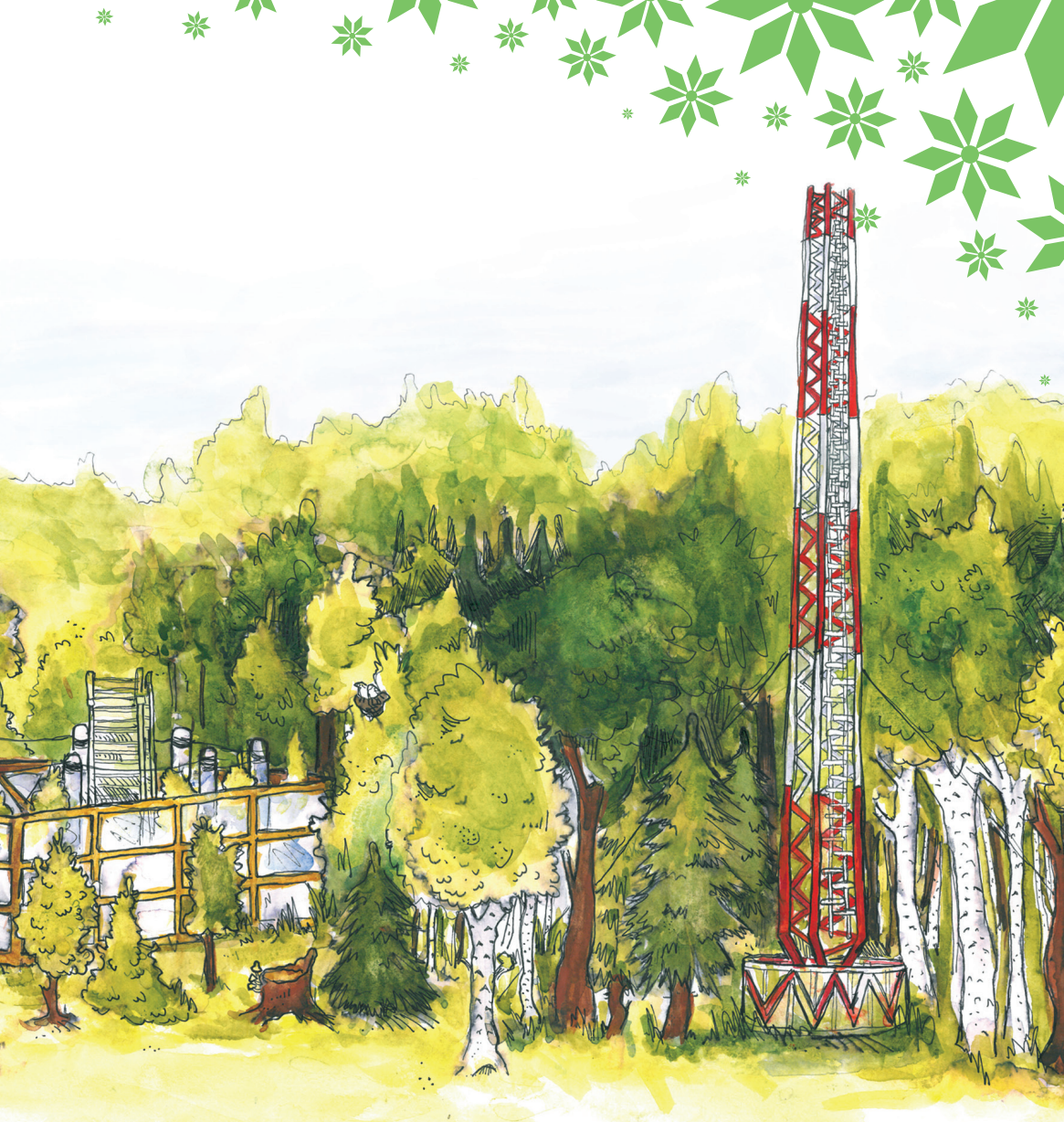

Research in Estonia

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FEATURED STORIES

INTRODUCTION

This little booklet presents a selection of Estonian science. Measuring the ecosystem, the only air humidifying experiment in the world, plants' tolerance to environmental changes are just one part of the selection you can find on this booklet. While the scope is wide, we hope that a theme emerges from many of the presented stories. This is the idea of Estonian research – growth and transformation.

