ACADEMY OF FINLAND

Centres of Excellence in Research 2014–2019

The Centre of Excellence Programme 2014–2019 involves 14 Centres of Excellence (CoE) in Research, composed of research teams from a total of twelve universities and research institutes.

Analysis and Dynamics research

The Centre of Excellence in Analysis and Dynamics Research consists of nine multidisciplinary research groups devoted to researching pure mathematics and its applications especially in the fields of physics and biology. The aim is to create a new culture of mathematics in Finland that will encourage mathematicians to work more closely with application developers and to rethink the researcher training system.

Research at the CoE covers a broad spectrum of mathematical analysis and its applications. Specific fields of research include dynamical systems, geometric analysis, fractals, random geometry, partial differential equations and applications in turbulence, statistical mechanisms and mathematical models of biological evolution.

The CoE brings together respected and internationally recognised mathematical analysis research teams whose synergy offers the potential to break open new territory. International cooperation is an integral part of the culture. The CoE's partners include researchers from the best universities in the world, including Fields medallists, the equivalent of Nobel laureates in mathematics.

The CoE aims at new breakthroughs by combining the latest ideas and approaches of analysis, probability theory and mathematical physics.

ACADEMY OF FINLAND

More information:

Academy Professor Antti Kupiainen, University of Helsinki (UH)
Maarit Järvenpää, University of Oulu
Tuomas Hytönen, UH
Pertti Mattila, UH
Eero Saksman, UH
Pekka Koskela, University of Jyväskylä (UJ)
Xiao Zhong, UJ
Mats Gyllenberg, UH
Kari Astala, UH
Website: The Centre of Excellence in Analysis and Dynamics Research

Atmospheric Science – From Molecular and Biological Processes to the Global Climate

The main research focus of the Centre of Excellence is on the atmosphere and its interactions with different ecosystems. The work is based on an extensive network of field stations that produce detailed measurement data on energy and mass fluxes between the atmosphere and terrestrial biosphere. At these field stations, measurements of particles formed in forests will be taken, for instance, in order to determine their role in the formation of clouds in the atmosphere and thereby their impact on the climate. The CoE's interests also extend to air quality and the relationships between the changing climate and airborne pollutants.

The CoE conducts a broad spectrum of research that extends from the molecular and cell level to the global climate. The observations of changes happening in the atmosphere and biosphere, not only in Finland but around the world, produce unique time series data. Focused experiments and models are used to try to unravel the processes underlying the phenomena observed.

The research is aimed at reducing the scientific uncertainties related to climate change. This will help deepen the understanding of and produce more applicable results on the

ACADEMY OF FINLAND

feedback mechanisms between atmospheric processes and natural ecosystems. The results will help curb climate change and also facilitate adapting to climate change. The CoE's research team includes scientists working in many fields. Each member of the international and multidisciplinary team brings their own expertise to the table to help resolve the bigger picture.

More information:

Academy Professor Markku Kulmala, University of Helsinki (UH)
Timo Vesala, UH
Jaana Bäck, Helsingin UH
Annele Virtanen, University of Eastern Finland
Yrjö Viisanen, Finnish Meteorological Institute
Marja-Liisa Riekkola, UH
Website: The Centre of Excellence in Atmospheric Science

Biomembrane Research: From Lipid-Protein Interactions to Functions

Researchers at the Centre of Excellence are working to establish the laws that govern the interplay between proteins and fats or lipids, the main components of cells. While the mechanism of membrane traffic has been successfully studied, very little is known about lipid-protein interactions. Lipid membranes both help and hinder interactions between proteins. In fact, the membrane environment may determine what function a protein is capable of performing, and which other proteins it communicates with. This is the mystery the CoE is investigating.

Researchers at the CoE are developing and using new techniques that will help shed light on these interactions. The tools that are used include imaging, biophysical and biochemical methods and mathematical modelling. The focus of the research is at the level of basic cellular mechanisms, and the study will not be limited to the treatment of any specific cell tissue, cell part or disease. The results of the work have implications in a wide range of fields. Indirectly, they can contribute to the development of new medical

drugs and to understanding the mechanisms of, for example, cardiovascular and Alzheimer's diseases.

