore allow cell therapy to become accessible on a much broader scale in the clinic.

A major breakthrough in this field happened in 2012, when Malin Parmar's research group presented a paper revealing a new technique that streamlines the differentiation of stem cells into brain cells. This method was simpler and quicker than what had been produced before and has since laid the foundation for a shorter route towards cell transplants in the clinic.

By adding two different molecules, the researchers discov-
vantage here, as it will put coming clinical trials on a faster track towards reaching the patient.

“If we get a good result from TRANSEURO in a few years, meaning that patients are stabilised at a high functioning level, we believe that stem cell-derived studies will have reached the point that a study can be launched that takes full advantage of the organisation and procedures built up within TRANSEURO. We will be able to apply the same imaging methods, protocols and evaluation processes. This puts us at a massive advantage”, says Malin Parmar.

From skin cell to brain cell
Beyond the development of stem cell-derived dopamine cells, yet another generation of transplantable cells are being researched at Lund University. Also here, we find Malin Parmar’s research group at the forefront of truly experimental science. In the summer of 2011, they published a paper illustrating one of the first ever examples of a human skin cell being turned into a brain cell. By reprogramming connective tissue cells, called fibroblasts, directly into nerve cells, Parmar and her colleagues have helped to fundamentally change previously held views on the function and flexibility of mature cells.

The initial breakthrough that led to the development of this method, called direct conversion, was rather unexpected, to say the least.

“We didn’t really believe this would work in the first place. To begin with, it was mostly just an interesting experiment to try, as work often goes in the laboratory. However, we soon saw that the cells were surprisingly receptive to instructions”, says Malin Parmar.

Unlike stem cell-derived nerve cells or iPS cells, where skin cells are turned into pluripotent stem cells before they are further programmed, the method of direct reprogramming means that the skin cells do not pass the stem cell stage when converted into nerve cells. Skipping the stem cell phase minimises the risk of tumours developing. This presents a major advantage since the field of stem cell research has long been obstructed by the risk of the pluripotent cells continuing to divide after being transplanted.

Besides sidestepping the tumour risks and ethical dilemmas associated with stem cells, the method of direct conversion offers another great benefit as the skin cells can be taken from the very patient who will later receive the transplant. Using the patient’s own cells means that the brain’s immune system will not react negatively upon transplantation, allowing for the omission of immunosuppressing drugs that otherwise are a must in cell therapy.

The vision for the future is that researchers will be able to produce the specific brain cells that a patient needs from a simple skin, blood or hair sample. One should remember, however, that this work is still at an early stage. Before the direct conversion technique can be used in clinical practice, more research is needed on how the new nerve cells survive and function in the brain.

A treatment revolution?
The different Parkinson’s treatments that exist today have without question helped millions of people live a longer and a more fulfilling life. The standard medication L-Dopa, which arrived in the clinic as a direct result of that unique discovery by Arvid Carlsson, was a revolution when it was introduced in the late 1960s. It has since given people with Parkinson’s a second chance, allowing them to stay in the workforce and remain active participants in society.
Although cell therapy for Parkinson’s disease shouldn’t be viewed as a cure, at least not judging by where the research field stands today, it may yet revolutionise the treatment of Parkinson’s in the not-too-distant future. However, it is becoming more and more evident that Parkinson’s is a systemic disease, not only limited to the movement disorders that has long characterised it. Symptoms relating to cognition, memory, sleep and depression are now part of the broader clinical picture being addressed by neurologists and rehabilitation specialists. While dopamine nerve cell transplants may not address these symptoms, which often occur in the later stages of the disease, they could still significantly increase the chances of a longer and more productive life for people with Parkinson’s.

“The positive results we have seen in some of the patients who received transplants over two decades ago lead us to believe that we can really change peoples’ lives with this treatment. The non-motor symptoms that they are experiencing today are not very different from other age-related disorders experienced by people of the same age. If we can restore the brain’s dopamine system early on in the disease progression, Parkinson’s could perhaps become a disorder that doesn’t show any real symptoms until the later stages of life”, says Anders Björklund. There is no doubt that the world will be watching as the first reports from the TRANSEURO trial surface. A positive outcome could very well signal the beginning of a treatment revolution for Parkinson’s disease. It is therefore only fitting that Lund University once more finds itself on the frontlines in the battle against one of the world’s most devastating brain disorders.
Coordinator – Susanne Iwarsson is Professor of Gerontology at Lund University and the coordinator of MultiPark. Her group Active & Healthy Ageing focuses on environmental gerontology in combination with health sciences and neuroscience, studying the ageing individual’s and population’s opportunities for activity and participation in society.

Assistant Coordinator – Gunnar Gouras is Professor of Neuroscience at Lund University and the assistant coordinator of MultiPark. He is group leader of the Experimental Dementia Research Unit, focusing on elucidating the mechanisms of early synapse dysfunction in Alzheimer’s disease and related neurodegenerative disorders.

Author – Jens Persson is public relations officer for MultiPark. His responsibilities include planning, developing and implementing PR strategies, developing media relations, and writing and editing in-house newsletters, brochures and strategic documents.

About MultiPark

MultiPark builds on the strong tradition of cutting-edge research on Parkinson’s disease at Lund University. Our vision is to improve the quality of life for people with Parkinson’s disease and related neurodegenerative disorders through a union between preclinical, clinical and health sciences. From the laboratory bench to the patient our aim is to tie together innovative research in order to make the road to the clinic shorter and faster. Several drugs are currently available to treat Parkinson’s disease, but their effects often diminish with time. Therefore, new treatments are needed to slow, or stop, the course of the disease. We continuously work to map disease development, understand how it progresses on a cellular level, how it relates to the nervous system and finally how it affects the everyday life of people living and ageing with these diseases. MultiPark relies on interactions between Lund University and Skåne University Hospital, together with the co-applicant University of Gothenburg.

www.med.lu.se/multipark
Diabetes – treatment, prevention and cure

ERIK RENSTRÖM
Five percent of the world’s population – every twentieth person on earth – is today suffering from Diabetes, and the number is rapidly increasing. It is a chronic disease, mainly caused by genes and lifestyle, affecting the daily life of all patients. Its complications have vast consequences for personal health and are making health care costs soar.

EXODIAB is one of the most sophisticated diabetes research networks in the world, firmly placing Sweden on the map in the battle against the disease. Our 450 scientists are devoted to discover new understanding, treatments, preventions and the ultimate goal – a cure for diabetes.

**DIABETES IS** the fastest growing disease in the world. World-wide prevalence figures estimate that there were 347 million diabetic patients as of 2011 and that this number will increase by 50 per cent by 2030. The International Diabetes Federation has put together a map of the number of diabetes cases seen in the world in 2013 (below). WHO projects that diabetes will be the seventh leading cause of death in 2030. According to the Swedish Association of Diabetes, one in nine Swedes already has diabetes or runs the risk of developing diabetes. Diabetes and its complications impose an immense burden on the quality of life of the patients and account for more than 10% of health care costs in Sweden or approx. SEK 50 000 per patient per year.

What is diabetes?
Diabetes is a lifelong, incapacitating disease caused by a lack of, or inability to produce sufficient amounts of, a hormone known as insulin, which is produced in the pancreas. The disease is lifestyle-related and associated with a sedentary lifestyle and obesity. The disease cannot be cured and affects multiple organs. It is associated with devastating chronic complications such as kidney failure, blindness and amputation.

Diabetes develops as a result of a lack of insulin. Insulin helps cells convert the glucose in the blood stream, derived from food, into energy. Depending on the amount of glucose, the beta cells in the pancreas release just enough insulin to regulate blood sugar and keep it at a smooth level. If the blood sugar level is too high, the patient develops hyperglycaemia, a condition that, if sustained and recurring, leads to severe complications. On the contrary, a blood sugar level that is too low, hypoglycaemia, can lead to unconsciousness and coma which is a life-threatening state. Without insulin, you die; it is as simple as that. What is not simple is the regulation of blood sugar in connection with every meal. Exercise, stress, general mood and lots of other factors affect your blood sugar. Having diabetes requires lifelong monitoring and treatment and is at times considered a difficult disease as it affects life in so many ways.

EXODIAB has three priorities
Since its start in 2010 EXODIAB has been working with three priority areas:

1. diabetes research
2. innovation
3. education

1. Diabetes research The scientific challenges for EXODIAB concern elucidation of disease development, design of biomarkers for prediction of disease development and vascular complications, testing of novel drug targets, exploration of new methods for prevention and management of diabetes, obesity, and cardiovascular complications. EXODIAB has used its funding not as individual project funding but to make long-term strategic investments. In this we have deliberately built infrastructures aimed at ensuring continued excellence rather than-upholding existing research efforts. Examples of strategic investments are the generation of long-lasting research resources to facilitate national diabetes research. Key personnel competence such as talented researchers, senior mentors, bioinformaticians, system engineers and grant administrators have been recruited. The latter four categories work in such a manner that numerous research groups and individuals benefit from their work and project assistance.

2. Innovation To accelerate the translation of basic research findings into new drugs, biomarkers, and know-how that can be utilised by both diabetes patients and the health care sector, we have prioritised the establishment of an Innovation Office. Through successful recruitment of skilled Innovation Office staff, EXODIAB researchers have raised their awareness about the innovation process and can receive hands-on assistance from the Innovation Office on practical issues concerning innovation.

3. Education EXODIAB has noticed an increasing need for trained bioinformaticians to process large experimental data sets. In response, EXODIAB has concentrated educational efforts into this area. A visiting professor in bioinformatics, Stephen Friends from Boston, USA, has been recruited to Lund University.
EXODIAB is a team effort
Over the last decade Lund University Diabetes Centre has become a world-leading institute within several areas of diabetes research. In collaboration with Uppsala University, EXODIAB aims to make Sweden the most successful country in the world within all aspects of diabetes research, contributing to an increased understanding of the underlying mechanisms of diabetes.

Both universities give top priority to diabetes research and are committed to taking research in this field to an even higher level. The diabetes programmes at our universities have previously been assessed as outstanding in international evaluations. Thanks to EXODIAB, this world-leading position has been widely and deeply consolidated. Through good leadership, a culture of professional programme management has evolved, involving routines for joint meetings, discussions and strategic decision making.

Diverse research areas with a common denominator
EXODIAB is a network of around 450 skilled colleagues, all possessing diverse competence and research specialities. The common denominator is diabetes. Some of the staff specialise in genetics, others in areas such as gene-environment interactions, insulin secretion from the pancreas, cell signalling, metabolism, diet and functional foods, exercise, vascular complications, transplantation, clinical trials or epidemiology. Thus EXODIAB has a broad and multidisciplinary approach that will help to achieve the goals and pave the way for new strategies and therapies for the prevention and cure of diabetes.

Research platforms
A central theme for EXODIAB has been to generate national platforms which can facilitate diabetes research in Sweden as well as stimulate further interaction between academia and life science industry. For example, insulin-producing beta cells from donors are distributed exclusively to the researchers within EXODIAB, making it possible to study mechanisms in the most important tissue for diabetes research. The Human Tissue Laboratory not only provides insulin-producing cells from the pancreas but also distributes other target tissues of importance for diabetes, e.g. fat, liver and muscle. Access to human research material for experimental studies is fundamental as we have learned that animal models cannot replace human material. Research groups are required to propose research projects to a steering group so that duplication of research is avoided. Furthermore, it is mandatory that researchers share their results within EXODIAB. In this way our collective knowledge is constantly increasing and the most is made from the donated material. The Human Tissue Laboratory now serves as the basis for numerous research and innovation projects.

EXODIAB has also contributed to the generation of the human observational studies ANDIS (All New Diabetics In Scania) and ANDIU (All New Diabetics In Uppsala). More than 10,000 individuals have joined the studies and the genetic information in combination with biomarker results has allowed us to reconsider the old classification of diabetes in favour of more diabetes subclasses. This provides vital information that can be used to find novel drug targets that are personalised and based on individual genetic setup.

By using our expanding biological infrastructures, the Human Tissue Lab and the human observational studies ANDIS and ANDIU, we can continue our ambition to describe the underlying mechanisms behind the disease with the goal of being able to improve treatment, prevent disease development and prevent vascular complications of diabetes.
EXODIAB has contributed to yet another research platform, the Clinical Metabolic Laboratory. The aim is to perform excellent clinical studies, employing state-of-the-art clinical physiology investigations combined with genetic characterisation.

**Type 2 diabetes**
Technical advances in recent years have made it possible to learn more about our genes and how we are affected by lifestyle and environment. Studying families and populations over time has shed light on the importance of heredity. Lund University Diabetes Centre has some of the best biobanks in the world for diabetes research. For decades people have contributed to research by participating in important surveys and sharing samples and information. The surveys and biobanks are unique and today’s scientists gain a lot of understanding when revisiting data from these studies. Over the years they have contributed to important and cutting-edge findings in several areas of research. Participants of today will contribute even further to the understanding of interaction between genes and lifestyle in the future.

In 2007 Lund University Diabetes Centre was part of a publication that was selected as “Breakthrough of the Year” by Science, one of the most prestigious scientific journals. Together with other top international researchers, we managed to map the whole human genome associated with type 2 diabetes. The human genome contains the genetic instructions of our DNA, and for the first time we could show a number of genetic variants contributing to type 2 diabetes.

Compared to just a few decades ago, when we only got rough information from small snapshots, the techniques for the study of genes have developed tremendously – making it possible to see details in no time. What took weeks a couple of years ago can now be performed within days. The study mentioned above represents the first time that several independent research groups came up with the same result regarding the underlying genetics of type 2 diabetes. It was a breakthrough of great importance and has opened up new avenues of diabetes research.

Approximately 60 genes are known today to be associated with diabetes in one way or another. However, although molecular techniques give us a lot of information, we are still far from fully understanding all the data. However, seeing is a first step towards understanding.

**Type 1 diabetes**
Type 1 diabetes is a disease that mostly affects young people and is caused by a lack of insulin production. The reason why insulin-producing cells are lost is unknown, and EXODIAB puts a lot of effort into trying to elucidate the mechanism behind the destruction of these cells. A major focus is the way in which the immune system attacks the insulin-producing cells, causing type 1 diabetes.

Today it is actually possible, in some cases, to predict the development of type 1 diabetes. The challenge is to predict when the disease is going to develop, and how to prevent it. Before the beta cells are broken down by the immune system, autoantibodies appear in the blood. The autoantibodies are like soldiers protecting the body from foreign material and substances, in this case a human enzyme called GAD.

In the TEDDY study researchers follow 8 000 children in four different countries (Sweden, Finland, Germany and the USA) from birth until 15 years of age. The children have shown a higher genetic risk of developing type 1 diabetes. The essence of the TEDDY study is to find out why children with genetic risk develop these autoantibodies and identify the mechanisms in order to interrupt the process. Findings from the
TEDDY study have shown that the autoantibodies, which are directed against the insulin-producing cells, seem to appear when the child is between one and three years of age. We are now studying blood samples and stool samples, collected before the antibodies appear, to find out whether there was an infection that can explain why the autoantibodies developed. The hypothesis is that a virus induces the autoantibodies. If that really is the case, scientists can come up with a vaccine against that virus. By treating antibodies, researchers hope to stop the process that will eventually lead to type 1 diabetes. This is now undergoing clinical trials.

Some people with the most severe form of type 1 diabetes can actually be cured. By having a transplant of insulin-producing beta cells, the patient can recover from the disease and live a normal life without daily injections for a long period of time before the disease returns. This operation is currently only offered in very severe cases, for people who have difficulties managing the disease and whose quality of life is compromised as a result. The reason why treatment is restricted is the lack of beta cells that can be used for transplantation. One way to offer this treatment on a wider scale is by using cells generated from stem cells, and EXODIAB is currently putting a lot of effort into that area of research.

A breakthrough was made a couple of years ago when EXODIAB researchers described a very strong inflammatory reaction that is triggered when beta cells are transplanted. This was previously unknown, and by discovering the reaction we were able to create new means of treating patients at the moment of transplantation, and this has extensively improved the results of the transplants.

There are different types of diabetes
Diabetes is much more heterogeneous than the current subdivision into type 1 and type 2 diabetes would imply. A better classification into subgroups is a prerequisite for individually targeted therapies. Over 10 000 newly diagnosed patients with diabetes have so far contributed to ANDIS (All New Diabetics In Scania) and ANDIU (All New Diabetics In Uppsala) – two important studies supported by EXODIAB, which aim to map the spectrum of the disease and categorise the subgroups of type 1 and type 2 diabetes. Type 2 diabetes makes up 85–90 per cent of all cases, while 10 per cent represent people suffering from type 1 diabetes. Other forms of diabetes are gestational diabetes, LADA and MODY. EXODIAB researchers have found that there is a spectrum of diverse forms of diabetes. In order to design individualised and improved treatment, we have to understand which type of diabetes the patient suffers from.

EXODIAB is making special efforts to identify biological markers, for instance from blood, to be used as indicators for sub-classification of diabetes. Our aim is to strengthen collaboration between academia and industry in order to speed up new innovations.

The insulin-producing beta cell
The beta cells are produced in the pancreas and cling together in islets called the Islets of Langerhans (after their discoverer), or “pancreatic islets”. The pancreas is a very delicate organ consisting of a lot of blood vessels making it impossible to study in human subjects. Thanks to collaboration within a Nordic network, researchers connected to EXODIAB have the opportunity to study islets from deceased donors. Being able to study mechanisms in human tissue instead of animal models has made research more relevant for human situations. Com-
pared to cancer researchers, who have had access to their most important tissue for a long time, this has been a major step forward in diabetes research. As the islets are “the real thing”, the possibility to study the mechanisms in the cells has profoundly changed the conditions for diabetes research.

A lot of research is now focusing on the beta cell and what goes wrong when diabetes develops: why do certain persons become diabetic whereas others remain healthy even though they have a similar lifestyle? One way to answer this is to look for reactions – things that take place in the cell that make the cell deteriorate at a faster rate once we have diabetes. By combining all we know about human genetics and the clinical features of diabetes and then translating that into cellular mechanisms and reactions, we aim to find new drug targets. New drug targets can eventually lead to new drugs, new techniques and new treatments.