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Research news and institutions:
www.researchinestonia.eu

Produced by Estonian Research Council

Texts compiled by Piret Pappel and Arko Olesk

ESTONIAN SCIENCE SCENE

A small country with population of 1.3 million people.
Is Estonian science any good?

The small country is well-known for molecular biology and biotechnology. There are eight research centers and approximately 60 biotechnology enterprises. The Estonian Genome Center is a fully functional biobank.

Estonians have great ambitions in digital innovation. Estonia is first country in the world to offer e-residency – a digital citizenship – for the people around the world. State-proven digital identity gives easy access to several online services – healthcare, banking, education.
The new hype is space. Remote sensing of environment is developing fast. Student satellite ESTCube was hugely popular among Estonians. Estonia became member of European Space Agency in early 2015.

Estonia is birthplace of the semiotics of culture and biosemiotics. The oldest periodical journal of semiotics - Sign Systems Studies - is published in Tartu.

Research is mostly performed at the universities. The largestest public research universities are University of Tartu, Tallinn University of Technology, Tallinn University and Estonian University of Life Sciences.

There are several independent research institutions as well - Estonian Literary Museum, The Institute of the Estonian Language, Estonian Biocentre. The best scientists gather at the Research Centres of Excellence, where they can work at the internationally highly regarded research groups. The Competence Centres collaborate in strategic fields between the public, private companies and universities.

Almost all fundamental research is conducted in the public institutions and the private sector concentrates mainly on product development.

The Estonian Academy of Sciences it is an independent group of top scientists whose stated aim is to promote research and help to implement research results in the interests of Estonia. It also encourages research cooperation and represents Estonian science internationally.

The importance of Plant Science

Everybody knows green is good. Lettuce and cabbage are part of healthy diet. Decorative plants are nice to look at. We all know that different plants provide the major food source for the people. Also wood is very important. But let´s remember – plants provide use with very much more.

What would happen if there were no plants at all? Do we survive eating only meat? Sometimes, almost accidentally we remember that green plants do produce oxygen. Hmm…. What about breathing?

Let the plant science explain the importance of plants. Our earth is called the Blue Planet, but from human perspective it is the Green Planet first of all.

Plants provide habitat for millions of different species – bacteria, fungi, lichens, mosses, very different types of animals depend on plants to get food and shelter. You can see it walking in the forest or sitting on the meadow. Without plants there would be no hares, no little birds, no bugs, no butterflies at all.

But there are many things a human cannot see. Let´s count some of them. Yes, plants provide oxygen. O2 is byproduct of photosynthesis.

Plants regulate the water cycle. Their task is to help purify and distribute water on Earth. Plants purify air and ground. They protect soils against erosion.

Plants store carbon. They help to keep carbon dioxide out of atmosphere. CO2 is the gas that humans produce burning fossil fuels. Without plants carbon dioxide accumulation would be much faster as it is today.

So there are many important things we know about importance of plants. But there is also serious lack of knowledge about different questions in plant physiology.

How can plants contribute to solving the energy crisis and ameliorating global warming? Are humans capable to build an artificial green leaf and copy photosynthesis?

Can plants be bred to overcome drought or even reverse it? How do plants communicate with each other?

Let´s remember that plants provide very good model systems to understand general biological principles. Even evolutionary biology and genetics labs do work with plants.

Estonian plant science - amongst the global elite

Botany has traditionally been excellent in Estonia. Now it is absolute world-class science.