The research conducted at the CoE is supported by an extensive international network with researchers in the field. The CoE is now in the position to formulate broad research questions that no individual research team could tackle alone. The unit is divided into two groups: one team is studying cholesterol and the other team is studying actin, the most abundant protein in cells and responsible for forming support structures in cells. Furthermore, the theoretical physics and FiDiPro groups simulate nanoscale phenomena, such as interactions between molecule parts and atoms.

More information:

Academy Professor Elina Ikonen, University of Helsinki (UH)
Pekka Lappalainen, UH
Ilpo Vattulainen, Tampere University
Website: The Centre of Excellence in Biomembrane Research

Cardiovascular and Metabolic Disease

The main themes of the research at the Centre of Excellence are cardiovascular and metabolic diseases. The aim is to develop new diagnostic methods for the early detection and prevention of these diseases and for their effective treatment and rehabilitation.

Heart disease is the single leading cause of death in Finland. One of the CoE's major goals, therefore, is to understand how heart disease begins and develops. Cardiovascular and metabolic diseases are interwoven and interconnected in many ways. Obesity-related diabetes is a major risk factor for atherosclerosis, or hardening of the arteries, a key research focus at the CoE. Obesity and metabolic diseases place a considerable economic burden on the healthcare system.

The CoE has at its disposal an exceptionally diverse toolkit that combines both basic

research and clinical research. It follows that among its ranks the CoE has a wide range of professionals from many fields. The unit uses the latest genetic engineering techniques as well as animal models. Furthermore, it has access to one of the world's largest cohort datasets in diabetes research. All this means it is well placed to develop new diagnostic methods and gene therapies. Other technologies in the toolkit are advanced molecular imaging, positron emission tomography or PET scanning and special cameras.

The CoE has set itself ambitious goals. One of them is to identify the ultimate cause of type 2 diabetes and to be able to influence its development. The CoE's work will facilitate admission to treatment, the making of accurate diagnoses as well as rehabilitation. In order to reach these ambitious goals, the different units of the CoE have to work seamlessly together. The CoE's personnel represent a good mix of researchers at different levels of their careers. It is important for the unit to ensure that recent doctoral graduates always can move forward by providing them the opportunity to build up their senior profile.

More information:

Professor Juhani Knuuti, University of Turku (UTU)
Nuutila Pirjo, UTU
Laakso Markku, University of Eastern Finland (UEF)
Ylä-Herttuala Seppo, UEF
Website: The Centre of Excellence in Cardiovascular and Metabolic Disease

Changes in Sacred Texts and Traditions

The Centre of Excellence is interested in studying how cultural upheavals in the Middle East have influenced the creation and evolution of canonical sacred texts – and vice versa. The text in the main focus of the research is the Hebrew Bible, or the Old Testament. The CoE's four research teams, consisting of scholars of the Old and New Testaments, Assyriologists and archaeologists, all approach the subject in hand from different angles. The aim is to bring together these diverse perspectives and to achieve

completely novel results.

The research examines the processes and mechanisms of historical change at both the micro and macro levels. The changes concerned range from minute discrepancies between texts, manuscripts and translations to profound social, political, religious and demographic changes that have shaken nations. The focus is on the purpose, sacredness and permanence of the texts. The CoE is also interested in comparing different historical versions and translations of the Old Testament. Even the smallest changes made over the years may have led to major disparities in interpretations.

The mission of the CoE is to constantly question and challenge old notions and to go back all the way to the foundation stone of religion. The goal is also to be able to contribute to raising public awareness and knowledge. The CoE's research community is characterised first and foremost by collaboration. It has succeeded in creating a comprehensive and active international network of partners including leading universities and research communities in the fields of both theology and ancient history.