One example of a scientific breakthrough is the findings connecting stress and diabetes. Adrenaline is a hormone produced by the adrenal glands during high stress or exciting situations. EXODIAB researchers identified a receptor that binds adrenaline in some people with type 2 diabetes – not in all but in a very significant group. This finding of a new genetic risk variant and the description of the exact underlying mechanism explain, on a molecular level, the connection between stress and diabetes. Carriers of the risk variant have stressed insulin-producing cells, which greatly reduces their ability to secrete insulin. As is already known, substances exist that completely restore the capacity of the insulin-producing cells. Work is currently underway to determine if they can be used as new treatment for diabetes, personalised for those individuals carrying the specific gene. The work opened new avenues to more exact diabetes diagnosis as well as treatments that directly target the disease mechanism, in contrast to the current therapies that are directed towards the symptoms.

Molecular metabolism
Diabetes could also be described as a metabolic disease. Another focus is therefore on the processes in the cells that control metabolism. The cytoplasm and its organelles are very important in the cells that make and release insulin, but it is also important in the cells that respond to insulin. If there is a perturbation in the metabolism, the disease will develop. One way of studying this is to figure out exactly how it works by dissecting those mechanisms in the mitochondria, one type of organelle in the cytoplasm. The mitochondria can be described as “cellular power plants” because they generate most of the cell’s supply of energy. Mitochondria are also involved in signalling, cell growth and cell death.

Scientists have been able to link a variant of a protein that controls metabolism in beta cells to increased risk of developing type 2 diabetes. Ongoing work will potentially resolve why insulin secretion is deficient in type 2 diabetes and may provide targets for treatment of the disease.

Complications
Heart attack and stroke are the primary cause of death in those with diabetes. One great challenge in diabetes research today, and in cardiovascular research in general, is thus to understand why diabetes cause cardiovascular disease. For a long time, scientists were convinced that there was a simple culprit – sugar! They thought sugar would increase the stress on the arterial wall, leading to inflammation, leading to disease… But then results from large-scale clinical studies showed that just lowering glucose does not solve the problem. It doesn’t prevent the risk of heart attack and stroke.

What makes the immune system attack the arterial wall, the main reason for the development of the plaques that eventually
cause heart attack and stroke? One of the most important aims of EXODIAB is to reach a better understanding of why diabetes activates the inflammation and instability of the plaques in the arterial wall, which then cause the acute events. Once that has been achieved comes the really interesting challenge – how to develop a therapy.

We believe that this misguided immune response when the immune cells start to attack something in the arterial wall, believing it to be a foreign body – is a very interesting target for new therapies. We have already developed a prototype vaccine which is generally aimed at cardiovascular disease, but which we think might be particularly effective in diabetes as well. Our long-term goal is therefore to develop a vaccine that will prevent cardiovascular complications and diabetes.

**Can we prevent diabetes?**
Yes and no. So far there is no way to prevent type 1 diabetes. However, type 2 diabetes can be prevented through a change of lifestyle including regular exercise and a healthy diet. Stress management and avoiding obesity are also key components in keeping diabetes at bay. EXODIAB researchers investigate how exercise and diet alter the expression of genes and have found that through chemical modification of our DNA, environmental factors have an impact on the development of diabetes.

**Can new ways to treat diabetes be found?**
Almost 100 years have passed since the discovery of insulin, which has saved millions of lives. Despite this fantastic discovery, a lot more needs to be done. Available treatment strategies, regardless of whether insulin or oral anti-diabetic agents are used, have not been able to change the progressive nature of the disease. Therefore, novel means to treat the disease and prevent these devastating complications are needed. These new therapies should be targeted at the underlying molecular defects. Strategic research funding via EXODIAB is vital for the creation of a successful life science ecosystem, involving academia, the health care sector and life science. EXODIAB has been instrumental in the launch of a new type of grant opportunity from VINNOVA “Strategiskt Innovationsområde – Folksjukdomar – Diabetes”. This will further increase the possibilities of discovering new treatment strategies, taking advantage of the knowledge and research platforms strategically generated by EXODIAB.

**To summarise**
An estimated 347 million people suffer from diabetes worldwide, a disease mostly caused by a combination of genes and lifestyle. EXODIAB is a joint research initiative in the field of diabetes combining internationally competitive diabetes research at Lund and Uppsala universities. In collaboration with industrial partners we develop novel approaches and tools for prevention, individualised treatment and cure of diabetes. The funding of the Strategic Research Area EXODIAB has given diabetes researchers a chance to emphasise long-term strategic planning. Efforts such as creating long-lasting research tools and platforms, strategic staff recruitment and mentorship to younger scientists are examples of strategic actions taken. We have also accelerated innovation aspects of our research with the hope of benefiting diabetes patients and society at large. The funding for EXODIAB has also allowed us to have an impact on key educational matters, especially in the area of bioinformatics. Continued funding for EXODIAB is essential for us to learn more about how to prevent diabetes and discover new treatment strategies. □
Erik Renström, coordinator of EXODIAB, Professor of Experimental Endocrinology, Physician, leader of the Islet Pathophysiology research group, with 9 group members. Erik has also developed the concept of innovation in diabetes as coordinator for the national strategic funding initiative from VINNOVA “Strategiskt Innovationsområde – Folksjukdomar – Diabetes”, launched in 2014.

Leif Groop, professor in endocrinology and director of Lund University Diabetes Centre. Leif is internationally well-renowned for his pioneering work in genetic discoveries in type 2 diabetes. His research focuses on the heterogeneity of diabetes and aims to re-classify the disease in order to develop a more personalized medicine.

Olle Korsgren, professor of transplantation immunology at Uppsala University. Olle had a scientific breakthrough when he described a very strong inflammatory reaction, triggered when beta cells are transplanted. A new treatment has since extensively improved the results of the transplantation. He also investigates stem cell therapy for diabetes.

Åke Lernmark, professor of experimental diabetes research at Lund University. Åke discovered the GAD-enzyme against which autoantibodies are developed before the outbreak of type 1 diabetes. He is the leader of the Swedish part of the TEDDY-study aiming to find out why - and how - diabetes type 1 develops.

About EXODIAB

EXODIAB is a joint collaboration between Lund University and Uppsala University coordinated by Lund University. Our aim is to make Sweden the most successful country in the world within all aspects of diabetes research, contributing to an increased understanding of the underlying mechanisms in order to achieve the goals and pave the way for new strategies and therapies for the prevention and cure of diabetes.

EXODIAB has a broad and multidisciplinary approach. There are approximately 450 people working within EXODIAB, all possessing diverse competence and research specialties. The common denominator is diabetes. Some of the staff specialise in genetics, others in areas such as gene-environment interactions, insulin secretion from the pancreas, cell signalling, metabolism, diet and functional foods, exercise, vascular complications, transplantation, clinical trials or epidemiology.

EXODIAB has developed national platforms to facilitate diabetes research in Sweden (e.g. Human Tissue Lab) and interaction between academia and industry in order to accelerate innovations in the field.

www.exodiab.se
www.diabetesportalen.se
07:

Moving stem cells towards the clinic

ZAAL KOKAIA
JONAS LARSSON
Stem cells self-renew and differentiate into the various cell types of our bodies – creating hopes for ways of restoring function after disease or injury by replacing dead and damaged cells with healthy new cells.

STEMTHERAPY develops stem cell-based approaches for regenerative therapy. It supports translation of stem cell research into therapies and cures – in accordance with the highest ethical, scientific, and medical standards – in order to relieve human suffering from disease and injury. Through this mission, the strategic research area unites basic researchers and clinicians working in the fields of stem cell biology and regenerative medicine respectively. The goal is to identify the clinical needs and bottlenecks in the treatment of ischemic stroke, diabetes and haematological diseases, and to develop new therapeutic options based on use of the potential of stem cell-based approaches. The overall objective is to build a strong base of knowledge about stem cells and disease mechanisms to pave the way for future efforts to devise new therapies.

A new era in science and medicine has emerged as a result of all possibilities offered by human pluripotent stem cells, including embryonic stem cells (ESCs) and induced pluripotent stem (iPS) cells, and by tissue-specific stem cells. These cells can self-renew indefinitely and differentiate into the various cell types in our bodies, which have created hopes for new ways of restoring function after disease or injury by replacing dead/damaged cells with healthy new cells. Hence, it seems feasible to use these stem cells to treat or even cure severe diseases, e.g. diabetes, neurodegenerative diseases, blood disorders, spinal cord injury, arthritis, burns and retinal disease. Eventually, stem cells may even be used to reconstruct whole tissues/organs under artificial conditions or in the living organism. Finally, stem cells offer new opportunities to address the underlying cellular and molecular mechanisms of diseases, such as diabetes,
neurological diseases, and cancer, as well as providing new ways of identifying and validating drug targets.

STEMTHERAPY builds on the success of the previously Swedish Strategic Foundation for Research (SSF)-funded “Lund Centre for Stem Cell Biology and Cell Therapy” (currently Lund Stem Cell Centre) and in a more goal-directed way aims towards clinical implementation of stem cell-based therapies.

The overall objectives of STEMTHERAPY are to build strong knowledge of stem cells and disease mechanisms and to advance the development of stem cell-based therapies for diabetes, stroke and haematological diseases. STEMTHERAPY is reaching these aims by combining very strong competence in basic stem cell biology and biomaterial science with expertise in clinical cell therapy. Interdisciplinary research teams within STEMTHERAPY are addressing research questions common to all clinical translational programmes, which make it highly likely that progress in one disease area will catalyse progress in the other disease areas.

Significant progress in STEMTHERAPY is achieved by using a strategy where interdisciplinary research teams address research questions common to the clinical translational programmes. In addition to generating the right type of stem cells, the major obstacles to bringing stem cell therapies to the clinic are identified as immunological issues, tumourigenicity, scale-up production of cells, cell survival after implantation, and regulatory issues. STEMTHERAPY aims to address all these issues and develop strategies to overcome them with efficient and targeted actions.

STEMTHERAPY unites scientists and clinicians who have been identified based on relevant expertise and expected contributions towards the goals of the programme. Particular emphasis has been put into defining teams and networks that will combine preclinical and clinical expertise to promote the translational aspects of the programme. STEMTHERAPY constitutes an outstanding group of scientists representing expertise in basic, preclinical, and clinical stem cell research in three specific disease areas – diabetes, and neural and haematological disorders, including research on haematological and brain malignancies.

The advantages to the organisation of STEMTHERAPY are several-fold: (1) unique expertise in stem cell research is gathered; (2) sharing ideas and solving scientific problems are strongly promoted by the day-to-day interaction; (3) advanced and modern technology platforms are shared, e.g., cell sorting, ESC/iPS technology, viral production and imaging. This is in striking contrast to earlier efforts, which dealt with differentiation to specific cell types without translational applications. STEMTHERAPY is taking stem cell research to a higher level by translating basic stem cell research in order to solve major health problems. It should be pointed out that STEMTHERAPY, if it is successful in coming years, will become unique in Sweden and Europe, and at the international forefront of stem cell research.

STEMTHERAPY helps to power up the knowledge triangle – research, education and innovation – which are the key drivers of a knowledge-based society. In addition to generating scientific breakthroughs, it promotes creation of educational arenas. The topics offered by STEMTHERAPY are at the scientific frontier of the themes represented by the respective initiatives. Thus it plays a decisive role in implementing the goal to provide research-based education of the highest quality. Furthermore, it contributes significantly to the advancement of research infrastructure, and by making this infrastructure accessible to external user groups, the researchers contribute to the propagation of knowledge, skills and research opportunities. STEMTHERAPY’s initiatives have come a long way with
implementing a very promising developmental dynamic. This has been achieved by recruiting young researchers who contribute different expertise and different angles on the research challenge, and by empowering them to develop their own line of thinking. Yet another bonus effect is that the funding received by STEMTHERAPY has made possible several strategic recruitments. The research environments created by virtue of the strategic initiatives are a very valuable resource for the future. A greater variety of attractive research environments are available both at a university level, and at national level, providing options for talented researchers, whether just starting out or already far advanced in their careers.

Pre-defined clinical road maps/translational goals are developed for different diseases to take stem cell research to new applications in treatment and diagnostics. These road maps illustrate the common as well as disease-specific basic, preclinical, and clinical research questions that will have to be addressed.

Importantly, although STEMTHERAPY will make efforts to reach the clinic in all clinical translational programmes, this is not expected to be achievable at the same time for all programmes. Whereas the gene therapy efforts within the haematology programme will require more time to address fundamental basic research questions, cell therapy in diabetes using an encapsulation strategy for beta cells is closer to clinical reality. STEMTHERAPY ensures that resources are allocated to both basic and applied clinical research as long as it is oriented towards the clinical end goals. However, since STEMTHERAPY prioritises achieving proof-of-principle for our overall stem cell-based clinical objectives, resources are concentrated to projects entering clinical trials.

The major impact of STEMTHERAPY’s research on society will be the development of novel stem cell-based therapies for diseases which currently lack efficient treatment. The involvement of clinicians as principal investigators in STEMTHERAPY ensures the translational orientation of the research, and that the development of therapeutic strategies is based on the needs of the patients and aims for the improvement of their quality of life.

Moreover, STEMTHERAPY supports large clinical projects to implement basic findings in stem cell and gene therapy research into clinical practice, and to obtain proof-of-concept for the feasibility of further clinical trials and the development of new therapies.

Other major areas of impact of STEMTHERAPY on society are preventing unrealistic hope and expectations from stem cell-based therapies, familiarising society with scientific data on stem cells, and advising patients and their relatives not to accept unproven stem cell therapy offered by obscure clinics, i.e. counteracting stem cell tourism. Stem cells obtained from human fertilised eggs (embryonic stem cells) or foetuses are ethically controversial and the development of new technologies overcoming these issues will be of major importance to society. Therefore, STEMTHERAPY has established a hi-tech platform for the generation of induced pluripotent stem (iPS) cells from post-mitotic (e.g., human skin) tissue, which in the future may eliminate the need for human embryonic stem cells.

A significant proportion of patients suffering from haematological malignancies who would benefit from a haematopoietic stem cell transplant cannot receive this life-saving treatment due to a lack of suitable donor cells. Successful expansion of stem cells from umbilical cord blood would implement this as an accessible and sufficient source of stem cells for many of these patients. Given recent findings by STEMTHERAPY of novel stem cell regulators and discovery of molecules that en-
hance ex vivo expansion of human haematopoietic stem cells in preclinical models, it is now a major goal for STEMTherapy to bring these stem cell expansion strategies to clinical implementation for treatment of haematological malignancies.

STEMTherapy has established a strong strategic administration to provide support in important areas such as: recruitment efforts, grant management, support and development of joint technology platforms, organisation of internal and international seminars, meetings, workshops, an international guest professor programme, a postdoc exchange programme with internationally leading stem cell institutions, establishment and management of a research school, a mentoring programme for young group leaders, and regular interaction on translational research issues. STEMTherapy has also initiated and supported interdisciplinary collaborative projects to increase the added value of the programme. Collaborations between researchers from different programmes, between basic and clinical researchers, and between local and international groups have been established and have already resulted in strong joint publications.

STEMTherapy puts significant emphasis on and will provide resources to develop a strong programme to facilitate the recruitment of promising young researchers and supports new and existing junior group leaders.

The recruitment policy is oriented toward attracting promising young scientists with strong track records in the areas that need to be strengthened. Such efforts have led to the recruitment of several prominent young researchers who have established new groups within the Strategic Research Area. STEMTherapy will support young scientists and group leaders to enable a smooth transition from junior to senior scientific positions. Financial support is provided to bridge the gap between the postdoc and young group leader positions.

As mentioned above, STEMTherapy is dedicating substantial efforts and resources to education and training. This goal is achieved through close interaction and orchestrated efforts with the “Research School in Stem Cell Biology (RSSCB). This interaction is instrumental to support the long-term development of Swedish research within the field of stem cells and regenerative medicine in academia, health care and industry by providing excellent training programmes. The RSSCB is headed by a steering group composed principally of scientists in the area of stem cell biology and regenerative medicine at Lund University. The school engages approximately 25 PhD students, and 20 postdoctoral fellows. The school increases the interchange between different environments and areas of stem cell biology through collaboration with the faculties of Science and Engineering in Lund, other strong research environments at the Faculty of Medicine at Lund University, as well as through interaction with the Research School in Developmental Biology for Regenerative Medicine (DBRM) at KI in Stockholm. Among the visions for the RSSCB is to become a national resource for training and education in the area of basic and translational stem cell biology and regenerative medicine. A long-term goal is to ensure sustained high-quality graduate education within the field by generating funding for scholarships/salaries for PhD students in the school and for the running costs of their research projects. The school provides opportunities for outstanding students with relevant backgrounds to apply and compete for positions as a PhD student within the RSSCB. The school arranges various hands-on courses in advanced methods in modern stem cell biology as well as theoretical courses, all designed to provide PhD students as well as postdoctoral fellows with theoretical and practical up-to-date knowledge relating to basic stem cell biology as well as current and future
potential for clinical application of stem cells as a therapeutic modality. The school also has a strong curriculum for training in a variety of complementary skills, such as scientific communication, grantsmanship and leadership, and has developed a specific programme for the support of career planning as well as personal and professional development for students and researchers within the environment. The RSSCB is hence providing a foundation for advancing knowledge and skills and for strengthening the future career prospects of the individual students and young scientists, both in academia and industry. The school is also an integrated partner in the efforts of STEM- THERAPY to reinforce clinical links and assure a strong future programme for research and training in translational stem cell biology. It already offers an extensive range of courses and activities pertinent to basic and translational research within the field of stem cells and regenerative medicine. A principal task for the research school is to offer solid training of medical students in key concepts and cutting-edge technologies used in the field of stem cell biology and regenerative medicine. In addition to the existing programmes, the school intends to arrange specific training within the medical degree programme.

In conclusion, the outstanding scientific qualifications of STEM THERAPY and its highly relevant objectives for society and industry make this SRA a unique and valuable enterprise which serves the important objectives and needs of Swedish society. STEM THERAPY has already proved its excellence and created solid and fertile ground for further development of research, education and innovation.