Estonian plant science started with early naturalists in the 18th century at the University of Tartu. After regaining independence all Estonian universities and research institutions went through complete reorganization in the 1990s. Nowadays the University of Tartu and the Estonian University of Life Sciences are the main centres of plant science.

There are two centres of excellence in plant and also animal sciences. **The Centre of Excellence in Environmental Adaptation (ENVIRON)** focuses on the mechanisms of environmental adaptation and feedbacks between plants and ecosystem adaptation in a changing climate.

The Centre is led by professor Ülo Niinemets (Estonian University of Life Sciences) who is the first Estonian scientist to receive the European Research Council's advanced grant (for the project "Stress-Induced Plant Volatiles in Biosphere-Atmosphere System").

The Centre of Excellence Frontiers in Biodiversity Research (FIBIR) tries to understand reasons behind the variable biodiversity in ecosystems with a different history and human impact. The Centre is led by professor Martin Zobel (University of Tartu), who is interested in patterns in grassland and forest communities, meadow restoration and diversity of arbuscular mycorrhizal fungi.

Scientists at **Tallinn University** study the impact of natural processes and human influences on different ecosystems, including wetlands and coastal area.

Researchers at the **Tallinn University of Technology** study plant genetics and cell biology. They focus on defense mechanisms of plants and genetic engineering of plants.

According to different science indexes plant science is one of the most successful research field in Estonia. The citation rate of Estonian botanists is about 30 % higher than global average.

Why? Probably this is a unique mixture of history and traditions, a little bit of luck, a lot of hard work and some charismatic leaders.

"Botany has traditionally been good in Estonia. The science has had decades of time to evolve and become mature with the support of strong leaders", Ülo Niinemets has said.

Investigating links between plants and air.
Ecosystem level.

HOW TO ANALYZE THE SMELL OF THE FOREST?

The sweet perfume of pine forest after rain. What is so good there? How does this smell change in time? You can analyze it, just a 130 m high tower is needed. Pay a visit to the science station in Järvselja forest, Estonia.

The Järvselja forest is a nature conservation area. It looks like a primeval forest – old downed trees decaying, covered with green mosses and rare lichens. Since 1921 this area has served as an experimental station for scientists and now it is home for the station for measuring ecosystem-atmosphere relation (SMEAR).

SMEAR stations provide data for energy and matter exchange analysis between atmosphere and biosphere. Cooperation between similar stations in Estonia and Finland is leading to a powerful scientific network. SMEAR Estonia is part of the project "Estonian Environmental Observatory".

What data does SMEAR collect and record? Just some examples: CO2 and H2O fluxes, wind, aerosols, leaf litter and root growth.

These parameters help to explain some really important aspects of interactions of trees and air.

How are clouds born and what influences these processes? How does pollution influence air quality and health of trees and the forest?

The Estonian SMEAR station has the highest mast among the SMEAR-network in Nordic Countries. 130 metres high mast provides a unique opportunity to measure and analyze different chemicals produced by trees and how air quality influences trees and other plants.

Steffen Noe is a senior researcher at the Estonian University of Life Sciences. His research focus is the smell of forest. Specifically – substances called monoterpenes. These molecules are known as components of the fragrant oils obtained from plant leaves and flowers.

Monoterpenes give plants their specific smell but these molecules also take part in cloud formation. Sounds surreal? Well, it isn´t.

In the morning sun starts to shine. But by midday there are first fog-like clouds in the sky. Surprisingly – many forest plants are to blame. When temperature rises, plants produce more volatile substances and these accelerate cloud formation. How do we know that? Thanks to data from the SMEAR-stations.

Investigating links between plant communities and environment.

HOW TO MANIPULATE AIR HUMIDITY IN THE FOREST?

Plenty of sunlight, enough water, good and rich soil – all three elements are essential for the growth of trees. Plant physiology experiments manipulate with light, water and nutrients mainly in greenhouses. In the wild it is much trickier. In 2005 Estonian scientists started an experiment to manipulate air humidity in the forest. It is the first of the kind in the world and has produced some really interesting scientific results.