More information:

Professor Martti Nissinen, University of Helsinki (UH)
Jutta Jokiranta, UH
Anneli Aejmelaeus, UH
Juha Pakkala, UH
Website: The Centre of Excellence in Changes in Sacred Texts and Traditions

Experimental and Computational Developmental Biology Research

The Centre of Excellence conducts research in experimental and computational developmental biology. It has diverse expertise in the development of different organs as well as in computer modelling of development and evolution. The main areas of focus are the development of teeth, hair, mammary glands and fly wings. All these organs develop from the outer layer of the embryo, and their development is regulated by

similar mechanisms.

The CoE is interested in understanding the logic governing the shape and regeneration of organs. What is it in the gene regulatory networks that directs the formation of different organs? What kinds of developmental changes are seen during evolution? And how are new organs constructed from stem cells?

The aim of the CoE is to gain an understanding of the general principles governing the formation of different organs and to understand how gene mutations cause disturbances in organ development. In addition, it is working to develop different kinds of tools for the modelling of organs as well as imaging and culture methods for the experimental analysis of organ development and regeneration. The results obtained and tools developed in this work have application in basic research, teaching and in the future in building organs from stem cells.

More information:

Academy Professor Jukka Jernvall, University of Helsinki (UH)
Isaac Salazar-Ciudad, UH
Irma Thesleff, UH
Osamu Shimmi, UH
Marja Mikkola, UH
Website: The Centre of Excellence in Experimental and Computational Developmental

Laser Scanning Research

The basic idea behind the laser scanner is simple and straightforward: the distance between the object and scanner is measured based on the time travelled by the laser pulse. When the laser scanner's exact position and orientation are known, the distance measurement can be converted into location information of the object. The laser scanner produces a cloud of points of the object that can be used for highly accurate and detailed 3D mapping. The Centre of Excellence in Laser Scanning Research covers the

development of hardware electronics, system integration and positioning technologies and in-depth research into new innovations, information extraction methods, visualisation techniques and applications based on these technologies. Laser scanning has important applications, for instance, in the estimation of standing tree stocks and in 3D modelling of the built environment.

The CoE takes a cross-disciplinary approach to the research. It is privileged to have a number of world-leading researchers on its staff, most of whom are exceptionally young. Laser scanning itself is a young field of research, going back no more than some 15 years. The CoE believes in the omnipresent and positive impact of the laser scanner on the lives of every citizen in the modern information society of the early 2020s.

More information:

Professor Juha Hyyppä, Finnish Geospatial Research Institute
Markus Holopainen, University of Helsinki
Juha Kostamovaara, University of Oulu
Hannu Hyyppä, Aalto University
Website: The Centre of Excellence in Laser Scanning Research

Molecular Biology of Primary Producers

The Centre of Excellence in Molecular Biology of Primary Producers is interested in exploring the growth, development and stress and energy metabolism of plants and photosynthesising micro-organisms. It applies the most up-to-date research methods in the field of systems and synthetic biology.

Basic research in this field – and therefore related applied research that promotes bioeconomy – is highly fragmented throughout the world. The consumption of fossil fuels has caused the climate to change, and the continuing growth of the world population requires that food production is stepped up. The European Union has proposed new strategies for the transition to bioeconomy, but the key lies in the limits of

primary energy production. It is imperative to increase the ability of plants, algae and cyanobacteria to capture solar energy in a form that is useful to humans as food, fuel and animal fodder.

The aim of the CoE is to find out how photosynthesising organisms integrate the absorption of solar light energy and the consequent carbon metabolism pathways, and to explore opportunities to improve the efficiency of primary production. The photosynthesis researchers and the plant development and stress biology researchers are internationally respected experts in their fields. To date, they have had only limited contact with one another, but the CoE offers a unique opportunity for them to join forces.

More information:

Academy Professor Eva-Mari Aro, University of Turku (UTU)
Jaakko Kangasjärvi, University of Helsinki (UH)
Yrjö Helariutta, UH
Esa Tyystjärvi, UTU

Molecular Engineering of Biosynthetic Hybrid Materials

There is great demand for renewable and bio-based materials and biological processes in society. At the same time, there is an even greater need in technology for better, more functional and reasonably priced materials. This, however, must not draw our attention away from material qualities. Reconciling all these elements will require a whole new approach in research.

