

**Estonian Centres  
of Excellence in Research**

**2012**

# Estonian Centres of Excellence in Research

FOCUS AIMS PERSPECTIVES

2012

The booklet presents a short overview of Estonian centres of excellence in research as they stand in 2012

This collection is the outcome of a joint effort by heads of all centres

ISBN 978-9949-9203-4-1

ISBN 978-9949-9203-5-8 (pdf)

## CONTENTS

CENTRE OF EXCELLENCE IN COMPUTER SCIENCE	4
CENTRE FOR INTEGRATED ELECTRONIC SYSTEMS AND BIOMEDICAL ENGINEERING	6
CENTRE OF EXCELLENCE IN GENOMICS	8
CENTRE OF EXCELLENCE IN BIODIVERSITY RESEARCH	10
CENTRE OF EXCELLENCE FOR TRANSLATIONAL MEDICINE	12
CENTRE OF EXCELLENCE IN CULTURAL THEORY	14
CENTRE OF EXCELLENCE IN CHEMICAL BIOLOGY	16
CENTRE OF EXCELLENCE IN RESEARCH ON ADJUSTING TO ENVIRONMENTAL CHANGES	18
THEORY AND APPLICATIONS OF MESOSYSTEMS	20
HIGH-TECHNOLOGY MATERIALS FOR SUSTAINABLE DEVELOPMENT	22
DARK MATTER IN (ASTRO)PARTICLE PHYSICS AND COSMOLOGY	24
CENTRE FOR NONLINEAR STUDIES	26
CENTRES OF EXCELLENCE IN RESEARCH FOR YEARS 2008-2015 IN ESTONIA	28

The quality of research has been one of the cornerstones of the reforms in the Estonian research and higher education system. During the first decade the structural reform came to an end and the whole system was rearranged according to the principles inherent in the democratic world. Since the beginning of the 1990s, most of the funding instruments of research have been based on peer review evaluation by foreign experts, taking into consideration the quality of research and also the elements of stability and continuity of the R&D system as a whole.

Under established conditions, some of the research groups have been more productive and more visible internationally despite rather even funding levels.

To promote the productivity and international competitiveness of the best research groups working at the forefront of their respective fields, the programme of Centres of Excellence in Research was launched in 2001.

A centre of excellence in research is a consortium of several internationally recognised research groups. To improve the quality and efficiency of scientific research through cooperation between research groups, the centres are provided with extra funding enabling to create more favourable working conditions. The first programme supported 10 Centres of Excellence covering a broad spectrum of research fields.

Since the first 10 Centres of Excellence (2001-2007) were successful, the following Centres of Excellence programme supported by the EU Structural funds was launched in 2008.

During the first call, 7 centres were funded and in 2011 during the second call 5 more centres were chosen for support. According to the rules of implementation of structural funds, the current programme will be completed in 2015. The total funding of the Centres of Excellence is 46.5 million euros.

The current booklet is a brief overview of the activities of Estonian Centres of Excellence in Research. I hope the readers find this information about Estonian research interesting and it might help to find new cooperation partners both in Estonia and abroad.



*Jaak Aaviksoo*  
Minister of Education and Research  
Professor, Member of Estonian Academy of Sciences



# CENTRE OF EXCELLENCE IN COMPUTER SCIENCE

<http://cs.ioc.ee/excs/excs@cs.ioc.ee>

The Centre of Excellence in Computer Science (EXCS) consolidates Estonian research in computer science and computational sciences (bioinformatics, human language technology). It comprises the teams of five target financed research themes of the Estonian Ministry of Education and Research at three institutions: Institute of Cybernetics at Tallinn University of Technology (IoC), R&D company Cybernetica AS and University of Tartu with two units (Institute of Computer Science and Chair of General Linguistics). EXCS involves approx. 60 senior staff (including postdocs) and 60 junior staff, mainly PhD students. It includes most of the computer science groups in Estonia.

The research is organised around cross-institutional working groups (WGs) for each of the strength areas.

## PROGRAMMING LANGUAGES AND SYSTEMS

Prof V.Vene ([varmo.vene@ut.ee](mailto:varmo.vene@ut.ee))

This WG develops language-based technology for making software correct and safe. This covers both methods and tools for analysis, verification and certification of code written in programming languages that are the current industrial standard as well as design and implementation of novel programming languages with built-in mechanisms for enforcing such properties. The areas of expertise and research activity cover type systems and program logics, program analysis and transformations, functional and dependently-typed programming, categorical semantics, automata theory and context-dependent computation.