The primary aim of project FAHM (a Facility for Free Air Humidity Manipulation) is to study the effects of air humidity on ecosystems and on the processes within those ecosystems.

Water vapor is one of the most important greenhouse gases. It absorbs heat emitted by the Earth and affects the global heat balance.

If humidity increases, will there be changes in species composition or in water, carbon and nitrogen cycles?

The project area in the Järvselja forest looks a little bit suspicious and extraterrestrial. One may ask - what are these devices for? What do these people do here? But the locals are used to scientists as the area has been used for forest research since 1921.

FAHM grows aspen and birch trees in experimental cells where air humidity is artificially increased. These cells are open from the top but surrounded by walls made of plastic to stop rapid movement of air out of the cells.

Water is passed through the nozzle system to form a fine mist that is spread throughout the experimental cell with the help of wind and a ventilator. Influx of moist air is controlled by a computer program. The system produces about 100 kilograms of mist in an hour.

During the vegetation period different parameters are measured and recorded: air humidity, temperature, soil temperature, sap flow in tree trunks.

Scientists assess the effects of air humidity on temperature of foliage, photosynthesis and leaf growth.

In short this experiment is about climate change. When climate is getting warmer will trees be bigger and taller? It may sound logical but the answer is actually no. Excess of water disturbs plants and trees and they start to suffer.

Lab work.

HOW DOES PLANT CHATTER CHANGE CLIMATE?

Humans do not consider plants as communicative living organisms. But plants do communicate and their language has great impact on climate.

Plants form an important pathway between ground and air. Vegetation has a major role in carbon cycle, water and energy exchange. Plants produce a lot of different substances. These molecules are part of "plant language". Caterpillar munching on juicy plant leaves forces the tree to produce specific molecules that signal to other trees to start protect themselves and produce bitter tasting chemicals.

Some plants produce these language molecules all the time, but in stressful conditions all plants synthesize them. Plant stress talk is of short-term but its influence is not well known.

Air becomes filled with different molecules which condensate and influence ozone and cloud formation and climate. How does plant stress influence climate?

Ülo Niinemets is professor and head of the Department of Plant Physiology at the Estonian University of Life Sciences.

Research at his laboratory focuses on plant stress in changing climates from stress responses to acclimation and adaptation. Plants are grown in glass chambers on different stress levels and the amount of stress hormones are recorded and analyzed.

The results of his work have been summarized in more than 230 international articles and book chapters. Niinemets is the first Estonian scientist to receive the prestigious European Research Council's advanced grant (for the project "Stress-Induced Plant Volatiles in Biosphere-Atmosphere System").

According to Niinemets plant adaptation data should be included in climate models to improve them. Biosphere has much greater influence on climate than commonly thought.

Last not least: relationship between plants and climate is mutual – plants influence climate and weather influences trees and flowers.

Take a look what breaks ground on Estonian research scene.

THE FUN OF LEARNING SCIENCE

Margus Pedaste is convinced that students have to learn too many scientific facts and terms at school. It would be much more effective, the professor of technology education in Tartu University argues, to have students learn science by solving problems.

"We found it was really helpful, and our research found that specific support on inquiry skills, whether Web-based or involving an actual experiment in the lab, had a great effect on students' learning."

He and his colleagues have devised software programs that are able to analyse how students solve problems and support every student according to their needs. "Such learning is possible in the "smart classroom" which effectively combines people and technology," he says.