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About STEMTherapy

STEMTherapy is a joint collaboration between Lund University and Uppsala University coordinated by Lund University. Our goal is to demonstrate that stem cell-based cell replacement therapy is effective and safe, and to develop therapeutic candidates for stroke, diabetes and haematological diseases. We aim to build a strong base of knowledge about stem cells and disease mechanisms to pave the way for future efforts to devise new clinically effective treatments.

STEMTherapy currently unites more than 25 groups engaged in basic and clinical research. We promote interdisciplinary interaction and support translational research in order to bring stem cell-based therapy closer to clinical application.

STEMTherapy has developed strong technical platforms to facilitate stem cell research (e.g. cell sorting, vector production, imaging, embryonic and induced pluripotent stem cells, genetic screen) and has recruited outstanding young scientists to establish new research lines and strengthen the existing research environment.

www.med.lu.se/stemtherapy
Can your diet affect which bacteria thrive in your gut?
And can the 1-2 kg of bacteria you carry inside affect your metabolism and immune defense? The answer, it seems, is yes.

Epidemiology – the understanding of disease distribution and mechanisms – make crucial contributions to down-stream research into cures and preventions.

EpiHealth, with more than 200 researchers, includes studies of gene-environment interactions, disease causation and the build-up of extensive biobanks.

Swedish ID numbers can act as common identifiers – linking different types of data-sets. This gives Sweden and EpiHealth an extra edge – producing results of great importance to public health.

**Epidemiology** in its classical definition centres on the statistical and scientific understanding of disease distribution. This includes, for example, infectious diseases (epidemics) – and their geographical, temporal and population-specific characteristics. To many, it is often seen as just a collection of statistics on different disorders and medical problems, as data useful for national as well as local and regional authorities for planning and implementation of health care and public health measures. However, this picture is now over-simplified due to the profound changes in the field of epidemiology in recent years. It is no longer merely a help discipline supporting other sciences, but a research area in its own right and with its own developed methodologies. Conventional epidemiology is used to map risk factors for disease – such as the association between smoking habits and lung cancer, or the association between dietary habits (fat quality) and chronic disease conditions such as coronary heart disease (CHD). In current times, the existence of large population-based screening cohorts with rich data sets, and associated biobank collections of blood samples and other tissues, has opened up new avenues for better understanding of the causes and origins of disease – and how these are influenced by interactions between genes and the environment. If true causal biological mechanisms can be defined and characterised at early stages of disease in the population, then the opportunity arises to find new drug targets involved in these specific mechanisms. This is a way to support the development of new treatment alternatives that can be further tested, first in animal studies and later in human studies, for efficacy and tolerability. Thus, the field of epidemiology provides crucial new avenues of research leading to improved public health.

Moreover, modern epidemiology can also contribute to a better understanding of prognosis in already diseased patients.
If two individuals or two groups of patients with the same diagnosis receive exactly the same medical intervention (drugs, surgery, radiotherapy) there may still be different outcomes during follow-up. Such differences occur between these individuals/groups due to differences in their genetic make-up (genotype) or in other bodily mechanisms in the constitution (phenotype) of the individual patients. A better understanding of the clinical course over time (prognosis) could help the medical profession to better tailor the right therapy to the right patient. Two examples of this are the dosage of potentially toxic drugs for cancer treatment and the dosage of drugs that may cause bleeding if overused for prophylaxis of venous or arterial thrombosis, as this can be influenced by individual differences in genetic and enzymatic factors regulating the metabolism or reaction to the drug.

EpiHealth for excellence in epidemiological research
When the new Strategic Research Area (SRA) “Epidemiology for Health” (EpiHealth) started its activities in 2010, following its appointment by the Swedish Research Council on behalf of the Swedish Government, it was built on a close collaboration between leading researchers at both Lund and Uppsala universities. Coordination of the project was given to Lund University.

The foundation was set as three “pillars” of research – all embedded within the larger EpiHealth infrastructure. The first pillar was “Basic epidemiology” dealing with molecular epidemiology (genes, “omics”) and gene-environmental interactions (including epigenetics) for a deeper understanding of disease causation (etiology) and with the aim of finding new causal mechanisms of common diseases. One aspect of this is called “causal inference” methodology (based on the “Mendelian randomisation” approach to data), much in progress over the recent 5-10 years representing a new era in basic epidemiology. This pillar uncovers data that is important for the identification of new biological mechanisms and potential therapeutic targets for intervention (vaccines or drugs). The second pillar was “Infrastructures for epidemiology”. Crucially, this pillar consists of the rich cohort data sets, biobank materials and laboratory facilities supporting the epidemiological research. However, it also encompasses the human resources to build excellence (data managers, specialists in biostatistics and bioinformatics, teachers) as well as advanced information technology infrastructures, a prerequisite of modern epidemiology. This infrastructure is the basis for continued excellence in epidemiological research and can serve several research groups, not only a few. Finally the third pillar is “Clinical epidemiology”. It involves data from patients and administrative registers on health care utilisation and outcomes (taken from medical records) to make it possible to understand differences in prognosis following medical treatment. Associated to this pillar is the discipline of health economics, with its increasing importance for cost-effectiveness analysis of interventions. Within it lie important efforts like the organisation of surveillance of infection exposure in the population, for example measures of the prevalence of human papilloma virus (HPV positive serology) in pregnant women – as this virus is a risk factor for some future cancer forms.

The EpiHealth cohort – contributing to a National Swedish Biobank Consortium
EpiHealth has developed a wide range of activities over the past five-year period, including the planning and launch of its own new population-based EpiHealth cohort in Uppsala and Malmö. At present this data set contains information about 18 000 screened individuals (age range 45–75) for clinical examination and biobank sampling. In addition to a physical ex-
amination, the information in the cohort includes assessment of cognitive function, a lung function test (spirometry) and a simplified electrocardiogram (ECG). This ECG is based on recordings from thumb electrodes, not from the chest, and the intention is to trace atrial fibrillation, a cardiac arrhythmia increasing the risk of stroke. It will be possible for us to collaborate with another large-scale population-based screening project named LifeGene (directed from Karolinska Institutet, Stockholm) to jointly form a rich, modern, national cohort with associated rich biobank. A new technical platform for genomics and other “omics” (Science for Life, SciLife) can be used for advanced studies of these data sets. This is a bold Swedish attempt to match more advanced international cohorts, such as the UK Biobank with more than half a million participants. Our Swedish cohorts have a crucial advantage in that it is possible to follow each individual – based on informed consent – in national registers of great information richness and accuracy. This is not possible to the same extent in countries lacking the Swedish 10-digit personal ID number – the common identifier that makes register linkage possible. Sweden thus has a competitive edge if data from population-based cohorts, biobanks, health registers and use of technical platforms can all be combined to elucidate research problems in medicine. In this we have an opportunity to prove that bigger is not always better. It will be a matter of quality and follow-up, where less extensive materials/cohorts (with respect to numbers of participants) can still have a clear advantage. In Germany, for example, federal laws prohibit the use of national registers for follow-up studies to analyse the risk of future clinical events in subjects participating in screening studies. Therefore, in Germany the full implementation of cross-sectional data sets is restricted and will never become equally useful for assessment of future risk and its consequences – even if they are based on large numbers and the most impressive technical investigations available. To put it simple, data from a smaller Swedish national cohort/biobank consortium will be more informative than data from very impressing large international materials where follow-up is difficult. In this David beats Goliath in science – based on quality, technical performance and follow-up – and Sweden can contribute greatly to epidemiological research!

Reproduction and nutrition – two important new research areas

Two new research focus areas have been developed by EpiHealth, bringing together experts and cohort materials from both Lund and Uppsala Universities. The first one is “Reproductive and Early Life Epidemiology” (RELE) with its focus on early life influences on adult disease. It has been shown that foetal growth patterns (before birth), in association with postnatal growth patterns during the first years of life, are shaped by genetic as well as nutritional effects and other environmental influences. These growth patterns can predict risk of cardiovascular disease, type 2 diabetes, as well as some other medical conditions in adult life. This is exemplified by the increased risk of cardiometabolic disease in adult life of growth-retarded babies (small-for-gestational age) who undergo a period of too rapid postnatal catch-up growth. This is known as a “mis-match” growth pattern of bodily development that can “overstretch” biological systems and resources leading to vulnerability and organ dysfunction, for example less reactive insulin-producing beta-cells in the pancreas – increasing the risk of type 2 diabetes. This leads to new perspectives in epidemiology when a so called life course approach can be applied as we try to understand the roots of disease appearing in later mid-life or in...
the elderly, for example cognitive decline or cardiometabolic disorders. Furthermore, this can also contribute to preventive efforts when early life factors are improved for the health benefit of the foetus or the young child, i.e. by implementing preventive maternal and child health care.

The other new research area is “Nutritional-Genetic Epidemiology” (NGE) where we try to understand the interplay between dietary intake and genetic factors in the individual – and how it plays a part in the causal chain in biology leading to chronic disease in adult life (for example cardiometabolic disorders or cancer). It is well-known that a correct assessment of dietary habits in an individual is very difficult to accomplish – and we apply a variety of methods to overcome this, for example four-day dietary registration using online forms together with dietary questionnaires (with added photos of meal size and components to select while reporting) – as well as diet interviews by skilled nutritionists. So far several studies have been published on gene-environmental interactions (diet, physical exercise) in the causative pathways influencing obesity and type 2 diabetes, but still more work is needed for prediction of cardiovascular disease and many forms of cancer.

A new and very promising arena of research is the understanding of the complex role played by gut microbiota (reflecting gastrointestinal bacteria, which occur in our gut and amount to 1–2 kg in every adult). The composition of microbiota in an individual can be mapped by advanced genetic screening methods (and hence there is no need to use the old-fashioned bacterial cultures any longer for this purpose, but still in clinical medicine). It has been shown that healthy individuals will have a more diverse composition of gut microbiota than individuals with obesity or overt type 2 diabetes, who will show less diversity. Preliminary analyses from one of our new population-based cohorts, the Malmö Offspring Study (MOS), has shown promising results with associations between dietary intake, medical history and microbiota composition. This brings together many important components of modern molecular epidemiology together with dietary assessment and physical examinations for a new and better understanding of disease mechanisms. For example, it has been shown that there are important correlations between the gut microbiota and both metabolic and immune function of the host. Some microbiota patterns are associated with unhealthy changes in these bodily functions. It will thus be interesting in the future to see if the microbiota pattern of an individual can be influenced by lifestyle-based methods, including dietary changes, or eventually by so-called functional food products. In these aspects, researchers within EpiHealth already play a leading national role, with more fascinating results soon to be published. In short, can we change our diet, thereby causing a chain reaction affecting the type of bacteria we host in our gut, which in turn affect our metabolism and immune function? This has to be proven by use of specific interventions. One way is to use bacteria-specific yoghurts from areas with long-living individuals, e.g. the mountain populations of Bulgaria or Caucasus. We have initiated such contacts.

The wide field of epidemiological research
Besides these new focus areas described, considerable activities have also been promoted within health economics, social epidemiology, occupational and environmental epidemiology, as well as clinical epidemiology related to health insurance data (in collaboration with EpiCentrum, an entity within the county council structure of Region Skåne in Lund). We are eager to further develop such contacts, first of all with the health care sector in general, represented primarily by Region
Skåne, but also with other Strategic Research Areas (SRAs) and faculties of Lund University. For example, we have established very close links with the SRA EXODIAB, as the study of disease causation of type 2 diabetes can benefit from rich cohorts and biobanks with prospective follow-up (such as the Malmö Preventive Project and Malmö Diet and Cancer cohorts, totalling more than 50 000 unique individuals with more than 8 000 cases of incident diabetes). Furthermore, we collaborate with the SRA MultiPark (specialising in Parkinson’s disease and neurodegenerative disorders) in running a graduate school dedicated to the study of ageing in health and disease (SWEAH). This is also the aim of another important local population-based cohort, “Gott Åldrande i Skåne” (GÅS) with rich prospective data on health and ageing in 4 000 elderly people – many of whom receive home visits for health checks by research nurses. Furthermore, we have close ties with other research entities at Lund University, for example the SRA BioCARE, for research on biomarkers of cancer – where SRA EpiHealth is striving towards similar aims. This also applies to research groups at the School of Economics and Management (for health economics and history of economics to see impacts on populations) and the Faculty of Engineering (for occupational and environmental epidemiology).

**Epidemiological research for the future**

What about the future for EpiHealth? It looks very promising, as we have a number of young and talented researchers within our extended EpiHealth network, now totalling more than 220 individuals characterised by gender balance (50% women) and growing diversity according to ethnical and cultural background. The total number of publications from EpiHealth was over 800 in 2013, giving us a leading position (at least in numbers) among all 42 existing SRAs in Sweden.

Molecular epidemiology is on the rise and builds on the support for life sciences and biobanks described in an official document for research strategies from the Swedish government in 2012 (“Propositionen för forskning och innovation”, Prop 2012/13:30). We can deliver not only traditional epidemiology – but more and more modern and very sophisticated epidemiological data reflecting disease causation and prognosis. If the previous (old) epidemiology could be characterised as mostly describing disease frequencies and distributions in the population, epidemiology of today focus on the causes of disease (causal inference) and the quest for new treatment targets that can be substantiated into new industrial products (drugs, functional food, etc.). Research on prognostic factors in patients with established disease undergoing treatment is also part of modern epidemiology. The epidemiological research of tomorrow will further explore rich cohorts, biobanks and registers. It will also link this with data from sophisticated technical imaging of bodily functions (special investigations such as neuroimaging of the brain or functional heart studies to describe the beating heart), to better understand normal physiology during the transition to pathophysiology of disease. The disease entities themselves will also change from diagnoses based on symptoms, as was praxis in the past, to new and more correct diagnostic classifications based on the understanding of molecular mechanisms and pathophysiological changes.

**Why are some risk individuals protected? Understanding epidemiological anomalies**

An emerging field is the search for anomalies in epidemiology, for example the reasons why some individuals seem to be protected from adverse outcomes – in spite of a high risk or disease
burden. This is currently being investigated in a study ("PRO-
tective genes in diabetic complications and LONGevity" the
PROLONG study) where patients with longstanding type 1
diabetes and daily insulin injections for more than 30 or even
50 years, but without major diabetes complications, are investi-
gated for protective factors (genes, treatment, personality, etc.).
If such protective factors can be better defined, by use of all
branches of modern epidemiology, there exists an opportunity
to find new treatment.

Another example of anomaly epidemiology is the recent study
("Impact of Migration and Ethnicity on Diabetes in Malmö";
the MEDIM study) where differences have been detected be-
tween adult immigrants from Iraq living in Malmö, compared
to matched Swedish-born subjects. Iraqi immigrants have lower-
than-expected mean brachial blood pressure levels for the same
degree of obesity and metabolic syndrome, a risk factor cluster
linked to abdominal obesity and underlying insulin resistance.
Similar findings have previously been reported from studies of
Pima Indians in the US compared to matched controls of indi-
viduals of Caucasian origin – where less responsive sympathetic
nervous system (SNS) receptors were found. This system is es-
sential for survival in cold climates (since it regulates thermoge-
nesis) whereas other systems regulating water and electrolytes are
more important for survival in hot climates. If such variations
in protective mechanisms between human populations could be
better understood, new drug targets for preventive therapy could
eventually emerge and be of great importance.

What has EpiHealth achieved –
and how does it impact you?
What about the scientific achievements reached by EpiHealth
over the five years since it started? A number of excellent pub-
lications have been recorded (in Nature, Nature Genetics, Lan-
cet, New England Journal of Medicine, Diabetes, Diabetologia,
American Journal of Epidemiology, etc.), many of them de-
scribing findings based on molecular epidemiology in cohort
materials. Another area of research is register-based analyses,
for example based on the Medical Birth Register of Sweden –
showing the impact on health for newborns of being carried
overtime and delivered post-term – findings that have changed
national and regional guidelines for timing of induced labour.
Still another field is the mapping of environmental health haz-
ards by use of geographical indicators in relation to emissions
of health-hazardous chemical compounds. This has contrib-
uted to local planning by county administrations as well as to
improved legislation on safe levels for environmental exposure.
In social epidemiology, researchers have mapped the distribu-
tion of social risk factors of poor health and the impact of resi-
dence area, adjusted for individual socioeconomic risk factors
and adverse lifestyle (by use of so-called multi-level analysis).
Such findings can contribute to social and community plan-
ing, for example in the important document of the Malmö
Commission in 2012 to improve health and social capital in
the city of Malmö – supporting integration and healthy living
conditions as well as schooling for children, especially those
from deprived areas or disadvantaged groups. This has been
supported by epidemiological research carried out by social ep-
idemiologists from Lund University.

At Uppsala University, excellent research has been carried
out and published within EpiHealth, for example related to
local population-based cohorts (ULSAM and PIVUS) but also
from the Uppsala Family Study and cohorts exploring changes
in bone metabolism and risk of fragility fractures. The health
care patient registers in Uppsala are of international importance,
for example the SWEDHEART register of acute coronary patients and outcomes (www.ucr.uu.se/swedeheart/ ). Of considerable importance to EpiHealth in Uppsala is the closeness to the planned and existent infrastructures at SciLife and other advanced technical platforms and biobanks in the Uppsala region.

Finally, the third-stream activities of Lund University should not be forgotten. Any university has an obligation to engage in outreach towards wider society – to disseminate information and help implement important research findings – as well as to receive information regarding how research can meet societal needs. EpiHealth has developed an informative website (www.med.lu.se/english/epihealth ) as well as extensive contact with journalists and the media (for example involving the production of video clips published on www.youtube.com). A number of important meetings, seminars and symposia have been arranged, covering various aspects of epidemiology. One example of this was a Berzelius symposium (No 89) on “Life Cycles” in collaboration with the Swedish Society of Medicine and the local network “Centre of Excellence for Reproduction and Perinatal Science” (CERPS), held in Malmö in April 2014. The symposium addressed reproduction, the changing role of families, infertility issues and early life programming (www.sls.se/Utbildning/Berzeliusymposier/Life-Cycles/). In addition, a regional EU project for cardiovascular epidemiology linked Danish and Swedish researchers in the EU-Interreg IV project from 2011 to 2013 (www.skarf.eu ).