The Centre of Excellence in Molecular Engineering of Biosynthetic Hybrid Materials is focused on engineering and investigating materials from the molecular to the nano level. The aim of the CoE is to gain a deeper scientific understanding of how biological raw materials, the biological tailoring and production of materials, self-assembly and genetic engineering can be harnessed for the future needs of material science. The CoE integrates four areas of competence and expertise: the self-assembly of molecules and colloids, the

genetic engineering of proteins, the production and tailoring of cellulose and wood-based nanomaterials, and the biological production of engineered biomolecules.

The applicability of biosynthetic materials is limited by challenges in the production. The CoE is looking to change the production methods and promote the use of different biosynthetic materials in the production processes. The vision is that over the coming decades, the dividing line between materials and biological sciences will fade away and biological production mechanisms will become cost-effective. This would have a profound societal impact in Finland.

More information:

Academy Professor Olli Ikkala, Aalto University (AALTO)
Markus Linder, AALTO
Merja Penttilä, VTT Technical Research Centre of Finland Ltd
Janne Laine, AALTO
Website: The Centre of Excellence in Molecular Engineering of Biosynthetic Hybrid Materials

Reason and Religious Recognition Research

The research of the Centre of Excellence focuses on the question of how religious groups in the past as well as today have accepted or recognised other groups in society and vice versa, how religions have been accepted in different societies. Researchers at the CoE are interested in studying the era of Antiquity and Early Christianity as well as encounters between Christianity, Islam and Judaism. Another area of interest is the discourse on tolerance from the Middle Ages to Enlightenment. Indeed, the treatment of minorities, a recurring theme in public debate today, is one of the CoE's areas of focus. In addition, one of the research teams is working to develop philosophical models to help understand contemporary religious discourse.

The CoE's research methods are historical and philosophical: the aim is to gain a better

understanding of the subject and to develop as universal models as possible for religious thinking and behaviour. It also puts the results to practical use.

The first major report of then CoE is concerned with religious recognition in the history of ideas. It will be putting forward models of religious recognition that can help increase tolerance in multicultural society. The CoE presents an academic case for the view that despite their differences, religions could in fact share a common understanding of the opportunities and limits of rational discussion.

More information:

Professor Risto Saarinen, University of Helsinki (UH)
Sami Pihlström, UH
Ismo Dunderberg, UH
Virpi Mäkinen, UH
Taneli Kukkonen, University of Otago
Website: the Centre of Excellence in Reason and Religious Recognition Research

Research on Mitochondria, Metabolism and Disease (FinMIT)

The Centre of Excellence in Research on Mitochondria, Metabolism and Disease (FinMIT) is focused on the molecular mechanisms that regulate mitochondrial homeostasis. The CoE applies disease models aimed at understanding pathological processes and testing treatment strategies. A major area of focus is the pathophysiology of direct and indirect mitochondrial dysfunctions. The unit is also interested in the associations and mechanisms between metabolic obesity and mitochondria. The unit combines basic research with solid practical medical expertise.

Mitochondrial dysfunction is known to be a major factor in many diseases, including nervous system degeneration, heart disease and general metabolic diseases. As yet there is no cure for mitochondrial diseases, and there are few effective treatments. Therefore, the therapies developed based on the research represent significant new advances.

The CoE focuses on how the mitochondria residing in our cells remain healthy and how they communicate with other parts of the cell in order to maintain metabolic balance. The CoE couples this knowledge with genetic analyses in families with mitochondrial diseases in order to develop disease models that can help test the efficacy of treatments.

More information:

Academy Professor Howard Jacobs, Tampere University (TAU)
Anu Wartiovaara , UH
Brendan Battersby, UH
Kirsi Pietiläinen, UH

Research on the Relational and Territorial Politics of Bordering, Identities and Transnationalisation

Border research has proliferated in recent decades and attracted growing interest especially in connection with world-shaking events. The research interests of the Centre of Excellence are in the areas of state spatial transformation, spatial socialisation and identities, border crossings and the management of global flows. Instead of a traditional focus, the research efforts are designed and geared to open new perspectives on borders and on the identities of nations and individuals. The CoE's work has high current relevance and interest both in research and society generally.