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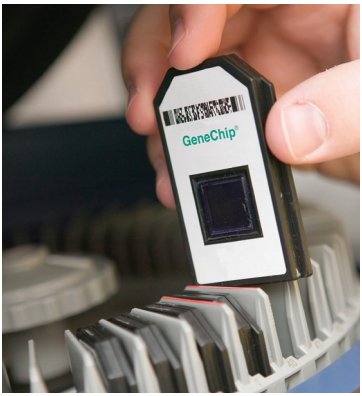
GETTING PERSONAL WITH YOUR GENES

50,000 Estonians have voluntarily donated blood to create the Estonian Biobank, a science project that has already greatly contributed to world knowledge about genes and their relation to various conditions and illnesses. But the aims of the scientist at Estonian Genome Center are much higher: everyone in Estonia aged 35 and higher should have their personal gene chip. This means the full genome sequence which would reveal any health risks and which their doctor could readily consult for any decision relating to the patient's health.

"The most important thing is that such personal approach will make people act for the benefit of their health," says professor Andres Metspalu, head of the Estonian Genome Center.



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HEARTS AND COINS

There is an electrical phenomenon – impedance – that allows us both to build better pacemakers and detect counterfeit coins. This is exactly what Mart Min, researcher at the Tallinn University of Technology has used impedance for.

Impedance, a measure of that how strongly a given material impedes travelling electricity through it - can be used to test the characteristics of many materials, both living and non-living. Min, a nominee for the European Inventor Award in 2011, has devised smarter cardiac pacemakers that can detect patients' workload and automatically adjust their heartbeat and also a device to discover counterfeit Euro coins.

His new impedance measurement technique could, in principle, be applied to all kinds of material, for example to assess the viability of organs for transplant and to monitor their functioning after the operation. "We are now discovering possible irregularities with freshly transplanted organs very early on", says the inventor.

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ALL GENETIC ROADS LEAD TO ESTONIA

Tartu, Estonia is the place to turn to when a nation gets gripped with the eternal question 'Where do we come from?'. Looking at the variation of genes, the scientists at Estonian Biocentre have traced ancient human migrations, helping to shed light on to the genetic origins of, among others, Native Americans or Aboriginal Australians.

They have also been collaborating with Danish scientists who have managed to sequence some of the oldest oldest anatomically modern human genomes so far. Most recently, they published in the journal Nature the genome analysis of a boy who lived 24,000 years ago on the shores of Lake Baikal in Siberia.] – kui kärpida vaja, siis see lõik

Currently, Estonian Biocentre coordinates a consortium of some of the top labs in the field analyzing one of the biggest full genome sequences sets in the world specifically meant for doing population genetics. " One of the central questions we want to look into, and where the new complete genomes dataset comes especially handy," says Mait Metspalu, Vice Director for Research in Estonian Biocentre, "is the out of Africa migration - things were perhaps more complicated than one single and simple migration out of Africa."

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DARK BIODIVERSITY

Estonian wooded meadows are some of the most biodiverse places on Earth where dozens of different plant species have been counted on one square metre. But why are not all similar areas equally inhabitied by plant species, asks Professor Meelis Pärtel from Tartu University's Macroecology work group. To describe this, he has coined the term 'dark biodiversity'. "We can understand ecological patterns and their underlying processes better if we examine not only observed but also absent species," he explains. The knowledge about species that could be in an ecosystem but for some reason are not could provide practical tools for biodiversity conservation and invasive species control, he suggests.

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MEDICINES FROM MILK

"The number of cows whose milk can be used to produce pharmaceuticals is still very small," says Ülle Jaakma, professor of reproductive biology at Estonian University of Life Sciences. "At the same time, this technology is eagerly awaited in the pharmaceutical world. It is revolutionary since it allows making the production of medicine cheaper and more reliable."

The research group headed by Jaakma and her colleague Sulev Kõks from Tartu University is trying to contribute to this revolution. A number of Estonian cows are now waiting to give birth to cloned calves that have one extra gene in their genome. These genes allow them to milk insulin, growth hormone or other therapeutic substances once they grow up.