Summary
In summary, EpiHealth has developed into a vibrant and very active research network for all forms of epidemiological research and developments of applied methods, and we have greatly increased the value of our technical platforms (biobanks, IT, registers) over the first five years of the SRA’s existence. We are proud of our high ambition – as stated already in our first application and strategic plan – to support “healthy ageing for all”. This aim is fully in line with current research policies within the EU, but also adds a more Swedish touch for social equity – “for all” – in health matters. We are confident that this ambition can flourish over the coming five-year period as well, when our rich data sets, registers and biobanks can be even further developed and explored. In the end, we are not only focusing on academic research advancements, but also on contributing to better health for the Swedish population. In fact, in a global perspective we face an ethical responsibility to carry out high-class epidemiological research based on follow-up studies by use of personal ID numbers – as this strategy is in many ways uniquely possible in the Scandinavian countries. What epidemiological research cannot illuminate – regarding patterns of public health challenges and disease mechanisms that influence clinical prognosis – will remain in darkness. Our scientific ambition is thus scientific illumination, quoting the famous Swedish novelist and dramatist August Strindberg: “Ljus öfver landet, det är det vi vilja” (in translation: “Enlighten the nation – that is our ambition”). In this ambition lies our strong commitment to continue to meet the expectations invested in us by the Swedish government and tax-payers – to promote excellence in science and thereby increase healthy living conditions.

EpiHealth is here to stay – and we are proud to make our contribution in collaboration with our partners at other Swedish universities and on the international arena. Without the support of all citizens who volunteer for population-based screening studies and biobank collections this would never have happened. Therefore science and society owe every single participant a great debt. □
Peter M Nilsson, MD, PhD, is the current director of EpiHealth and also the appointed head of the BBMRI.se hub (node) at Lund University to promote collaboration on issues of biobanking. He is a Professor of Clinical Cardiovascular Research and leads a research group with a focus on vascular ageing, cardiovascular risk factors, type 2 diabetes and pathophysiological mechanisms. Currently he is the principal investigator of the Malmö Offspring Study (MOS) supported by the Swedish Research Council. Over a five-year period he has shared responsibility for EpiHealth with vice-director Marju Orho-Melander, Professor of Genetic Epidemiology, and an internationally recognised expert on gene-environmental interactions leading to obesity and cardiometabolic disease. She is currently in charge of the diet-gene-microbiota research within MOS.

About EpiHealth

EpiHealth is a collaboration between Lund University and Uppsala University. We pursue advanced epidemiological research in order to understand disease mechanisms and the clinical course in patients with already established disease. Among our focus areas are: “Basic epidemiology”, where we apply methods in molecular epidemiology (gene-environment) to analyse causation of disease; “Infrastructures” to build biobanks and IT, and to recruit experts in bioinformatics/biostatistics; and finally “Clinical epidemiology” where data from patients is analysed. To achieve our goals we use large-scale population-based screening studies with biobanks for later follow-up in national health registers. Two focus areas are reproductive epidemiology (research dedicated to early life origins of adult disease) and nutritional-genetic epidemiology, where associations are studied between dietary intake, genetic mechanisms (also in gut bacteria, the microbiome) and disease. The SRA EpiHealth network includes over 200 members (50% women) and is proud of its high scientific production with many papers in high-impact journals.

www.med.lu.se/epidemiology_for_health_epihealth
09:

Biomarkers in cancer medicine

SVEN PÅHLMAN
GÖRAN STENMAN
THOAS FIORETOS
More than one in three people living in Sweden will receive a cancer diagnosis during their lifetime. With an increasingly ageing population the cancer incidence is rising, leading not only to human suffering but also to steadily increasing health care costs. BioCARE is a translational research program based on modern technology platforms, extensive biobanks and close collaborations between two universities and two university hospitals. We strive for more effective diagnostics and treatments of untreatable cancers by identifying cancer biomarkers – molecules and genes with properties characteristic for tumour cells.

THE DISEASE. Today more than one in three people living in Sweden receive a cancer diagnosis during their lifetime. Each year approximately 58 000 new cases of cancer are diagnosed in Sweden. With an increasingly ageing population, the cancer incidence is rising, and two-thirds of those who receive a cancer diagnosis are 65 years or over. At the same time, improvements in cancer diagnostics and more effective treatment alternatives have led to improved overall survival of patients diagnosed with cancer. Today approximately 65 per cent of all cancer patients will experience a cure, although the prognosis varies significantly between different cancer types. Importantly, cancer not only affects the patients. Relatives and close friends become secondary victims, making cancer a disease with a strong impact on modern society as a whole.

Most cancers are caused by unknown mechanisms and are unlikely to be preventable by change of lifestyle factors. A few exceptions exist, such as the connection between cigarette smoking and lung cancer and the association between human papilloma virus infection and cancer of the uterine cervix and head and neck. In about 10% of all cancer cases, the patient carries an inherited mutation or another genetic aberration that makes the carrier pre-disposed to a specific form of cancer.

CANCER AND SOCIETY. In a report from 2008 the estimated future cost of health care, with a steadily ageing population, will increase by 270% over the next three decades. In 2008, 17% of the population was 65 or over, but in 2040 this group will constitute 24% of the population. The cost of health care would then constitute 36% of total tax revenue, compared to 20% today. The incidence of cancer increases with age, and clinical management of cancer is thus a major clinical and eco-
onomic challenge in the 21st century. Although therapeutic improvements have been achieved, the cost of cancer treatment has increased dramatically over recent years, partly due to the use of novel biological drugs.

**THE CHALLENGE.** Cancer is a multigenic and multicellular disease that can arise from virtually all cell types and organs. At cellular level the disease affects all aspects of cellular life, i.e. survival, cell division, differentiation and cell migration. At the systemic level cancer co-opts and mimics developmental programmes such as angiogenesis, lymphangiogenesis, stromal organisation, and organ formation. Multiple genes and cellular pathways are affected and there is a considerable genetic and epigenetic variability even within a specific subtype of tumour. These facts, together with the tumour stem cell concept, provide explanations for the tremendous heterogeneity observed in most malignancies, as well as the shortcomings in establishing efficient treatment protocols for aggressive cancers. In the clinical setting, the complexity of cancer behaviour is not only determined by tumour cells properties, but aggressiveness is also determined by the interplay between genetically instable and altered tumour cells and the immune system, the blood vessels and connective tissue, which most profoundly determines tumour behaviour. Thus, future refined treatment strategies have to take into account that i) tumour cells are different within a given tumour because they have gained different numbers and types of genetic alterations, ii) the cell mixture of transformed tumour cells and normal, non-transformed cells (blood vessels, immune cells, stromal cells) differs between tumours, and iii) these cell mixtures change the behaviour of cancer cells in a context-dependent fashion. All these diversities within and among tumours of a given type lead to cellular diversity and escape from current treatment protocols. In this context, biomarkers (any marker such as gene expression profile, biomolecule or pattern of molecules that distinguishes subgroups of cancers within a given type) are indeed mandatory tools to diagnose and stage tumours in order to predict the outcome of different treatment regimens.

**OUR VISION** five years ago was to create a programme based on pre-existing, well-equipped modern technology platforms, extensive biobanks, close multi-disciplinary collaborations between basic and clinical experts from two universities and two large hospitals with the aim of identifying and characterising cancer biomarkers in common cancers. We anticipated that this programme would have a major impact on the way cancers are diagnosed, treated and managed, which in turn would lead to more efficient treatment, less suffering for patients, and in the long run a reduction in cancer deaths.

**Implementation of the programme**
BioCARE is led by a board of researchers and student representatives from Lund University (LU) and the University of Gothenburg (UGOT), with the coordinators, Sven Påhlman (LU), Göran Stenman (UGOT) and Thoas Fioretos (LU), responsible for the executive tasks. At the onset of BioCARE, cancer research at both universities was fragmented and an early key issue for BioCARE was to create critical masses of cancer researchers by forming new physical cancer centres and by recruiting top scientists at different career levels. Another aim was to create a forum for scientists, postdocs and PhD students from Lund and Gothenburg to build networks.
To meet this need we started the BioCARE Research School, which has organised one-day advanced seminars on different cancer topics and two-day retreats for principal investigators, postdocs, and PhD students to present results and share ideas. BioCARE has also supported biomarker-oriented translational cancer research projects and equipment. In addition, by inviting representatives of small and large pharmaceutical companies, BioCARE has created a forum for interactions between academia and industry. Together with the two other national strategic research areas in cancer, StratCan (Karolinska Institutet) and U-Can (Uppsala and Umeå Universities) BioCARE has actively worked towards building a Swedish cancer network and the first joint national cancer meeting was organised by BioCARE in Malmö in 2012.

**New cancer centres at Lund University and the University of Gothenburg**

BioCARE has enabled us to strengthen and develop our research infrastructures by supporting existing and new technical/omics platforms, recruitment of top scientists, and the creation of a research school and cancer centres at both universities.

The *Lund University Cancer Center at Medicon Village* and the *Sahlgrenska Cancer Center* have brought together a critical mass of pre-clinical and clinical scientists with different backgrounds and competences that were previously geographically spread out. Functioning as interdisciplinary hubs, these centres and their affiliated members have generated new projects and potentially groundbreaking data. The milieu created at these centres has proved to be very attractive to young cancer researchers who after an international postdoc with support from the Swedish Research Council, the Swedish Cancer Society, and the Swedish Childhood Cancer Foundation decided to establish their projects or become affiliated with these two centres. Thus, the cancer centres will ensure the continued success of our internationally competitive cancer research activities and the ability to recruit top international researchers to our universities.

**Recruitment**

The BioCARE programme is scientifically broad. Therefore, to maintain and update our competence at the highest international standard, we continuously search for suitable top candidates to recruit. We have successfully recruited key scientists to strengthen central competences, such as for example preclinical animal models, drug screening, and imaging. We have also recruited many young researchers and provided financial support and scientific environments to facilitate the establishment of their own research programmes. Among these young researchers are several female scientists with strong track records and promising research projects.

**Scientific output**

BioCARE has focused on identifying biomarkers with diagnostic, prognostic, and therapeutic significance in cancer. Our programme was built on the realisation that biomarkers can significantly improve cancer treatment by avoiding overtreatment and by identifying patients who are responders. Furthermore, the biomarker strategy is a comparatively fast and effective way to improve treatment outcomes through better stratification (sub-grouping) of patients. The BioCARE initiative has substantially increased our capacity to deal with these issues. The establishment of the two new cancer centres decisively improved this capacity and our ability to transfer knowledge between basic and clinical scientists, as well as between
academia and the health and business sectors. BioCARE has created interfaces for researchers with different backgrounds and competences, including scientists from medical, engineering, and natural science faculties.

During the first four years, the number of peer-reviewed scientific papers increased from 133 in 2010 to 447 in 2013. This strong output is partly explained by project support, successful top recruitments, and increased collaboration with clinicians at the university hospitals. A cornerstone of high-quality translational cancer research is availability of clinical materials from large and well-characterised patient cohorts. BioCARE has provided an excellent network for clinicians and basic scientists to meet and establish new collaborations. With BioCARE support for translational research projects, these new collaborations have started to generate exciting data.

An illustrative BioCARE-supported translational research project is the work of the BioCARE principal investigator, Professor Thoas Fioretos at Lund University. In 2010, Fioretos and colleagues discovered that the cell-surface biomarker IL1RAP is upregulated on cancer stem cells from patients with chronic myeloid leukaemia (CML). In collaboration with a local biotech company, Innovagen (Ideon Research Park, Lund), they showed that newly generated antibodies against IL1RAP kill leukemic stem cells from patients ex vivo by antibody-dependent cellular toxicity. Working with the Lund University Innovation System, this discovery formed the basis for several patent applications and led to the establishment of the company Cantargia AB (Medicon Village, Lund). Early on, BioCARE recognised that the discovery of IL1RAP as a leukemic stem cell biomarker was a project with great potential to improve the diagnostics and treatment of leukaemia. To speed up the development of an anti-IL1RAP therapy for leukaemia, BioCARE supported the project through a major translational project grant that allowed Fioretos and colleagues to further demonstrate that IL1RAP is a promising therapeutic target in acute myeloid leukaemia (AML), a disorder with high unmet medical needs. Substantial co-funding from Cantargia allowed the recruitment of two postdoctoral researchers to establish humanised mouse models that were used to demonstrate anti-leukemic effects in vivo. In addition, Cantargia generated critical and costly reagents, including several recombinant antibodies against IL1RAP, that are provided free of charge on a continual basis to the research group. Cantargia is currently developing an antibody-based therapy targeting IL1RAP on leukemic stem cells for future clinical trials. This collaboration illustrates how strong interactions between Strategic Research Areas and companies formed through such initiatives can result in innovative research findings of the highest international calibre and form the basis for the development of new cancer treatments. Such collaborations provide strong strategic value for society at large.

Another example of BioCARE-supported cancer biomarker research of great importance for society is further evaluation of screening for the well-known PSA (Prostate Specific Antigen) biomarker for prostate cancer. BioCARE researcher Professor Jonas Hugosson at the University of Gothenburg, a world-leading authority on prostate cancer screening, showed a 21% reduction in prostate cancer mortality in the European Randomised PSA Biomarker Screening Study, comprising over 200 000 men. Based on this and other studies, leading scientists in the field now conclude that PSA screening results in a reduced risk of dying from prostate cancer but the question is at what price? In the first report evaluating quality of life in men participating in a PSA-based prostate cancer screening programme, Hugosson and colleagues showed that, of the life
years gained, almost a quarter (23%) were lost due to reduced quality of life, mainly due to treatment-related long-term side effects and the risk of overtreatment. Longer follow-up studies will address the role of treatment-related long-term side effects and the risk of overtreatment. These longer follow-up studies and better quality of life data are necessary before a recommendation of general PC screening can be suggested or discarded.

Education
The collaboration between Lund University and the University of Gothenburg has been a success. To promote education, BioCARE established a joint research school for PhD students and young postdocs, which organises annual retreats and one-day advanced seminars twice a year. Each of these events has attracted more than 100 participants. BioCARE has also organised annual retreats for principal investigators (PIs) and co-PIs from LU and UGOT. Thus, we have established an active and productive network between scientists at all levels at both universities. Most importantly, new scientific collaborations have been initiated with shared supervision of PhD students, and some of these projects have been funded by both BioCARE-LU and BioCARE-UGOT. In view of this success, we decided to further develop our collaboration. The BioCARE Research School will be merged with CARES, a new research school initiative modelled on our existing school. The merged school, which is partly financed through a new grant from the Swedish Cancer Society (SEK 2 400 000 over three years), will have a new course programme open to students from the whole of Sweden.

BioCARE has also initiated a revision of the medical school curriculum dealing with cancer at both universities in order to update relevant courses with state-of-the-art cancer biology. At UGOT, this work might result in a new course, organised by the Sahlgrenska Cancer Center, with a comprehensive approach to current cancer medicine.

Societal impact – Health care
Generally, the time between biomedical discoveries and their implementation in society is much longer than five years. However, certain findings have had an immediate impact on society. For example, the concept that antioxidants can help fight cancer is deeply rooted in the general population, promoted by the food supplement industry, and supported by some scientific studies. However, clinical trials have reported inconsistent results. In a BioCARE-sponsored project Professor Martin Bergö and colleagues at UGOT recently showed that antioxidants in fact accelerate tumour growth in a lung cancer model. As a result, the use of antioxidants as supplements and pharmaceuticals in patients with lung cancer (and people at risk of lung cancer) is now hotly debated worldwide, and the results are already influencing the clinical management of this large patient group.

Several BioCARE-sponsored projects have generated new knowledge about biomarkers that have already been introduced in the clinic. Among these markers are those that increase the diagnostic or prognostic precision, leading to better classification and treatment stratification of cancer patients. Similarly, biomarkers with prognostic and predictive information have been introduced, and several additional markers are in the pipeline. Biotech companies founded by BioCARE researchers have had direct societal impact in terms of job creation and economic activity. Improved diagnosis has a significant economic impact. For example, it reduces the cost of health care because better-
stratified patients only receive treatment from which they may benefit. Early diagnosis will also increase overall survival and patient suffering, since treatment can start earlier.

**Innovation**
The identification of new diagnostic, prognostic and therapeutic biomarkers for cancer has a strong potential to improve the diagnosis, monitoring, and treatment of malignant diseases. In Sweden, we have witnessed a dismantling of major pharmaceutical companies and decreased spending on basic and preclinical research within the life science industry. Thus, the life science industry both in Sweden and internationally is becoming increasingly dependent on new innovations generated within academia. At the same time, clinically useful biomarkers can only reach the patient through commercial endeavours. Such endeavours require considerable investment, but can be achieved by collaborating or signing licensing agreements with established pharmaceutical companies or by starting new companies.

Research performed within BioCARE has attracted considerable interest from Big Pharma (e.g., Roche Diagnostics, Sysmex, Merck) as well as from small and medium-sized Swedish biotech companies (e.g. BioInvent Intl, Alligator Biosciences, WntResearch). In addition, discoveries made within BioCARE have formed the basis for novel start-up companies, such as Immunovia (focusing on diagnostics of complex diseases, such as cancer) and Cantargia (developing antibody-based therapies for leukaemia; see above). Thus, our programme has already had a strong strategic impact on the business sector and has provided clear evidence of the translational value that BioCARE has delivered to the business sector. For example, double-digit growth is predicted for diagnostic products over the next five years.

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**Future perspectives**
Building on the success of the BioCARE programme, we will continue to strengthen and deepen the collaborations between our universities. We will also continue to develop the newly created cancer centres at both universities. These new competitive research environments of scientific excellence have a strong potential to become top European cancer research centres. With these centres as a basis, we will continue to recruit leading international cancer scientists and promising young researchers. The establishment of our extended research school (CARES) will foster a new generation of leading cancer scientists and increase collaborations between LU and UGOT, the healthcare sector, and the industry. Translational cancer research will continue to be at the focus and we will build new strategic alliances with international academic organisations and increase collaborations with industry and the health care sector, including the regional cancer centres RCC South and RCC West.