In today's world, borders are no longer attached to a state, but appear as both social and technological landscapes of power and control. Closed states have elevated to a new scale and evolved into networks. One area that holds special interest to the CoE in the research on transnationalisation or cross-border processes is the Finnish regional planning system. The research interests also extend to the construction of socialisation, national identity and citizenship. The core of the research lies in human geography, but much of the work cuts across disciplinary boundaries, both in theoretical and empirical research.

The goal of the CoE is to achieve results that can help change the concepts and key approaches of the research tradition. One of the biggest challenges for the unit is to bring international exposure to Finnish social and cultural research. The anticipation is that the CoE will give added prominence to the role of geography in the field of sciences.

More information:

Professor Anssi Paasi, University of Oulu (UO)
Jouni Häkli, Tampere University
Jarkko Saarinen, UO
Sami Moisio, UO
Website: The Centre of Excellence in Research on the Relational and Territorial Politics of Bordering, Identities and Transnationalisation

Research on Solar Long-Term Variability and Effects

ReSoLVE, the Centre of Excellence in Research on Solar Long-Term Variability and Effects, specialises in research on space climate, that is, the long-term variability in the Sun's magnetic field and magnetic activity and its effects especially in near-Earth space.

The Sun's magnetic activity has varied dramatically in recent decades. Researchers at the CoE are working to find out what has happened in the Sun over the past 100–150 years and how this has impacted the occurrence of magnetic storms in the Earth's magnetosphere. Solar wind disturbances may cause significant disruption to technological systems, such as satellites, data communications and electric power lines. The behaviour of the Sun also impacts the Earth's atmosphere and climate in many ways, but as yet we have only limited knowledge about these effects.

The CoE consists of five research teams that work very closely together, for instance, in numerically modelling solar magnetic fields and the atmospheric effects of particles and in the comparison, analysis and interpretation of long time series of satellite and

terrestrial measurements. The CoE is widely regarded as an international pioneer in the field and probably covers the field of space climate research from the Sun to near-Earth space and the Earth's atmosphere more thoroughly than any other research team in the world.

More information:

Professor Kalevi Mursula, University of Oulu (UO)
Timo Asikainen, UO
Maarit Mantere, University of Helsinki
Ilya Usoskin, UO
Eija Tanskanen, The Finnish Meteorological Institute
Website: the Centre of Excellence in Research on Solar Long-Term Variability and Effects

Translational Cancer Biology

There is a pressing need for better and more individually tailored cancer therapies. Targeted therapies are highly effective, but it is crucial that combinations are carefully selected so as to avoid the development of tumour drug resistance.

The Centre of Excellence in Translational Cancer Biology is committed to identifying new targets for therapy among the body's own cells that are necessary for the growth and spread of cancer. In addition, it will explore other cellular structures that have proved significant in the immediate vicinity of cancer cells. Blockers targeting these cells can open up huge new opportunities to develop targeted combination therapies.

The goal of the CoE is to identify new treatment strategies designed to prevent the growth and spread of cancer by using preclinical models. The expertise of the researchers ranges from the basic biology of cancer to treatment trials, providing an optimal setting for the translation of research results into practice for the patient's best.

ACADEMY OF FINLAND

The CoE is ideally placed to conduct basic research that can pave the way to effective methods for the diagnosis and targeted therapy of cancer.

More information:

Academy Professor Kari Alitalo, University of Helsinki (HU)
Sirpa Jalkanen, University of Turku (UTU)
Johanna Ivaska, UTU
Olli Kallioniemi, Institute for Molecular Medicine Finland
Heikki Joensuu, HU
Päivi Ojala, HU
Tomi Mäkelä, HU
Pipsa Saharinen, HU
Website: The Centre of Excellence in Translational Cancer Biology