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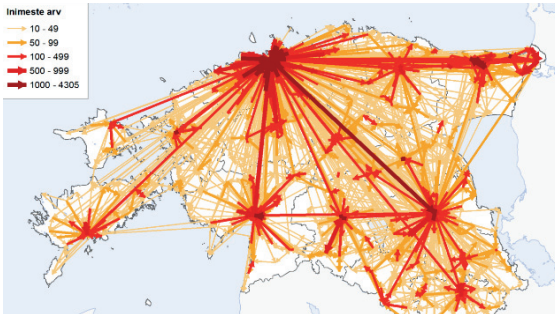
MAPPING HUMAN MOBILITY



To make smarter city planning decisions we need to examine the entire scope of everyday activities of individuals. "The old analyses often mapped "sleeping populations" using census data," says Rein Ahas, professor of human geography at University of Tartu. "The new type of analyses will put the all daily activities into studies and show the movement of people."

The making of such analysis and maps has been made easy by the fact that we all carry our mobile phone with us. Ahas and his colleagues at the Mobility Lab have developed a novel methodology based on mobile telephone use and the use active and passive mobile positioning data that allow them to investigate the mobility of people: where do people live and where do they work, where do they travel on weekends, which area of the city do they prefer during certain time of day etc. Such data allows for better environmental and city planning decision, Ahas believes.

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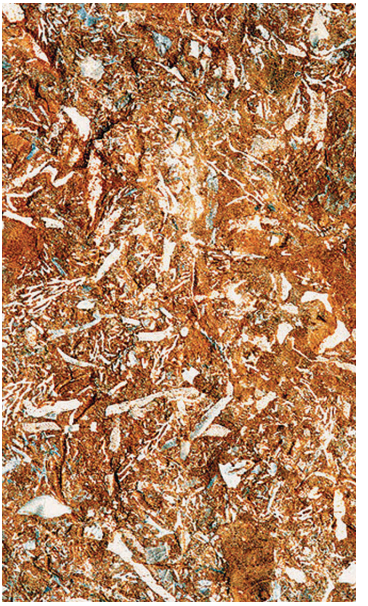
OIL SHALE – NATIONAL TREASURE



In Estonian we call it "põlevkivi" – "burning rock". This is oil shale, the fossil remains of primitive organisms that lived on the bottom of the sea some 450 million years ago. Today, more than 90 per cent of electricity in Estonia is produced by burning oil shale, making Estonia the only country in the world to harness this resource to such extent. And one of the few countries to have extensive scientific knowledge about oil shale: not only its use for energy and chemistry but also about its environmental impacts.

"if earlier the best use for oil shale was to produce electricity by burning it than now we know better ways to use it, for example to produce valuable shale oil or sophisticated chemical products," says Margus Pensa, research manager at Oil Shale Competence Centre, a subdivision of Tallinn University of Technology.

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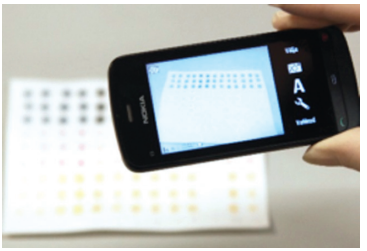
CAN CHEMISTRY BE GREEN?



Instead of running some very expensive machines, some chemical analysis could be done much more simply, quickly and cheaply, argues Mihkel Kaljurand, professor of chemistry at Tallinn University of Technology. He is one of the proponents of a new movement called green analytic chemistry. "Green stands for sustainability and less polluting,"says Kaljurand. "The amount of chemicals we use is minimal," Kaljurand says. The first practical example he and his team developed is testing wines for their content of antioxidants. A drop of wine, a drop of chemical onto it, then take a picture with your mobile phone and analyse it with a free software. "We are reviving some old methods of analysis that are based on colour change," Kaljurand explains. "But instead of looking with plain eye, now we can analyse them quantitatively with technology."