The budget of BioCARE is relatively small when compared to the total sum of external grants from bodies such as the Swedish Cancer Society, the Swedish Research Council and the Swedish Childhood Cancer Foundation awarded to individual BioCARE investigators. Following the strategies of the first five years of BioCARE activities and with a continued limited budget, the major focus for BioCARE in the future will still be on supporting infrastructure and on building networks locally, nationally and internationally. □
Sven Påhlman, coordinator of BioCARE, is Professor of Molecular Medicine at Lund University. His long-held research interests are tumour cell differentiation and how hypoxia affects tumour differentiation stage. Major model systems are neuroblastoma and breast cancer. His work has translated clinically into increased understanding of mechanisms behind tumour heterogeneity.

Göran Stenman, co-coordinator of BioCARE, is Professor of Pathology at the University of Gothenburg and director of the Sahlgrenska Cancer Center. His research interest is cancer genomics with focus on studies of the role of fusion oncogenes and other genomic alterations as biomarkers for diagnosis, prognosis, and treatment of cancer.

Thoas Fioretos, vice-coordinator of BioCARE at Lund University, is director of the BioCARE Research School and Professor of Clinical Genetics at Lund University and senior consultant at Lund University Hospital. His research interest is in identifying genetic alterations in leukaemia and using the identified markers for improved clinical diagnostics, follow-up and treatment of patients affected by these disorders.

About BioCARE

BioCARE is a joint programme between Lund University (LU) and the University of Gothenburg (UGOT) open to all cancer researchers, with the aim to explore the use of biomarkers to improve cancer diagnosis, identify new therapeutic targets, and implement biomarkers in clinical trials. BioCARE is led by a board of researchers and student representatives from LU/UGOT. BioCARE’s priorities during the first five-year period have been to build infrastructure (cancer centres at LU and UGOT), recruit top scientists, support individual and joint cancer biomarker projects, establish a research school to support PhD students, and organise one-day advanced seminars on timely cancer topics. Promotion of networking has been an overall theme to amalgamate the capacities of LU and UGOT. Together with the two other cancer SRAs, StratCan (Karolinska Institutet) and U-Can (Uppsala and Umeå universities), BioCARE has organised national cancer meetings held in Malmö (2012), Uppsala (2013) and Stockholm (2014).

www.biocare.nu
Exploring new frontiers of Technology
10:

e-Science: the e-volution of science

GÖRAN SANDBERG
MAGNUS ULLNER
et al
e-Science is pushing every field of research forwards.
eSSENCE models materials to understand their properties, and overlap historical data of death and births with geographical data to enable studies of how people's location affected their health. They strive for increased resolution of images of the human brain, and for better tracking of eye movements – used to explore how we read.

eSSENCE is a e-Science collaboration between the universities in Uppsala, Lund and Umeå. The common denominator is the advanced use of computers, storage and networks to solve scientific problems.

ONCE UPON A TIME, “computer” was a job title, but in the middle of the last century, something happened. Electronic circuits came into the service of science and engineering and quickly became an indispensable tool, not only because of the higher efficiency of electronic computers compared to the mechanical ones before them, but also due to the versatility of the programming. Today, computers are ubiquitous, but not only as calculation machines. Computers can also tirelessly collect data and shift it around, thus, another aspect of the electronic revolution, the e-volution, is storage devices for large amounts of data and networks to connect everything.

The technological advances have spread into many branches of science, but whereas some have a long tradition, others are just discovering the possibilities. Furthermore, there is a question of an increasing scale that creates other challenges, especially with more and more research facilities and infrastructures being able to produce large amounts of data. While the subject matter of the research may be different, there are similarities in the approach to solving problems with computers and managing and analysing data. This was recently given a common name: e-Science. Thus, as a research area, it is not defined by disciplines, but through the scientific method, which has the advanced use of computers, storage, and networks as the common denominator. It includes simulation, acquisition and analysis of digital data and provides new opportunities for many research groups at Lund University. This will be illustrated with some glimpses into various projects, but first a few words about eSSENCE, an environment in the strategic research area of e-Science.

e-Science and eSSENCE
By its very nature, taking the tools of research as the starting point, e-Science is very broad and has the potential to bring
researchers together from many disciplines to work on common problems or to pool different kinds of competences. To support e-Science and establish a common forum, Lund University joined with the universities of Uppsala and Umeå to form the collaborative e-Science consortium eSSENCE, where Uppsala is the lead partner responsible for overall coordination. The three universities have slightly different profiles that complement each other, with Lund leaning more towards the applications of e-Science, Umeå towards the generic tools, and Uppsala being poised somewhere in the middle. eSSENCE supports about 35 projects that generally belong to one of the four focus areas Materials Science, Life Sciences, Human Function and Environment, and Generic e-Science Methods and Tools. The projects contain fruitful collaborations between colleagues within and also outside eSSENCE as well as with partners from industry and other non-academic organisations.

**eSSENCE@LU**
In Lund, we have formulated a subdivision of e-Science into research based on sensor data, register data, and high-performance computing. This provides a logical structure to address different areas and describe the multifaceted activities at the university. It also points to a natural connection between research groups.

By sensor, we mean an instrument that produces data from measurements. It can be local, in a lab or a large research facility, or at distributed measuring stations. As examples of sensor-based research, we may mention the upcoming synchrotron facility MAX IV or two of the projects described below, the magnetic resonance imaging at Lund University Bioimaging Centre and measurements of EEG, eye-tracking and more at Lund University Humanities Lab. Collection, storage, transfer, and analysis of the data are all activities that involve e-Science.

A further example is the needs to distribute data from the Large Hadron Collider (LHC) at CERN worldwide, which led to a special e-Science infrastructure – or an e-infrastructure – the Worldwide LHC Computing Grid (WLCG). Members of eSSENCE from all three universities have contributed to this infrastructure, in particular in the development of grid software as a means to securely access and process data across large e-infrastructures, independently of the nature of the research.

Register-based research is in part similar to sensor-based, but a difference is that the data is more structured and consist of information collected over a long period of time, such as records of births and deaths with information about family relationships. To make such data useful, they have to be put into searchable databases using standardised formats, which is an effort in itself.

Finally, high-performance computing (HPC), which links back to the start of the current electronic era more than 50 years ago, involves calculations or simulations of complex systems using the laws of nature as the starting point. The art of HPC lies both in setting up a model that is simple enough to be calculated in reasonable time, yet advanced enough to capture the essential mechanisms of the system and in finding clever algorithms for speeding up the calculation.

**eSSENCE@LU** currently covers 14 projects within Lund University with roots in science, engineering, medicine, humanities, and economics. The projects show the diversity of the area and also the opportunities to address questions and challenges that are common to many research fields. One of the benefits of establishing eSSENCE has been the enthusiasm to define common needs and the potential for future research.
Cellulose is one of the most abundant, renewable bio-materials on the planet and its uses in refined materials are of increasing interest not least to the Swedish forestry industry. In particular, wooden fibres could potentially be used for textile production as a replacement for cotton. The latter requires vast amounts of water — often in places where this is in scarce supply — and is around ten times more expensive than cellulose obtained from wooden fibres. In collaboration with Södra and other industry partners we develop computer models for studying the dissolution of cellulose in aqueous solvents. In particular we are interested in molecular details of how and where small co-solutes bind to cellulose polymers. This helps us understand the strong forces holding cellulose together and, importantly, how to design new agents for gently dissolving pulp. Wooden fibres from slow growing, Swedish forests are of high strength, making them ideal for spinning yarn. This strength should ideally be maintained during dissolution and we are providing insight into how this can be achieved by providing a deeper understanding of the molecular behaviour of cellulose in aqueous environments.

The studies of these diverse materials — clay, cellulose, silk, and cement — are done using designed molecular modelling software, jointly developed by PhD students and their supervisors working in different projects. Via so-called “social programming”, new algorithms are publicly shared online and an improvement or a new module originally developed for silk simulations may immediately benefit another project on cement setting.

Adding the geographic context into register research

The basic idea of register research is to structure large amounts of data of the population, for example, into databases and then utilise these databases for research. Register research is common in many disciplines such as sociology, demography, and
lyse the impact of land reforms in rural areas. Which impact did these reforms have on the health of different social groups? In urban areas we can, among many things, study how environmental pollutants and sanitation infrastructure affect demographic outcomes such as mortality and fertility.

To introduce the geographic context into demography, all the individuals must be linked to locations. For historical populations, the geographic names of where individuals were born, lived, married and died are often available. Such names can be addresses, property units, buildings, etc. To be able to analyse the demographic data together with geographic data, these geographic names must be geo-referenced, i.e. the geographic names must be linked to a physical location. This can be performed by allocating each geographic name to a historical unit (property unit, building, etc.). However, this requires data about the development of the historical units, i.e. when they were created, changed and ceased to exist. Since there is a long space of time between the historical maps, we have to utilise textual sources (e.g. poll-tax registers and cadastral dossiers) to identify what happened in between. By using these external sources we can improve the time representation of the geographic data, which is a prerequisite for integration with the register data.

In recent years, geographic data have become more readily available. Geographic data offers the potential to add the geographic context into register research. We can, for example, ask questions about how geographic environmental factors such as pollution and noise are affecting health. However, to enable this research we need appropriate methods to integrate register data with geographic data. In some cases this is quite straightforward, but in other cases it entails a major challenge. A common problem for the integration of such data concerns the time representations. Registers often contain longitudinal data, i.e. data based on regular observations (e.g. each month or year). Until quite recently, geographic data have, only updated sparsely. In the 20th century it often took more than a decade between two mappings of the same area. And if we go to historical maps, it often took much longer than that. This implies that we need to develop methods to integrate longitudinal data in registers with the geographic data that are more snapshots in time.

In this eSSENCE project we have studied the integration of register data with geographic data and applied it in historical demography. Register research in historical demography aims to answer vital questions about what factors have affected living conditions in the past, which of course has a bearing on the current and future population. This research requires demographic databases that contain data about individuals and families, as well as economic conditions. By adding geographic data, including the geographic locations of individuals, it enables us to understand more deeply and accurately how geographic context has affected people. We can, for instance, ana-
Bioimaging and Powerful Magnetic Resonance (MR) Scanners

Bioimaging is a rapidly advancing field of research with unique potential, to a large extent brought forward by the non-invasive technique Magnetic Resonance Imaging (MRI). Over thirty years ago, Paul C. Lauterbur, Nobel Laureate in 2003, first formulated the idea of using nuclear magnetic resonance (NMR) as a basis for imaging. Since then, the technique now known as MRI has developed into one of the most flexible tools in medical research and diagnostic imaging with well over 20 000 MRI systems worldwide being in operation today.

One current trend in the MRI world is to increase the magnetic field strength, primarily since the signal-to-noise ratio increases with increasing field strength, thereby allowing for high-resolution anatomical structure visualisation. Other advantages are higher accuracy in functional studies and even molecular-level description of metabolic events in the cell.

At present, clinically used MRI scanners normally have a field strength of 1.5 or 3 tesla (T), while scanners for front-end neuro research reach up to, and even above, 7 T. At the field strength of 7 T, accepted for human use as a non-significant risk device by the FDA, remarkable image resolution can be obtained and image structures on the order of a few hundred micrometres can be visualised in the living human brain. Indeed, using ultra-high field (UHF) MRI scanners, a whole new world is revealed and the impact of such scanners on brain research is only beginning to show – at present there are approximately 50 scanners in existence worldwide. Using UHF MRI, progress in basic understanding of the brain and its function can be foreseen, and once such scanners are implemented more widely in hospital environments, significant added diagnostic value is very likely in areas such as neurodegenerative diseases, brain tumours and epilepsy.

Lund University Bioimaging Centre (LBIC), a partner in eSSENCE, will host a national resource for human 7 T Magnetic Resonance Imaging (MRI) from early 2015. The equipment will be available for all researchers in Sweden and, owing to the large investment required, it is likely that this will be the only UHF MRI scanner in Sweden during the next five-year period.

There are several challenges in the field of e-Science when building this type of infrastructure:

Firstly, a national infrastructure placed inside the firewall of a university hospital requires data transfer and data storage solutions that comply with legislation as well as being attractive for all users. Creating these solutions is essential, not only for LBIC, but also in a broader sense for all national imaging infrastructures.

Secondly, increased resolution and other imaging possibilities such as dynamic imaging over several time frames in three dimensions (3D) create a large amount of data to be stored, handled and used for various types of analysis.

Thirdly, and most importantly, MRI images are not only used as they appear on the computer screen. Rather, the data available in the images is also used to derive information about the human brain and its function. Such information could include quantitative values of cerebral blood flow, water diffusion in the brain, flow in large vessels, and information about brain function in response to brain activation. Therefore, advanced image analysis, transferring image information into maps and values of biologically relevant information (so called imaging biomarkers), is an essential tool to harvest the full capacity of UHF MRI scanners.
New methods for understanding human cognition, communication, culture, and learning

Man’s effort to understand himself and his relationship to the physical and social environment are key questions to science, the humanities, and social science alike. Traditionally, the humanities and social sciences have mainly worked with qualitative and interpretive approaches. However, technology and quantitative methods are now available to the humanities, enabling scholars to combine old and new methods to investigate issues of cognition, communication, culture, and learning. Lund University Humanities Lab is a research infrastructure and training facility that provides access to sensor-based research technology such as eye-tracking, EEG, and motion capture, and to visualisation techniques such as virtual reality. We also provide tools for analysis and short- and long-term storage of multisource data sets such as corpora with linked text, audio, video, and GIS material. It is a key arena for multidisciplinary e-Science work, bringing the humanities closer to other disciplines.

For example, linguists and cognitive scientists use eye-tracking and software that records keystrokes to explore how we read and write, whether reading patterns differ depending on our skill level and the method we use to write. Communication scholars employ eye-tracking to compare reading on paper to reading on a web page, and to explore whether adults, adolescents, and children differ. Linguists and psychologists use EEG to record the brain’s electrophysiological activity to study mental processes and learning. The technique is used to examine brain activity during vocabulary learning in twelve-month-olds, adults’ acquisition of grammar in a foreign language, and Swedes’ processing of dialects and word tone (änden/änden). Archaeologists use 3D scans and virtual reality to build models, for example of Pompeii, often linked to GIS data.

The eSSENCE projects have focused on methodological developments. In the domain of eye-tracking, work has focused on developing algorithms for event detection, that is, on finding ‘eye fixations’, and on following eyes in ‘smooth pursuit’, that is, cases where the eye smoothly follows a moving target rather than jumping from point to point. These are crucial developments for the technique to be applied to real-life scenarios such as driving, watching a film, or following a lesson in school. A second key domain examines how we can combine eye-tracking and EEG recordings in order to study attention, for instance, both by overt eye movements to objects on a screen and in the more ‘secret’ responses of the brain.

These developments all reflect a steadily growing reliance on e-Science in the humanities, and a parallel need for computational solutions to data and work flows as applied to human data, online computation, flexible storage and retrieval solutions, know-how, and e-Science collaborations.

What’s next

We have highlighted a few activities. The common denominator is the use of computers, storage, and networks, although these activities are by no means the only ones with this characteristic. Other areas include bioinformatics, climate modelling, and more general computational sciences (physics, chemistry, and
mechanics), to name a few. High-performance computing has been around since the beginning of the 1960s, but in the last 10 years or so, activity has accelerated into new areas and widened in scope, such as the need to handle larger data sets from sensors.

So what comes next? Ambitions will increase. The possibilities of using e-Science quite independently of scientific field will become more apparent following examples such as the projects described above, and new applications will emerge. We have only seen the beginning.

Göran Sandberg is Professor of Structural Mechanics and Head of the Department of Construction Sciences. His primary research area is computational mechanics, especially the finite element method with applications in coupled problems and structural dynamics and computational strategies in general. He has been involved with the Centre for Scientific and Technical Computing at Lund University since its inception.

Magnus Ullner is Senior Lecturer in Theoretical Chemistry and also associated with the Center for Scientific and Technical Computing at Lund University. His primary research area is simulations of systems of highly charged molecules or particles, such as polyelectrolytes (charged polymers) and clay particles.

About eSSENCE

The technological advances of computers, storage, and networks have spread into many branches of science, but whereas some have a long tradition, others are just discovering the possibilities. Such activities, with links to computing, databases, and sensors, have been given the collective name e-Science. To support e-Science and establish a common forum, Lund University joined with the universities of Uppsala and Umeå to form the collaborative e-Science consortium eSSENCE, where Uppsala is lead partner.

eSSENCE supports about 35 projects that generally belong to one of the four focus areas Materials Science, Life Sciences, Human Function and Environment, and Generic e-Science Methods and Tools.

The activities at Lund University link to five faculties: Science, Engineering, Medicine, Humanities, and Economics and have led to intensive collaborations between researchers developing common tools, procedures, and research results.

www.essenceofscience.se
11:

Nanoscience for Sustainable Energy

HEINER LINKE
LARS SAMUELSON
Nanoscience is the art of understanding and using the new physical behavior exhibited by very small material components – and it offers a wealth of opportunities to help achieve a sustainable energy supply.

This is one of the aims of Lund University’s Nanometer Structure Consortium with more than 200 scientists at the faculties of engineering, science and medicine. A special focus is on materials science and applications of nanowires – thin needles about 100 nanometers in diameter (a nanometer is one billionth of a meter). The use of nanowires allows us to achieve entirely new combinations of materials that previously were impossible, and allow, for example, for more efficient solar cells, light emitting diodes and devices that convert heat into electricity.

A GLOBALLY sustainable energy supply will be possible only if we harvest many types of renewable energy sources (such as wind, sunlight, waves and tides) in combination with reduced energy consumption. In other words, we must find better and more efficient ways of converting one form of energy into another. Crucially, this must be done in a way that is sustainable in the broadest meaning of the word: the novel techniques must be economically affordable, must have no adverse impact on environment and health, and must be achievable within the scope of Earth’s natural resources, including its supply of raw materials.