## INFORMATION SECURITY AND CRYPTOLOGY

Dr P.Laud ([peeter@cyber.ee](mailto:peeter@cyber.ee))

This WG develops methods and tools for multi-party computation, cryptographic protocol analysis and risk analysis of systems based on attack trees. It studies the limits of proof methods in cryptography. It has designed and implemented one of the most efficient frameworks for secure multiparty computation as well as tools for sound analysis of protocols, for the construction and analysis of multi-parameter attack trees. It has extensive experience in public-key infrastructures, especially time-stamping, and in privacy-preserving data-mining.

## SOFTWARE ENGINEERING

Prof M.Dumas ([marlon.dumas@ut.ee](mailto:marlon.dumas@ut.ee))

This WG conducts research on the question of how to build and maintain integrated software systems that are aligned with business operations. It focuses on the approaches of business process management (analysing and building software systems based on models capturing how an organisation works, also called business process models), service-oriented computing (analysing and building software systems based on the metaphor of 'software as a

The general objective of EXCS is to consolidate and advance Estonian computer science in six areas of recognised strength detailed below. The specific objectives are: (i) to boost the research potential of the involved groups by facilitating collaboration and safeguarding their sustainability and growth, and (ii) to enhance the impact of their research results in academia, industry and society as well as to popularise them. These aims are to be achieved by carefully planned research coordination and joint actions, to create a thriving, highly reputed research environment, attractive for young researchers, particularly from abroad.

service', usually on top of web technology) and semantic technology (capturing metadata about information and software resources to guide the construction of interoperable information and software systems).

## SCIENTIFIC AND ENGINEERING COMPUTING

Prof E.Vainikko ([eero.vainikko@ut.ee](mailto:eero.vainikko@ut.ee))

The WG carries out research in scientific computing, cloud computing, peer-to-peer computing, mobile computing and information management. It works on parallel solution of large sparse systems of linear equations, automatic parallelisation of numerically intensive codes, friend-to-friend computing for easy setup of spontaneous desktop grids. It utilises cloud technologies for scientific computing applications, employs mobile computing for various purposes.

## BIOINFORMATICS

Prof J.Vilo ([jaak.vilo@ut.ee](mailto:jaak.vilo@ut.ee))

This WG deals with various aspects of biological data analysis with a general goal to advance our understanding of living systems. Areas as diverse as algorithm design, machine learning, statistics, natural language processing and scientific literature mining, pattern matching, database development, software engineering, visualisation, and even secure privacy-preserving data management and mining techniques become relevant for processing biological data.

## HUMAN LANGUAGE TECHNOLOGY

Prof M.Koit ([mare.koit@ut.ee](mailto:mare.koit@ut.ee)),

Dr E.Meister ([einar@ioc.ee](mailto:einar@ioc.ee))

The WG develops rule-based and statistical models of the morphology, syntax, semantics and pragmatics of the Estonian language and text, transcribed speech and dialogue corpora. It also studies the Estonian sound system and prosody, building speech synthesis and recognitions tools for Estonian and corpora of recorded speech. The researchers of this working group are key players in the Estonian national research programme for language technology.

## Host organisation

Institute of Cybernetics at Tallinn  
University of Technology

## Postal address

Akadeemia tee 21  
Tallinn 12618, Estonia

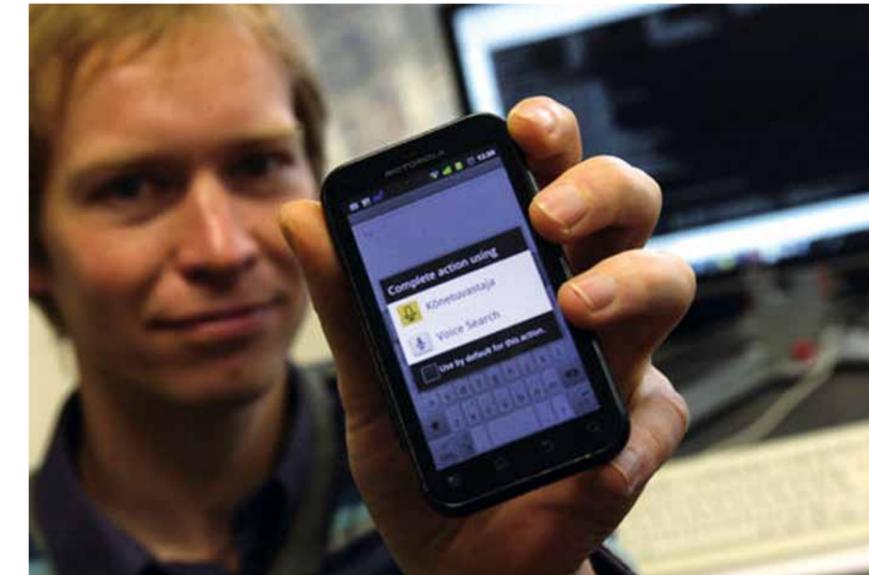
## Head of the centre

Prof Tarmo Uustalu ([tarmo@cs.ioc.ee](mailto:tarmo@cs.ioc.ee))  
Phone: +372 620 4250  
Fax: +372 620 4151