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CAPTURING THE SUN

"They say there is no sun in Estonia," says Professor Enn Mellikov. "But I always get the sun out when the investors arrive." Co-founder of the company Crystalsol, Professor Mellikov has been working on semiconductor materials development for more than 30 years. With the help of university, Crystalsol develops an entirely new type of flexible photovoltaic solar cell with a significant cost and versatility advantage compared to all currently known photovoltaic technologies. The secret? The light absorbing active layer of the solar cell is made of crystalline semiconductor particles that contain the abundant and low-cost elements copper, zinc, tin, sulphur, and selenium.

"There is no alternative to solar energy," Mellikov believes.

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UNDERSTANDING RUSSIA

"You can compare international law to a global language," says Lauri Mälksoo , professor of international law at Tartu University, "and there are several "dialects" in this international language."

Mälksoo has been studying one of those dialects that is in light of recent events in Ukraine more relevant than ever, namely, Russian. Mälksoo, the author of an upcoming book about Russia's understanding of international law, points out that Russia has emphasized the importance of international law and human rights in many instances, especially when criticizing the activity of other powers. "This indicates that international law can be a somewhat different phenomenon in different parts of the world," he says. "Russia has recently started with creating its own regional international law in Eurasia."

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THE BURIED WARRIORS

It might have been an ill-fated raid on Saaremaa or a similarly unsuccessful attempt to collect tribute. Whatever was the reason for the battle, the result were more than 40 dead bodies, buried with their ships in the south coast of the Baltic Sea island Saaremaa.

"These must have been fierce battles that already started on the sea because we have found many arrowheads," says archaeologist Jüri Peets, senior researcher at Tallinn University Institute of History who has done excavations at the Salme site. Beside weapons they have also found artefacts, such as game pawns, which indicate some of the visitors were nobleman.

The discovery is significant because the fateful battle has been dated to the year 750 or before. This means almost a century before the Viking Age officially began, making the Salme ships the most important pre-Viking era find in the Baltic Sea region, if not beyond.

"There are no similar battle burials with a comparable amount of victims from that period anywhere in Europe," Peets says.

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A FERTILE APPROACH

Only one of a three fertilized eggs that reach the women's womb, will actually develop into a new human life. What determines the success of the pregnancy is, however, still mostly shrouded by mystery. Scientists at Tartu University are gaining new insights by using omics-analysis, simultaneously looking at many biological processes at work around the embryo and how they interact with each other.

"This type of work allows us to understand why in certain cases the embryo will attach to the uterus membrane and pregnancy will start and in other cases it will not," says Andres Salumets, professor or reproductive medicine at University of Tartu. For example, his team was the first in the world to map all of the genes and proteins that are activated during the moment of embryo attachment and their interaction.

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ONE MORE PINT... FOR MY GENES

The rapid transformation of Estonia in the 1990s showed Estonia as a testing ground for innovative economic and social policies. But it also made Estonia a unique laboratory to study the interaction of genes and environment. A longitudinal study led by Professor Jaanus Harro has revealed how risk behaviour such as alcohol consumption is affected by the time when young people were growing up. Gene variants that have been so far dubbed as risk variants, i.e. enhancing risk behaviour, are shown in this study to increase early alcohol consumption in the group born at the end of the 80s but having a completely opposite impact in those born just six years earlier. Several similar findings have been revealed by the ongoing study.

„This will change how we understand and study the interaction between genes and environment for behaviour," professor Harro says.

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THE GREATEST SCALE

Zooming out from our planet, we first see the Solar System, then our galaxy, the Milky Way. This belongs to a galaxy cluster called Local Group, which in turn is part of the Virgo Supercluster of galaxies. And this is only one of millions of superclusters in the Universe.

These superclusters are not randomly distributed in space, scientists have found. Looking at the large-scale structure of the Universe they can see that clusters are connected with thinner filaments of galaxies, tens of millions of light years long. Jaan Einasto, the grand old man of Estonian astronomy, has proposed that on this level the Universe is structured like a honeycomb, a network of filaments with large voids between them.

"The study of the large-scale structure of the Universe also gives us information about the characteristics of dark matter," Einasto says.

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