Nanoscience – the art of understanding and using the new physical behaviour exhibited by very small material components – offers a wealth of opportunities to help achieve a sustainable energy supply. Therefore, sustainable solutions to more efficient energy conversion are naturally one of the overarching aims of Lund University’s Nanometer Structure Consortium (nmC@LU).¹

On the following pages we describe our activities in this area, ranging from basic research all the way to technology that is about to hit the market, and from education to collaboration with industry. Using several specific examples, such as the use of sunlight to generate electricity and efficient illumination techniques based on light emitting diodes, we will describe how nanostructures can make energy conversion more efficient, while at the same time drastically reducing the amount of raw materials needed. We will describe our efforts to ensure the safe handling of nanomaterials, from their invention to their use in products. And we will describe how we take a long-term view,

¹. In January 2015, the Nanometer Structure Consortium at Lund University (nmC@LU) will, after 25 years as nmC, change its name to NanoLund.
developing entirely new physics concepts for energy conversion at the smallest scale, which could lead to methods for efficient energy conversion that are not known today and that may be implemented decades from now.

**Nanowires: tiny needles with unique properties**

When the size of the components of a material are reduced below about a tenth of one micrometre (thousands of times smaller than the diameter of a human hair) we can achieve entirely new optical, electrical and mechanical properties. For example, nanoparticles made of gold do not have the characteristic shiny metal colour, but instead assume a gentle red – a testament to the different way the nanoparticles interact with visible light, compared to a larger “bulk” piece of gold.

For the past dozen or so years, scientists at Lund University have been focusing on a specific type of nanomaterials called nanowires. These are thin needles about 100 nanometres in diameter (a nano-metre is one billionth of a metre). The focus in Lund is on semiconductor nanowires made from elements from groups III and V of the periodic system. These materials are already widely used for electronics and optoelectronics: in mobile wireless networks, fibre optics, and light-emitting diodes.

Nanowires are made in a way that is very similar to the way crystals form naturally. By supplying the raw materials (the elements from which the target crystal is made) at a temperature and pressure close to where a crystal forms spontaneously, nanowires can be nurtured to grow to the desired length from a seed particle whose size determines the resulting needle’s diameter. The wires of the highest quality (with the best electrical and optical properties) are achieved when supplying the growth elements in gas form. This is the approach pioneered in Lund and a small number of other places around the globe in the early 2000s, and perfected since then.

So why have more than a hundred scientists in Lund spent over ten years focusing all of their attention on tiny needles?

A key reason is that the use of nanowires allows us to achieve entirely new combinations of materials that previously were impossible. This is important because all electronic and optoelectronic devices are enabled by effects that occur at the interface between two materials. However, in traditional electronics (where large plates of material, called wafers, are processed in one piece) severe limitations are imposed by what materials can
be combined: both materials must have precisely the same distance between their atoms, or else cracks will form that destroy the electronic and optical properties. With nanowires, we do not have this limitation: the wires are so thin that cracks don’t propagate along the wire, or don’t even form in the first place. As a consequence, we can use a much wider range of semiconductor materials to be sandwiched together in nanowires, with superior electrical and optical properties. This gives us the opportunity to construct better, higher performing semiconductor devices for a very large range of applications, ranging all the way from quantum mechanical devices to faster electronics and advanced medical devices.

Furthermore, the small dimensions of nanowires are comparable to the wavelength of visible light, and to the wavelength (or size) of electrons. By carefully choosing the dimensions of the wires and their components, and by creating regular arrays of nanowires in highly controlled patterns, it is possible to create completely new electronic and optical properties.

**More energy with less material: nanowire solar cells**

Solar cells (photovoltaic cells) are semiconductor devices that capture light (photons) arriving from the sun, and use their energy to push electrical charges through a wire – creating electric power. The amount of energy available from the sun is staggering: the light delivered by the sun to the surface of the earth in one hour would be sufficient to cover humanity’s energy needs for an entire year!

Why, then, do we not already use this almost inexhaustible amount of available solar energy to cover most or all of our electricity needs?

One answer is that we simply haven’t got round to it yet. In fact, the amount of solar power conversion capacity installed on fields and rooftops worldwide has been increasing exponentially for the past 15 years, and solar power is here to stay. However, for this trend to continue, and for photovoltaic energy to grow into a truly substantial contributor to electricity needs worldwide, we must further increase the efficiency at which solar cells convert light into electricity. This is because higher efficiency will reduce the amount of raw material (currently mostly silicon) needed to produce the same amount of photovoltaic power, and will thus reduce the cost and increase sustainability.

Nanowires offer unique opportunities to create more efficient and cost-effective solar cells. In 2013, nanoscientists at Lund University and their international collaboration partners attracted much attention by producing the solar cell with the highest efficiency ever achieved using nanowires, 13.8%. This may not sound very impressive compared to the best commercial, wafer-based (planar) silicon devices (23%) or to the record-high values of up to 44% achieved in research labs elsewhere for concentrator solar cells. However, crucially, by using nanowires, the Lund team achieved this efficiency with only 3% of the active material that would have been needed with traditional techniques. This dramatic reduction in material use, which offers great promise for future cost reductions, was achieved by very carefully positioning the nanowire solar cells in the form of an antenna array, which absorbed the sunlight very effectively, such that much less material was needed to capture the light.

This is only the beginning for nanowire-based solar cells. Advanced solar cells, such as those planar cells that achieve conversion efficiencies above 40%, use several layers of material, each converting one part of the solar spectrum into electricity. Such multi-junction solar cells are the next step also for nano-
wires, which will be helped by the fact that nanowires are much more suited for sandwiching materials on top of one another.

**Aerotaxy: flying nanowires boost traditional solar cells**

The techniques described above still have one major drawback: they rely on traditional crystal growth methods, where nanowires can be only grown one layer at a time and on expensive substrates. We have recently demonstrated a radically new method of manufacturing nanowires, offering unprecedented growth speeds and material production capacity. In this growth method, nanowires grow as an aerosol (in the form of particles “flying” in a stream of gas) without the use of any substrate. The method has been named aerotaxy. Using aerotaxy, wires can be grown in a continuous flow in large quantities, and one vision is to simply add a layer of nanowires on top of traditional silicon solar cells, boosting their efficiency by enabling them to more efficiently access a wider part of the solar spectrum. Fundamental studies of aerotaxy are presently funded by a grant from the Knut and Alice Wallenberg Foundation, and the technique is being upscaled for pilot production by Sol Voltaics AB in Lund.

**Pleasing the eye: LEDs made for humans**

General lighting – street lamps, household and factory lighting – today consumes as much as 20–25% of the developed world’s electric power. One reason for this is that traditional incandescent light bulbs and halogen lamps are very inefficient, since they produce much more heat than light. Even the use of the more efficient compact fluorescent lamps is unsustainable, since they contain the environmentally hazardous element mercury. The most energy-efficient lighting technology available is light-emitting diodes (LEDs). Today, white LED lamps have efficiencies of 30–50% in converting electrical power to light, which is ten times higher than traditional incandescent lamps. This is currently achieved by using a blue-emitting LED that is used to “pump” a phosphor material that emits in the green and red spectral regions, on average seen by the human eye as “white” light. One major challenge and opportunity for the future will be to directly create the three basic colours, i.e. blue, green and red, with LEDs, which would increase efficiency and long-term stability. Furthermore, light produced by combining the three LED sources can be “mixed” to tune the colour temperature to optimally match the preferences of the human eye, and adjusted for use in specific work or social environments. The nanowire technology developed in our laboratory enables the best blue and green LEDs for such lighting applications, and we are currently developing efficient red nanowire LEDs, something that would be impossible with traditional planar LED technology.

The Lund technology for nanowire-based LEDs has been transferred to the spin-off company Glo AB, which currently has more than 60 employees and is pursuing pilot production of perfectly mixed RGB light for displays as well as for lighting applications.

**Electricity from heat**

If you take a piece of electric conductor, such as a semiconductor, and heat one end while keeping the other cold, a small electric current can be generated. This effect, called thermoelectricity, can be used to convert heat directly into electric power, without a turbine or other mechanical device. Thermoelectric devices could thus be used to extract useful electricity from heat sources that now go to waste: for example from the heat emit-
types of nanoparticles, when inhaled or ingested, can be hazardous to human health. A number of factors can play a role: for example, the particle's catalytic properties, which can be much enhanced by its large surface-to-volume ratio, its size and shape (making it difficult for the cells of the immune system to absorb the particle) or other properties. Just as for any new chemical, it is very important to evaluate a nanomaterial's safety before it is used in the lab or in products, and to consider exposure risks to workers and customers throughout a product's life cycle. This applies to solar cells or LEDs as much as for any other nanomaterial-based device or product.

The exposure routes (the ways by which humans or other organisms may touch, inhale or ingest a nanoparticle) of nanomaterials are different from those of bulk materials. New methods need to be developed to measure and evaluate health and environmental risks during production and use of nanoparticles.

Within the Lund nanoscience environment, more than 20 scientists with backgrounds in occupational health, physics and chemistry combine their expertise to evaluate safety aspects of nanoparticles in general and of nanowires in particular. This includes the development of methods to accurately measure, for example, the quantity of airborne nanowires that may end up in the lungs of workers in university laboratories as well as in start-up companies that commercialise nanowire-based technology.

Safety: is “nano” always good?
Nanoscience is about understanding and eventually taking advantage of the new properties a material exhibits on the nanoscale, for example in the form of nanoparticles or nanowires. However, there is no guarantee that these novel properties are always exclusively positive. In fact, it is well known that some...
lieve that the answer is “yes”, and have initiated several fundamental science thrusts to explore such possibilities.

One example is the use of molecular devices for energy conversion. The prime example of such systems can be found in biology, where molecular motors (complex protein-based molecules) perform useful tasks such as intracellular transport. To do this, molecular motors convert chemical energy directly into mechanical work with higher efficiency than even the most sophisticated car engine. To learn from nature, we construct artificial molecular motors and explore synthetic nanodevices powered by biological molecular motors. As part of a collaboration financed by the European Union, we explore computing devices that use molecular motors instead of electrons, and that use a hundred times less energy than traditional electronic computers. We also study forms of energy conversion that are entirely different from anything that is used in existing technology. For example, we are learning how information can be transformed into useful energy in devices that can “observe” and take advantage of fluctuations of a small object such as an electron or molecule. This work involves a reformulation of thermodynamics on the nanoscale, since the classical thermodynamic theory was developed specifically for large-scale steam turbines or car engines, and cannot be used to understand energy conversion on the tiny scale of single molecules.

Looking ahead, there are many more opportunities for Lund nanoscience to address society’s grand challenges, leading to a better life for many. In one focus area we will target Nanoscience for the benefit of the developing world. Current research will help provide affordable access to both solar power and efficient LED lighting in the developing world, and will thus help improve living conditions and support children’s education. Further development of LEDs will allow us to efficiently produce deep-ultraviolet light to kill microorganisms, for use in water purification systems. Lund micro- and nanotechnology can also be used to develop cheap, hand-held devices for quick diagnostics for use in remote health clinics.

We also foresee the use of nanowire probes in neuroscience and in cancer and diabetes research and treatment, in collaboration with the strong Lund-based research efforts in these areas (including the Neuronano research Center, EXODIAB and BioCARE). The ability to probe, manipulate and monitor one or many individual cells may help answer important scientific questions in these fields.

Fundamental and applied science, education and innovation
The science described above is possible only in a highly integrated research environment that spans basic and applied research, materials science and physics, chemistry and biology, technology, and medicine. It is our mission to do both: focus on addressing important problems of today, while also allowing blue-sky research to thrive and provide novel approaches to solving the problems of tomorrow.

One of our most important roles is the education of nano-scientists for careers in academic research as well as in industry, with the ability to integrate knowledge and skills from many disciplines, and with a deep understanding of the need to apply this expertise safely and sustainably. We do this in our flagship degree programme Engineering Nanoscience, as well as in the education of the approximately 100 doctoral students engaged in Lund nanoscience. Currently, we are developing an internship programme with the aim of offering our doctoral students the opportunity to gain industrial work experience for a few months during their studies.
Lars Samuelson initiated the Nanometer Structure Consortium in 1988, shortly after being recruited to Lund as a young Professor of Semiconductor Electronics. In the late 1990s he focused the consortium’s work on nanowires. He is the founder of several spin-off companies, including Glo AB, which commercialises nanowire-based light-emitting diodes (LEDs).

Heiner Linke is a Professor of Nanophysics at Lund University and the director of the Nanometer Structure Consortium (nmC) since 2013. He joined the nmC in 2009, following eight years at the physics department and Materials Science Institute of the University of Oregon. His research focuses on energy conversion at the nanoscale in both semiconductors and biomolecular systems.

However, to turn ideas into commercial technology that can improve our lives, great interdisciplinary science and bright young people alone are not enough: it is a long road from basic research to a profitable product. Working jointly with regional policy-makers, research institutions and entrepreneurs, we are therefore currently planning for an expansion of the fundamental research facilities towards nano-production. We call this vision NANOVA, and it begins with an extension of our existing Lund Nano Lab with a wing for applied device R&D. On a longer time scale, it is our vision to ultimately create a complete innovation ecosystem, comprising all steps in the innovation production chain, using resources jointly operated and owned by academia and industry. NANOVA will preferably be located in the Science Village area close to the MAX IV and ESS facilities, with much of the necessary infrastructure and support facilities needed for industrial development. In this way, we will be able to vertically integrate unique competences all the way from education and basic research, via applied R&D and pilot facility establishment, to enable the development of an advanced industrial infrastructure for nanomaterials production. Our research can thus reach its full potential in terms of its benefit to society.

About Nanoscience at Lund University

Founded in 1988, the Nanometer Structure Consortium (nmC) is today Sweden’s largest research environment for nanoscience, engaging more than 200 scientists and PhD students at the faculties of engineering, science and medicine at Lund University. Its vision is to bring together the most creative minds in a world-leading interdisciplinary research environment to help overcome society’s grand challenges by pushing the frontiers of nanoscience.

To support these strategic aims, we provide multiple platforms for interdisciplinary exchange and collaboration across faculties and continuously develop joint, coherent goals. We fund strategically important projects, develop and maintain joint infrastructure for academic and industry users, and offer education in nanoscience at all levels, including a five-year programme in Engineering Nanoscience that is closely integrated with our research. Our effective innovation pathways have created several spin-off companies that currently employ more than 150 people.

Nanoscience at Lund University will change name to NanoLund in 2015.

www.nano.lu.se
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Mobile communications going massive

OVE EDFORS
FREDRIK TUFVESSON
Current estimates show that worldwide mobile data traffic will have grown massively by year 2020 – and there are no existing systems that can efficiently supply this increase. The radio spectrum is already crammed with mobile services and mobile communication technologies are performing near their theoretical maxima.

Researchers within ELLIIT identified at a very early stage the potential of massive MIMO, a technique where hundreds of antenna elements are used at the base station, as a promising solution to this challenge. ELLIIT researchers are seen as pioneers in the area and due to the establishment of ELLIIT we have, together with our colleagues in Linköping, built up a world leading position.

MOBILE COMMUNICATIONS have undergone an amazing development over the last few decades, with new generations coming out roughly every ten years. Each transition from one generation to the next has brought new capabilities and improved technology. The first generation was based on analogue technology and supported only traditional phone calls, while subsequent generations have become increasingly digital, making them more efficient, flexible and capable. Today a mobile phone is much less “a phone” than it is a centre for our social networks, a diary, a personal assistant, a camera, and the way we keep updated on the latest news. No matter how we measure the development of mobile communications, curves tend to show exponential growth without signs of slowdown. In this sense it is obvious that mobile communications are “going massive”, but it is a different aspect of going massive on which this text focuses. Current estimates show that worldwide mobile data traffic will grow from a current 3 ExaBytes per month (3 000 000 000 000 000 000 Bytes) to around 20 ExaBytes per month (20 000 000 000 000 000 000 Bytes) by the year 2020. There are no existing systems that can efficiently supply this increase in data traffic. The radio spectrum is already crammed with mobile services, and mobile communication technologies are performing near their theoretical maxima. To take the necessary leap forward we need to open up a new dimension in mobile communications. The spatial dimension, i.e. the location of mobile terminals in space, is still to be efficiently exploited. Massive increases in data traffic, through massive increase of spatial resolution, require massive numbers

1. These numbers are equivalent to the contents of 6 million and 40 million full 512 GByte hard disks per month respectively.
of antennas in our mobile systems. It is from this perspective we perform research in one of the ELLIIT projects, where we investigate mobile systems going massive.

To understand the fundamental principles of how spatial resolution can help us increase efficiency of a mobile communication system, we will use very simple optical light-based communication as an analogy. Assume that our mobile terminals are transmitting signals to a base station by switching a light source on/off, using for example Morse code. The base station has an omni-directional light detector, which you may think of as watching the world through a ping pong ball, where strength and colour of incoming light can be distinguished, but not its direction. This is a fairly close analogy of how current mobile communication systems operate. To separate signals from different terminals, there have to be some distinguishing features to exploit. One possibility is to use colours, where each terminal is assigned a unique colour. The base station can then separate signals by using colour filters. The corresponding technique in mobile communications is to assign different radio frequencies to each terminal. Another approach is to organise communication from different terminals in a strict time schedule, so that only one terminal is transmitting to the base station at any moment in time. A critical observation regarding both these techniques is that more resources are needed whenever a new terminal enters the system. In the first case, an additional colour/frequency is required, while in the second case another time-slot has to be assigned. Even the latest, fourth, generation mobile systems operate to a large extent according to these basic principles.