The highlights of the first three years 2008-2011 include the following:

- ▶ a highly successful international postdoc programme
- ▶ contributions to a number of EU FP6/7 and other projects
- ▶ successful training events (the EWSCS/ESSCaSS winter/summer schools, Estonian computer science theory days)
- ▶ two absolute top international conferences attracted to Estonia (EUROCRYPT 2011, ETAPS 2012), along with a number of smaller conferences.



Tanel Alumäe demonstrating the Estonian speech transcription app Diktofon for Android phones

Enriching our research environment with international postdocs was one of the pillars of our proposal for the CoE. In 2008, we conducted a major international recruitment campaign. Twelve international postdocs currently affiliated with EXCS are major contributors to the project through their research work, supervision of junior researchers, etc.

Our FP6 projects included the IST projects TYPES, MOBIUS, AEOLUS, BalticTime and LifeSciHealth projects ENFIN, COBRED, SIROCCO. Our contribution to FP7 is through the ICT projects HATS, VirtualLife, LiquidPub, ACSI, REMICS, UaESMC, Health projects ESNATS and DETECTIVE and Infrastructures project CLARIN. Other notable international projects include the EUREKA project SITIO, the COMPLEXITY-NET project CIESCI, the IMI (Innovative Medicines Initiative) project PREDECT and the DARPA project SEVILLA.



The centre's management committee 2009, from left, Varmo Vene, Kaili Müürisep, Jaak Vilo, Mare Koit, Peeter Laud, Eero Vainikko, Tarmo Uustalu

Centre for Integrated Electronic Systems and Biomedical Engineering (CEBE) is based on research cooperation of three departments at Tallinn University of Technology:

- ▶ Department of Computer Engineering
- ▶ Thomas Johann Seebeck Department of Electronics
- ▶ Technomedicum

The mission of CEBE is to carry out fundamental and strategic interdisciplinary R&D in the fields of electronic components, systems, computer and biomedical engineering

by a collaborating consortium with applications in medicine, semiconductor and information technologies.

To cultivate Interdisciplinary research in bio-, electronic and computer engineering and to achieve synergy from composing emerging knowledge of nanotechnologies, biomedical sensorics, novel signal processing methods, new design and test paradigms based on SoC/NoC technology and advanced design for dependability methods to come up with flexible solutions for reliable embedded systems (ES).

## CURRENT WORK:

### BIOMEDICAL ENGINEERING

Novel methods and applications of ES in biomedical engineering covering evaluation of the state of the brain, continuous and noninvasive optical monitoring of blood pressure and diagnosis of atherosclerosis, multicomponent monitoring of uremic toxins in biofluids, and distinguishing high sudden death risk patients in various heart diseases.

### SIGNAL PROCESSING

Novel principles are being developed for synthesis, generation and processing of signals used for identification and diagnosing of objects (biological and physiological, chemical and electrochemical, electrically conducting and semi-conducting materials, structures, organs, devices and systems) with the aim to obtain the required information faster and more precisely.