Now, let us take the conceptual leap of replacing the omni-directional light sensor at the base station with a digital camera. Suddenly, the base station can distinguish not only intensity and colour, but also the direction from which a light signal is coming. With this new arrangement, each little dot, pixel, in the image sensor of the camera can be used in the same way as the omni-directional light sensor in the previous example. As long as the image of transmitting light sources of two terminals fall on different pixels, they are easily separated by the base station even if they transmit at the same time. Only when they fall in the same pixel do they have to be separated using colour/frequency or time as in the first example. In principle, our communication capacity is multiplied by the number of available pixels on our camera sensor, without the need for more colour/frequency or time resources. By using a massive number of light sensors/pixels, communication capacity can be massively increased. The same basic principles can be used in radio-based mobile communication systems, with some minor conceptual changes. Light sources on terminals are replaced by antennas and the digital camera on the base station by a massive array of antennas. The two major differences between the light analogy and real radio-based mobile communication are that i) the focusing of light performed by a lens in the first case is replaced by digital processing of antenna signals in the second and ii) while light travel essentially in straight lines, radio signals can bend around corners, making it possible to communicate also out of the line of sight.

Improving wireless communication by using multiple antennas is usually called multiple-input/multiple-output (MIMO) communication, and it has been employed on a small scale in existing systems. Up to eight antennas are specified in fourth generation systems, while research within ELLIIT is taking the number of antennas to the extreme in what is called massive MIMO. Theoretical studies are performed with ar-
arbitrary numbers of antennas at the base station and real-time experimental tests are performed on a flexible 100-antenna testbed, where new algorithms and concepts can be verified. The custom-made testbed that we have developed within ELLIIT can be seen as a fully programmable base station, where every aspect of the radio transmission and reception on all 100 antennas can be controlled in great detail. It is the largest and most capable testbed of its kind in the world.

Researchers within ELLIIT identified the potential of massive MIMO at a very early stage, and the formation of the strategic research area enabled us to join forces and gather the critical mass to exploit different aspects of massive MIMO, spanning the entire range from pure theoretical analysis of possibilities and limitations to the testbed implementation where we bring advanced lab technology all the way to a real world deployment. ELLIIT researchers are seen as pioneers in the area and as a result of the establishment of ELLIIT we have built up a world-leading position together with our colleagues in Linköping.

The wide range of research disciplines needed to fully understand massive MIMO makes it a truly multi-disciplinary effort, where many fundamental questions land on the border between traditional research areas. Interaction between the propagation environment and the antennas is much stronger than in traditional systems, bringing antenna design and wireless propagation studies closer together than ever before. The specific properties of the resulting communication channel has a major impact on how antenna signals should be processed to obtain maximum performance at a minimum of processing effort, using novel hardware solutions. Entirely new approaches are required and this brings together the areas of communication theory, signal processing, and analogue/digital hardware design.

Massive MIMO results open up for many challenges when it comes to both fundamental research and implementation-related issues. Challenges include, for example, wave propagation in a massive MIMO context and the interaction between the wireless propagation channel, the massive antenna, and the signal processing algorithms, i.e. the mathematical calculations that are applied to attain high efficiency and separate the users that are transmitting at the same time on the same frequency. Radio waves do not behave exactly like light, so the analogy above with the camera is slightly oversimplified; in order to design and optimise algorithms that separate users transmitting simultaneously we need a deep understanding of the propagation behaviour. This behaviour is of course the same whichever radio-based technique we are using for transmission, but the importance of various properties changes with the transmission technology used. In conventional cellular systems, the base station antenna typically has a limited size and there are typically only up to four antennas simultaneously serving a user in the most advanced cellular systems of today. When we put hundreds of antennas at the base station, not all antenna elements experience the same channel properties, and this has to be taken into account in both system and algorithm design. Going back to the camera example, there can be very bright light in parts of the picture and very dark areas in the picture at the same time. This creates a problem for the detection and transmission algorithms as it can be hard to see the fine details in the darker areas, details which are needed to separate the users from each other. Also, in order to achieve the promises of highly energy-efficient transmission using massive MIMO, algorithms have to learn, follow and adjust to the instantaneous
channel condition thousands of times per second. It is therefore crucial that the complexity of detection and transmission algorithms is reduced to a level where processing requirements actually can be managed. It is still an open question how algorithms and shuffling of data inside the base station is to be implemented in the most energy-efficient and cost-efficient way, and hence this is another very important area of research. The energy and cost efficiency aspect is also essential when it comes to the hardware design. Massive MIMO offers new design challenges for the hardware, but also provides opportunities for efficient silicon implementations. The excess number of the antennas at the base station can to some extent be used to relax the requirements of, for example, highly accurate amplifiers, which in turn translates to even better energy efficiency and lower costs for the whole system. The highly parallel structure used to handle the many antennas in the base station also allows for efficient hardware implementation. As opposed to conventional wireless and cellular systems, the massive MIMO system is not dependent on a single antenna behaviour, including its radio and signal processing parts, but relies on the combined effect of hundreds of such radio chains. This opens up possibilities for using low-cost, low-power technology even in base stations that are traditionally based on more expensive and highly accurate components.

On top of the above-mentioned challenges to get a massive MIMO system to work and provide the basic service, i.e. transmitting bits from one place to another, with high efficiency from a transmission and energy perspective, there are all the other challenges typically encountered in any large-scale communication system. These are also dealt with within ELLIIT and concern applications, additional services, software development, etc. The breadth of expertise of the ELLIIT researchers has made it possible to include those aspects at an early stage in the discussions and solutions for a complete system.

The successful work on massive MIMO in ELLIIT has attracted a lot of international interest both in academia and in industry. Since the technology is a main candidate to be adopted in the next generation of wireless systems, 5G, we are cooperating with industrial partners both in Sweden and internationally to further develop the technology, to identify any possible bottlenecks and to establish best practice for how to apply and implement it. In January 2014 we started a new EU project, Massive MIMO for Efficient Transmission (MAMMOET), to take the technology from the lab to reality together with our partners: the research institute Imec in Belgium, the operator Telefonica in Spain, the Swedish systems provider Ericsson, the chip manufacturer Infineon and the coordinator Technikon in Austria and the universities of Linköping and Leuven, Belgium. We also cooperate with the originator of massive MIMO, Thomas Marzetta at Alcatel-Lucent Bell Labs in the US who is also in the advisory groups of both ELLIIT and MAMMOET.

All in all, the establishment of ELLIIT has spurred us to take new initiatives and gather a critical mass for exploitation of this new technology in the field of ICT. The coherent multidisciplinary effort would probably not have taken place without the creation of the strategic research area, and this has enabled us to move many traditional research areas forward. Seen from an academic perspective, these efforts have already paid off in terms of reputation, publications, citations and new interesting research projects, and we are convinced that in the near future they will also pay off from an industrial perspective by keeping the Swedish telecommunications industry at a highly competitive level and opening up new opportunities for the future. □
Mobile communications going massive

The coordinator of the Lund part of ELLIIT and the deputy coordinator of ELLIIT as a whole is Professor Karl-Erik Årzén at the Department of Automatic Control. His research area is embedded control systems and control applied to computing systems. He is member of the Royal Swedish Academy of Engineering Sciences (IVA).

The Lund University massive MIMO testbed, LuMaMi, with all its antenna elements at the front and the radio units behind. The testbed, including the antenna, is 1.2 m wide and 1.5 m tall.

The overall goal of ELLIIT is to improve performance, efficiency, and time to market of ICT systems, whilst reducing cost. ELLIIT covers communications and networks, electronics, embedded systems, software, autonomous systems, and complex systems. The departments at LU involved are Electrical Engineering, Computer Science and Automatic Control, as well as the Mathematical Imaging Group.

Half of the budget is used for high-profile, mostly international, academic staff positions. The other half is used to fund projects that should be inter-disciplinary and involve partners from multiple sites. ELLIIT arranges an annual workshop, has an industrial advisory board and issues quarterly newsletters.

ELLIIT is a collaboration involving Linköping University, Lund University, Halmstad University, and Blekinge Institute of Technology. The total budget for 2014 is SEK 31 513 000 with the following split: Linköping (45%), Lund (45%), Halmstad (5%), and Blekinge (5%). Erik G. Larsson, LiU, is coordinator with Karl-Erik Årzén, LU, as deputy coordinator.

www.liu.se/elliit
13:
Production and materials for long-term sustainability

JAN-ERIC STÄHL
We have production and materials engineering in focus – with an overall ambition to increase industrial competitiveness and to reach long term sustainability.

SPI – Sustainable Production Initiative – consists of research groups at Chalmers University of Technology and Lund University. The scope of our research is very broad and includes design and production of traditional products that people use in their everyday lives – such as household items, garden tools, household appliances and vehicles. The driving forces for our production research centre around environmental considerations, while still keeping the productivity and competitiveness of the manufacturing process as our constant target.

Production systems and manufacturing technology are at the heart of our work – with an overall focus on long term sustainability. SPI – the Sustainable Production Initiative – consists of research groups at Chalmers University of Technology (SPI/Chalmers) and Lund University (SPI/LU). The scope of our research is very broad and includes design and production of traditional products that people use in their everyday lives, such as household items, garden tools, household appliances and vehicles. The driving forces for our production research centre around environmental considerations, while still keeping the productivity and competitiveness of the manufacturing process as our constant target.

Introduction to SPI
Increased environmental awareness over the past two decades has contributed to production research taking a sharp shift towards development of more environmentally friendly products and technologies. These are expected to contribute to the reduction of greenhouse gases and toxic substances in combination with a general improvement in utilisation of resources. The fundament and the driving force of today's research and development in the field of production are based on the newly formulated societal challenges.

It is well documented and widely acknowledged that we face major societal challenges that are directly linked to both environmental impact and an incipient shortage of certain natural resources. There is an established four-step approach in the area of production science, which clearly links the research to the identified societal challenges. A research project should lead to certain outcomes (1) which give direct impact on the
Role and priorities of Lund University in SPI
Activities at Lund University are fully complementary to the research at Chalmers. Besides that, the activities at Lund University are the centre of gravity for the research done in areas I and II. The research at Lund University is mostly process-oriented and therefore it is of cross-disciplinary nature. Most of the research spans many classical disciplines such as applied mechanics, thermodynamics, materials science, electrical engineering and economics. Our research projects are divided into four categories (A-D): Machining of Advanced Materials (A), Complex Production Processes (B), Energy-Efficient Processes (C), and Sustainable Manufacturing Systems (D). This division is made despite some projects overlapping in scope and the same researchers being involved in several areas. This approach leads to broader projects, thus increasing industrial relevance and promoting professional development of researchers and their collaboration.

Collaboration with industry and other parts of society
Almost all research within the field of production science has a strong industrial relevance, with employees of the industrial partners regularly involved in the research project activities. The number of industry-employed doctoral students was increased, together with the number of students funded by external mobility programmes. More than 12% of the published scientific papers are co-authored by one or more industrial partners and about 25% are written in collaboration with other external partners such as Chalmers, Linköping University or the Institute for Superhard Materials.

Participation of industrial companies and their role
Both the large enterprises (XLE), for example Sandvik, Seco Tools, Volvo Cars and Siemens, and smaller companies (SME)
SPI/LU invests in specialised equipment for the measurement and analysis of production-related processes. Access to the other types of equipment is done through various forms of cooperation. Examples of important equipment partners are the Nanometer Structure Consortium (nmC) and the National Centre for High Resolution Electron Microscopy (nCHREM), both from Lund University, and also with partners at Chalmers and Linköping University.

Examples of research at Lund University
Our research group is involved in a wider range of activities and a few good examples are shown below.

Tooling as a key to efficient machining of advanced materials (A)
Efficient utilisation of a machining process, which still remains the dominant method in modern production, requires operation under the maximum possible material removal rate (MRR) in order to be efficient. MRR, being the volume of the material removed per unit of time, is decided by cutting data. The level of such maximisation is limited by the loads that act on a cutting tool that are brought by the selected cutting data. Five primary types of loads are distinguished: mechanical, tribologic, thermal, adhesion, and chemical, and the properties of a cutting tool ought to counterbalance either a single (dominant) load or their combined action. It is not possible to solve all load cases at once because a wide variety of unique applications exists. Over the past few years, our research group has started a collaboration with the Institute for Superhard Materials (Ukraine) in the area of tool material development. Tool materials based on application-driven ideas generated within SPI/LU are continuously produced at ISM in research quantities.

National and international cooperation
A key to success in the area of production science is cooperation, mainly with other researchers who have complementary skills, often specialists in any of the basic subjects that make up the field of production science. Especially important is cooperation on the use of sophisticated and expensive equipment, which is highly important if a research group is small. Our group has established a contact network which includes partners with specific key skills or facilities, for example some research is done together with groups in Ukraine, Poland, France, Germany and the USA in the field of super-hard phases, which constitute an important base component for new tool materials. An exchange of researchers is ongoing between Lund University and the Institute for Superhard Materials (ISM) in Kiev, which is one of the leading groups in the world in the field of materials for high performance tools. Tool materials based on application-driven ideas generated within SPI/LU are continuously produced at ISM in research quantities.

such as Willo and MMA are involved in activities within the framework of SPI. The role of companies in the research varies from company to company, some assist with equipment and materials, others are directly involved in the research through the involvement of industry-employed doctoral students. The main role of the companies is usually to join forces with academia in order to identify industrial problems that may later form the basis for research questions, which in turn can be related to the challenges described above which society is facing. Another important role that companies have is to assist with case studies and actual production lines or special equipment on which the laboratory research findings can be verified or possibly implemented at later stages.

Production and materials for long-term sustainability
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It is well known that machinability of a material is strongly related to the microstructure and micro-mechanical properties of the material. Factors such as grain size, phases present and their relative amounts, and micro-mechanical properties such as hardness play an important role in determining the extent of tool wear, stability and surface quality during machining. With a grid indentation approach, the micro-mechanical properties related to the phase variation and microstructure can be characterised, which may provide insight into the machinability of the material. Grid nano-indentation is based on a large array of nano-indentation tests used to analyse and characterise the mechanical properties of the material. Through collaboration with Xylem Water Solution, the current project is intended to characterise the micro-mechanical properties of the high-chromium white cast iron with different chemical compositions and heat treatments. The objective is to quantify the role of the microstructure and micro-mechanical properties of the materials on the wear of cutting tools during machining. The ultimate goal of the research will result in cost effective production of components made of wear-resistant materials through optimisation of the machinability and performance of the materials.

Effective utilisation of cutting tools is an approach for attaining sustainability during production which has largely been overlooked in previous research. By increasing the utilisation of the cutting tool, the need for new tools decreases as well as the resources and energy needed to produce these new cutting tools. The aim of this study has been to maximise cutting tool utilisation during machining operations without adversely affecting product quality, thus decreasing the environmental impact of machining operations. This was achieved by determining to what extent it is possible to increase total tool life by using previously worn tools in a secondary machining operation. For both the milling and turning cases investigated, experimental results showed that it is possible to increase total tool life by 50% to 100% compared to equivalent conventional machining operations. The increase in tool life could decrease the production cycle time by approximately 15% and reduce energy consumption by 12% as compared to conventional machining processes. Later research has also proven the proposed method to be a viable approach in the automotive industry.

Production of automotive components using lightweight materials is crucial for reduction of fuel consumption and CO2 emissions. For over a year our research group led by Jan-Eric Ståhl has collaborated with Volvo Cars in Floby on the project of manufacturing lightweight brake discs based on MMC.
(metal matrix composite) material, an aluminium alloy reinforced with silicon-carbide (Al/SiC). The MMC brake disc system has a potential weight reduction of as much as 50 to 60% compared to the conventional grey cast iron brake system. So far, about 12 000 such discs have been mounted on the rear axle of Volvo V40 cars, with a total weight reduction of 60 tons, possibly equivalent to a reduction in annual fuel consumption of about 40 m3. Volvo Cars has developed a production line for prototyping of complete MMC brake discs based on a modified squeeze casting process. The production line, however, is limited by production volume due to high production costs. Through the project SiCAlight II, which is a so-called bridge project, the conditions for mass production of components in MMC are being investigated. The project will continue throughout 2014 and is primarily directed towards die casting, hot forging and machining. In the project, part of the previous work will continue, including testing of new cutting tool materials based on superhard phases. SiCAlight II is a research and development project with a focus on the application, optimisation, and industrial implementation of MMC for various lightweight components.

**FEM analysis of specific phenomena in metal cutting (A)**

The finite element method is a numerical method which can be used, for example, to simulate mechanical and thermal behaviour. The method is of great importance for describing and analysing a machining process. The method makes it possible to investigate some phenomena in the machining process which are difficult to verify experimentally. One of these phenomena is the minimum chip thickness – the lowest thickness at which a chip is produced. The minimum chip thickness is closely related to the location of the stagnation point formed by the machining process. The stagnation point is the location where the workpiece material either flows upwards and forms the actual chip or is pushed under the cutting tool and forms a ploughed surface. The material that is pushed under the cutting tool will form a deformed layer at the new surface. This layer is of great importance for the strength of produced components, since this layer will be harder than the bulk material of the component. In the current activities a reliable FEM model of this phenomenon was built and the recent results have been used as a guideline for optimisation of tool geometry for the participating companies in the tooling industry.

**Energy-efficient production processes (B)**

Induction heating is a sustainable technology that enables both significant reduction of energy consumption in industrial processes and increased process performance and productivity. The department has been working in the area of induction heating for many years, combining development of new materials with improved induction technology. These efforts have resulted in new materials as well as new ways of producing induction heaters, allowing not only a simplified production method, but also a product with significantly improved efficiency as a result of reduced electromagnetic emissions compared to traditional induction heating. The results are now being implemented in an increasing number of industries both in Sweden and abroad, with large financial and environmental savings. The industries range from steel and engineering to the composite, laminate and food industries. The applications for industrial heating are many, but often require not only fast and efficient supply of energy, but also uniform temperature over large areas, which is
difficult to achieve using induction or many alternative methods. Development of an inductor able to produce uniform and controllable heating allows the technology to play a key part in an even larger range of applications than today. These kinds of heaters are currently being developed and analysed in detail by our research group. The technology has the potential to reduce energy consumption in a conventional industrial process by 90% and at the same time significantly increase productivity. A very interesting application area for induction heating is the processing of CFRP, carbon fibre reinforced plastics. Carbon composites display unique properties in many aspects, e.g. thermal conductivity and stiffness, properties that can be used to promote environmental friendliness and sustainability in products such as (electric) vehicles. Using induction heating in the processing of CFRP can enable more efficient production technology and thus introduce the material at a larger industrial scale and in a wider range of products.

Economic models with a direct link to production performance (D)
Models that describe the important link between technology and the economy are required in order to take optimal technical decisions for strengthening competitiveness. The economic models earlier developed at Lund University were both complemented and further developed in the course of SPI/LU implementation. Some models address issues of automation, for example manpower optimisation with focus on assembly operations, and decision support for selection of optimum automation. Some models look into performance issues, for example economically based key performance indicators, and batch size optimisation including the perspective of production performance. Others go directly into the costs, for example cost modelling of balance delay, analysis of dynamic costs through the statistics of the manufacturing, models for dynamic costs based on Monte Carlo simulation, and basic principles for incremental manufacturing development. Several of the models above have already been implemented in industry. The entire set of models is included in two degree programmes at Lund University, one an MSc and the other a PhD programme.

Cost-based decision support in production (D)
Many strategic decisions are governed by economic incentives and the results of any change in production layout, equipment, relocation of production or suchlike will cause a change in economic outcome, sometimes not in accordance with what was expected. This incurs a need for cost decision support capable of visualising the effects of a bundle of changes in the production system, known as scenario simulations. For this purpose a cost model linking economic outcome with production performance is under constant development in various ongoing research projects, in close collaboration with industry. The cost model has been used as a base for developing decision support in the following focus areas: production development, production location and production sustainability.

In production relocation, one major issue is estimating if the benefit from low wages exceeds the possible costs of quality, supplier assurance, knowledge provision, etc. In collaboration with colleagues at Mälardalen University and five industrial partners, we have developed a method to support companies in their decisions on where to locate production.

Another important issue when improving profitability is to select the production development activities that will have the greatest economic impact. Here we have worked with com-
panies to develop cost-based decision support for areas such as selecting between different finishing operations in gear manufacturing and analysing the effects of changing automation level. Sustainability is a growing concern for manufacturing companies, and there are not seldom economic benefits to sustainable strategic choices in production. In this area, we have analysed the costs and benefits of manufacturing with and without cutting fluids, in partnership with a vehicle manufacturer. Manufacturing cost analysis for hybrid and electric vehicle production is another research activity to help vehicle manufacturers to make strategic choices towards increased sustainability.

Dissemination of results
The research results from SPI/LU are used and disseminated in several ways. The greatest impact is achieved by packaging the results into courses for students at undergraduate or doctoral level. At present, there are several courses that are heavily based on the research results obtained. These include the advanced courses in Machining and Manufacturing Systems offered both to Lund University students and as national PhD courses under the auspices of the Swedish Production Academy. The research results are also reported in the form of regular seminar series for industry, in some cases even for the international industrial community.

Since 2007, prior to the allocation of the resources to Strategic Research Areas, there was a discussion at the Swedish Production Academy that the academics working in the area of production science should endeavour to change their policies regarding scientific publications. Prior to 2007, there was no desire or ambition to publish scientific papers in journals, since the value of this was limited. The few international publications made were primarily presented at conferences, often with a high degree of industrial application. The focus was solely on research reports and theses published as monographs. At that time the applied research stood closer to industry and the problems it encountered. Today, production science strives to work in the following directions for dissemination of results: scientific publications in indexed journals; a continuous process of updating teaching materials in order to maximise employability of the students; industrial implementation of research results; and participation in the development of competences for industrial personnel.

SPI/LU tries to keep a level of 50% of the publications to be made by senior researchers and 50% by doctoral students who have their name first in order to both maintain the high quality and the high volume in research efforts. Extra effort is put in to make sure that 50% of the scientific papers are published in journals and 50% at conferences associated with networking.

Examples of changes in research activities at Lund University within SPI
Essentially, the research will continue in line with the activities in the area of sustainable production reported above. The clear change that is coming up for the SPI/LU programme is a strong collaboration with the research infrastructures of MAX IV and ESS and their subcontractors, including issues of the production of accelerator components in exotic and advanced materials. Later, the use of the equipment is planned to be part of this collaboration including, for example, analysis of the degradation of cutting tools based on superhard phases. □
About SPI – Organisation and management of the Sustainable Production Initiative

Grant recipient and the main applicant for SPI is Chalmers University of Technology, which consumes about 80% of the available resources. The overall responsibility for SPI is held by Professor Rikard Söderberg. The research is controlled by roadmaps and 15 active interdisciplinary research fields within which Lund University and Chalmers interact. The SPI is grouped into three main areas, and the area of sustainable production processes is jointly led by Professor Jan-Eric Ståhl at Lund University and Professor Lars Nyborg, Chalmers.

The research at Lund University is led by Professor Jan-Eric Ståhl with assistance from a reference group and with the support of a deputy coordinator, Associate Professor Carin Andersson. The allocation of resources is based on established principles and takes place in dialogue between PI Professor Jan-Eric Ståhl, head of the Department of Mechanical Engineering at Lund University Mats Andersson, and representatives from Chalmers.

www.iprod.lth.se

Jan-Eric Ståhl received his MSc and PhD from Lund University, Sweden, in 1982 and 1986 respectively. He was appointed as Associate Professor and later Professor at the Department of Mechanical Engineering, Lund University, in 1987 and 1990 respectively. He initiated and started the Swedish Production Academy in 2006 and has been its president for two terms.
Epilogue
14:

In essence, this belongs to you

SARA NAURIN
We learn as we go along. Answers lead to new questions. If there really are limits to science that are not of our own making, we will only know it when we reach them. Until then, there is a lot of research to do.

PROFESSOR MARKKU RUMMUKAINEN
/ COORDINATOR OF MERGE

I SPENT SOME TIME thinking about this closing article as we started writing this book. My instructions had been brief: to write about science and the future from a more philosophical point of view. As the researchers started sending me chapter after chapter outlining their scientific breakthroughs, I decided that what I really ought to do is point out to all those who read this book that they, themselves, have helped bring about the science and the progress described in it. You, regardless of who you are, can claim ownership of the hard work and creativity presented here. It’s a fantastic thing to own – and to me, the real purpose of this book is to place it in the hands of its rightful owners: your hands.

During the past five years, researchers in the environments presented in this book have published many hundreds of papers in prestigious scientific and scholarly journals. They have engaged industry and decision-makers, and they have produced numerous patents and spin off companies – seeking to ensure that their innovations reach the public. They have engaged in political debates and contributed to the reports of the Intergovernmental Panel on Climate Change. They have advised landowners. They have made breakthroughs in the understanding of stem cells and cancer, and in the treatment of diabetes and neurological diseases. They have created huge biobanks to study the distribution and nature of common illnesses. They have improved climate models and published unique books on the protests in the Middle East. They have designed LED lights that please the human eye and new solar cells that use only a fraction of the material of conventional ones. They have worked towards new ways of revolutionising mobile communications and sustainable production. They have helped archaeologists make 3D images of Pompeii and are now trying
to perfect images from MRI scanners to ensure that miniscule structures in the living human brain can be studied. Flipping through the pages, I find it almost too much to take in. But it illustrates the human potential in a wonderful way.

What, then, is a university? Is it just a collection of buildings housing brilliant scientists? Or just an organisation meant to offer education? Or is it in fact something much bigger than that? Universities may host excellent research, but they also host ambitions and hopes of new futures – yours, and mine. They may transform society through brilliant science – but they also transform societies by bringing people from different backgrounds together, pulling their worldviews closer to each other, and filling them with new perspectives. If the excellent research groups represented in this book can pull more hopes and more potential futures to Lund University, then they will have served society just as well as they ever could through any cures, pieces of specific knowledge, political solutions or new techniques.

‘Does the university have a duty to set some kind of moral example?’ I asked its vice-chancellor, Per Eriksson.

‘Yes,’ he replied, ‘I think we do. And we have clearly stated our values. The critical scientific approach is among them, and human rights – and so on. Students today are often very ideologically driven, and it is important that we listen to them.’

‘I’ve been thinking,’ I said, ‘about how the research groups represented in this book may be hosted here physically – buildings, office chairs, printers, lecture halls. But intellectually, their geographical span is vast. It stretches over many borders, and the quality of their research is dependent not just on Lund University and the Swedish Government but on many universities and governments across the world. Would you agree that a university of today is like an airport: international territory, constantly full of people entering and exiting?’

‘Yes,’ he said, ‘the concept of a university is international by definition – after all, the word itself means “all-encompassing”.’

‘So what is a SWEDISH university, then?’, I wondered. ‘Is a Swedish university different in any way from other universities?’

He considered my question. ‘No,’ he said at last, ‘I don’t think you could truly claim that there is such a thing as a “Swedish” university, in particular since international connections are such a clear indication of quality for organisations like ours. In Lund, some 10-15% of our academic staff and students are international. But the very best and most prestigious universities in the world have much higher numbers, in the range of 20-25%. However, at the same time it is important that we should stay strongly connected to Sweden. If we don’t, we risk losing our legitimacy at home.’

‘You know,’ put in Sven Strömqvist, the pro vice-chancellor for research, ‘I believe that by asking that question you hit the nail on the head as regards the university’s role in society: to connect us with the world, to connect us to the newest and best thinking when it comes to humanity’s great challenges. What we aim to do is to understand, explain and improve the world around us.’

The vice-chancellor nodded. ‘And the world’, he added, ‘will always be much bigger than just Sweden.’

Yes, I thought, the world is bigger than just Sweden. It’s really quite simple. Being human is belonging to humanity, and humanity is global. Science, like all thought, permeates all of us – because humanity is simply a network of brains (and the internet, you could argue, is just a physical manifestation of what we have always been).

The network of thought that is humankind spans not only the entire planet, but also across the ages. It runs from the past, through the point that happens to be the present as you read
this, and on towards the future. We try our very best to influence what the future will be like, and our imagination is our key tool to make each new present a little better than the last. But how can we possibly judge what is better or worse unless we stay connected to the past? We need a trajectory – it is like judging where to stand in order to catch a flying ball: you cannot predict where it will move unless you know not only where it is now but also where it was a moment ago. Humanity’s network of thought will only ever be useful if it continuously stores memories of the past and uses them to make its predictions of what is likely to come. A university sits in a global network of universities, but – just as importantly for progress – it also sits on a node connecting the universities of the past with those of the future.

When I discussed this closing article with Professor Markku Rummukainen, who co-ordinates MERGE, the strategic research environment focussed on climate models, he suggested that perhaps I should write a letter from tomorrow, describing a world where all the goals pursued by the researchers in this book have been achieved, and where science has moved on from every question they are now posing. Imagine that: no diabetes, no cancer, no neurological disease, no destructive effects of climate change, more effective communication, sustainable production, nanotechnology revolutionising industry and health-care, and so on and on – the list is endless. It would be like describing utopia. Or would it?

‘Are there any limits,’ I asked Per Eriksson, ‘any limits at all to what we will be able to achieve in the future?’

‘There will always be new challenges,’ he replied. ‘That is what characterises good scientific development: whenever we have a breakthrough, we enter a new world, full of new questions.’

‘And besides,’ Sven Strömqvist added, ‘questions are more exciting than answers. It’s the questions that lead to new approaches, new avenues and a constant renewal of exploration.’

‘What you experience’, Per Eriksson continued, ‘is that science challenges boundaries, penetrates them, constantly pushes them forwards – in that sense we will never run out of problems to solve. The questions keep accumulating. As we find out more, we become more knowledgeable about our ignorance. In fact, the amount we don’t know anything about is constantly growing.’

Sven Strömqvist laughed. ‘It’s like entropy,’ he said.

‘Someone once wrote something funny about this,’ Per Eriksson replied, smiling. ‘It went something like this: “Thank God for all our brilliant experts who know more and more about smaller and smaller subjects, until they know everything about nothing”.’

I laughed with them, because it is funny – especially coming from the vice-chancellor where he is sitting in the University’s grandly designed main building. And of course it is true that the challenges just keep on accumulating. But still, I find the question interesting: in the long run, will we be capable of everything? Can humanity truly achieve anything? Are there no limits? I wanted to hear what the researchers thought about that, so I asked Professor Heiner Linke, who co-ordinates the strategic research environment focussed on nanoscience. In the future, I asked, will everything be possible for science? Are there any limitations? His reply came back partly echoing the one Per Eriksson and Sven Strömqvist had given me.

‘I am convinced’, he wrote, ‘that we will continue to see scientific breakthroughs and applications of scientific results that we today cannot imagine or anticipate. At the same time, even in the future each new insight will lead to new questions and
new directions of inquiry. By necessity, science needs to solve the relatively “easy” questions first, and we haven't even begun to tackle some of the truly complex problems.’

‘One step at a time’, the last part of that answer whispered to me. Progress is climbing one small obstacle at a time. It is like evolution – a million tiny, seemingly insignificant, steps leading from the very first living cell, millions of years ago, to the amazing variety of life today. Complexity is simply less complex things working together.

Still curious, I sent the same question to Professor Susanne Iwarsson, who co-ordinates MultiPark, the strategic research environment focussed on neurodegenerative disorders. I thought someone working in medicine might have another angle to offer.

‘Actually,’ she replied, ‘as a researcher I would like to think that there are no limits to science, given that our creativity and curiosity are unlimited and thus generate enormous potential. But the answer to this question is also dependent on the time frame – the longer the time perspective, the more likely it is that research really will move the knowledge borders beyond what we would think of as possible today. In a shorter time perspective, realistically speaking there are of course limitations. Nevertheless, the historical development in research within medicine and health shows that many achievements made by science have changed the prognosis and life situation of many people for whom survival and a good life were not possible until the most recent decades.’

I liked that. ‘There are no limits to science, because our creativity and curiosity are unlimited.’ That rings true to me. Science is thinking, and our thoughts can be endlessly combined into new solutions. And more: ‘The answer to this question is dependent on the time frame.’ Yes, the network of thought spans across the ages. If we could distance ourselves from it, we would see that, with time, anything can be achieved. But if you are suffering from an illness now, how much comfort does it give you to know that in a thousand years there will be a cure? The network is never-ending, but we, as individuals tapping into it for a single lifetime, certainly are not. And someone who is working on a daily basis with people suffering from disease will of course always be conscious of that truth.

Finally, I put my question to Professor Leif Stenberg, who co-ordinates MECW, the strategic research environment focusing on Middle Eastern studies. I thought that, given his field of research, perhaps he could provide yet another point of view.

‘In my view,’ he wrote back in reply, ‘research has no limitation either in regard to what we can or should study, or when it comes to what can be achieved. My sincere belief is that science and scholarship, in all their aspects, build on openness. And I am concerned about how current political, economic, social and religious interests strive to direct and regulate research globally.’

It might sound odd, given the gravity of his last sentence, but his answer made me happy. You see, all types of governmental funding of research could be seen as attempts to direct it. But when the Swedish Government funded the research groups in this book, they spent the money trying to encourage critical thinking. It makes me truly happy that, in some places at least, there are governments that recognise the value of challenging questions, and that are willing to pay to set minds free.
Still, none of the answers I had received said much about the limitations of humanity. I find that interesting, because I happen to be a biologist myself and, to me, those limitations are ever-present. Humans, as biological creatures, have inherent limitations. We cannot see all types of light – for example, we are blind to ultraviolet. We cannot hear all sounds, and a dog can pick up on thousands of more types of scent.

Science, like all thought, permeates humanity – that’s what I just wrote. And humanity is a network of brains. Brains, however, are physical organs. They are pure biological constructs, just like an eye, or a hand, or a heart. Thought is not without limit. Thought is a physiological process, limited by the structure of our brains. This makes me wonder whether what will truly limit us in the future may be what questions we think to ask? Because what is important to a human, truly? Where does our need, and our capabilities, direct our attention?

Surely, it takes specific training to be mesmerised by that which we cannot perceive? I wonder if that might be the true legacy of science: the ability to help us free our minds from biological and physical restraints – at least a little bit, sometimes? Look in the microscope, the telescope, the computer. It’s there – there are things there worthy of thought.

I remember the first time I bought a spotting scope. I was working as an ornithologist and needed to observe nesting birds. One night I directed it at the sky instead – it just occurred to me on a whim that I could. I found Saturn. It gave me goose bumps. Not because it was a fantastic image of a far-away planet. Actually, it was blurry and small – really, it was tiny – because the scope I was using was built to study birds, and they fly somewhat closer than a billion and a half kilometres or so. But still, that blurry image gave me goose bumps, because it was so obviously Saturn. You know, the rings around it – you know what it looks like. It was up there, undoubtedly. There was the sky above me, and in it hung Saturn. I was standing on my porch, scope pointed upwards, looking at it. I could not deny it, it would have been outright ridiculous to deny its existence, because there it was. At that moment, Saturn became something more to me than pictures shown to me by people who claimed to have seen it.

My crucial point is that I would never have thought to look for it unless someone had taken those pictures and pointed the way. Scientists point the way. At times, what they describe may seem far away, tiny and blurry – until you happen to buy a spotting scope and realise it’s much closer to you than you thought. Then it occurs to you, as you stare at Saturn hanging there looking exactly like they claimed it would: well, if it’s up there, what about that comet, the one they say wiped out the dinosaurs? Are there any more of them out there? Because you know, if there is, I’d like us to spend some money figuring out how not to be hit by one.

There are different types of comets, different types of spotting scopes, many different types of research. The truth is, we do not always know what to look for, or even where. So we cast our nets wide, try our best to cover even the places where we have yet to realise it is crucial to look. And here comes the truth. You are the one funding it. Your tax money pays for it. It is undoubtedly one of the most important things that you are funding, because that investment represents movement. It is the essence of our possibility to adapt and develop. Take a look at what the scientists in this book have achieved and realise that you have something to be proud of. Because the simple truth is that there would be no Lund University without
your hard hours of work. The researchers are pointing the way because you signed a covenant – I will agree to pay, you said, so we can capitalise on their curiosity. You pay them to look even where there is seemingly nothing to see, and because of what they have been trained to perceive, they find new paths through our collective blindness. Come to the university and they will tell you how. They will welcome the opportunity to shake your hand. □

Sara Naurin is the editor and project manager of this book. She holds a PhD in biology, is a researcher, writer and research advisor.
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