### DESIGN AND TEST OF EMBEDDED SYSTEMS

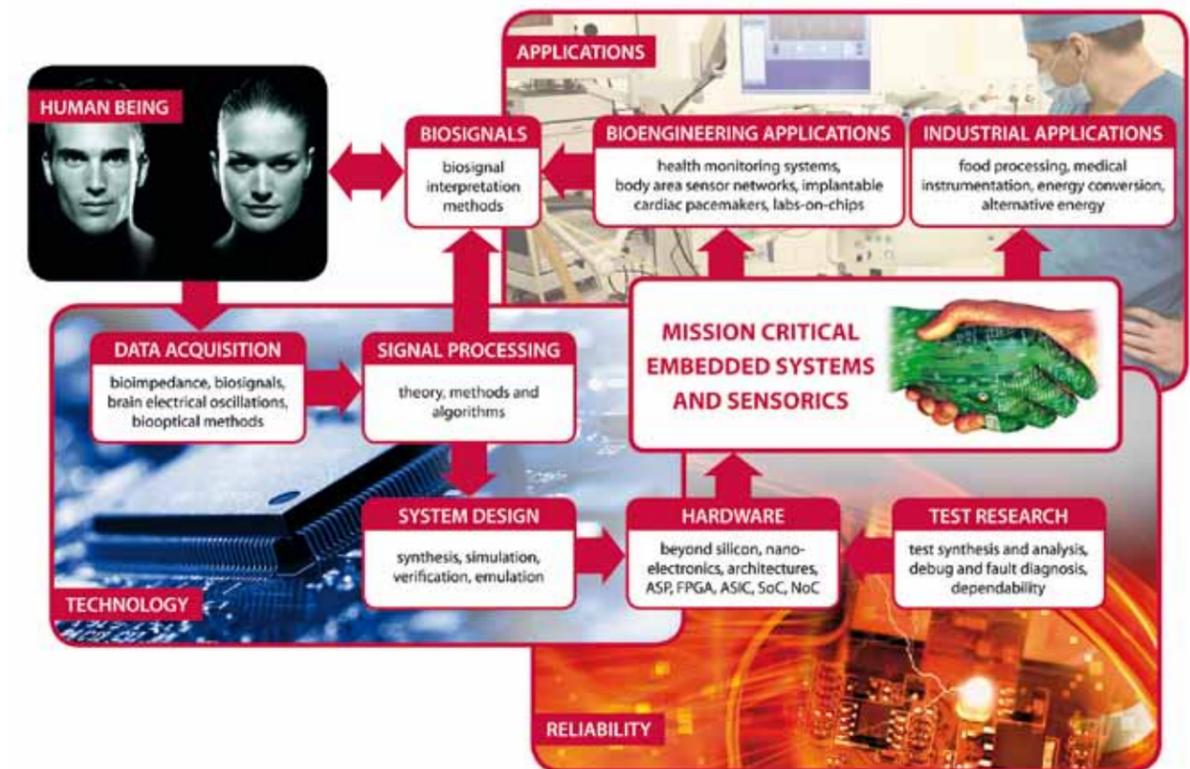
A novel, platform-based design environment for dependable embedded systems, supported by new advanced methods and tools for verification and testing. The new methods and tools supporting the platform cover: system verification with diagnosis, automated synthesis and analysis of test programs, fault simulation, system-level design and synthesis methods (for NoC-based MPSoCs), and dependable design.

### SEMICONDUCTOR ELECTRONICS

Investigations of the new phenomena in semiconductor (SiC, GaAs) structures by the aid of Deep Level Transient Spectroscopy (DLTS). The conditions are investigated for diffusion welding technology which widen the horizons for developing of high performance sensing and energy conversion devices.

# CEBE

Centre for Integrated Electronic Systems and Biomedical Engineering



CEBE is collaborating with more than 10 companies and the largest hospitals in Estonia, incl. ELIKO, Smartimplant, Cybernetica AS, Testonica Lab, Texas Instruments Estonia, Clifton AS, JR Medical, LDIAMON AS, Emros OÜ, Tensiotrace OÜ, Girf OÜ, AB Medical Teeninduse OÜ, North Estonia Medical Centre, Tartu University Hospital, East Tallinn Central Hospital and others.

Internationally CEBE cooperates with many world's leading industrial companies like IBM, Ericsson AB, STMicroelectronics, Texas Instruments, TDI Inc., Göpel Electronic, AerieLogic, TransEda and others. The cooperation network includes more than 20 high-ranked universities throughout Europe, together with European joint research centres, such as CERN and European Spallation Source (ESS).

CEBE includes about 90 researchers whereof about 40 are senior staff members and the rest are PhD students. During the last three years, 13 new international projects (incl. four FP7) have been launched and 19 national grants have been awarded.

CEBE is a natural extension of long term cooperation between the research teams. In 2005 CEBE research teams were chosen as one of five Estonian research centres for the R&D infrastructure development programme, funded from the EU Structural Funds. As a result, a new and modern Embedded Systems and Components research environment, consisting of three research infrastructure clusters: Communicative Electronics (SIE), Micro- and Nanoelectronic Components (MINAKO), Synthesis and Analysis of Embedded Systems (ASSA) have been developed.

The focus of the Centre of Excellence in Genomics is on basic and applied research of human as well as other genomes. The main objective of this consortium is to achieve, through dedicated collaboration, an added value, to be materialised and manifested in high-level scientific publications, enhanced international collaboration, creation of intellectual property and promotion of entrepreneurship in biotechnology. A particular goal will lie in applications in healthcare and in enhancement of the value of Estonian Biobank as a significant national asset. It is an interdisciplinary research consortium with a scope extending from creating tools to analyse genomic, proteomic and metabolomic information and search for 'disease genes', to the understanding of the origin of genetic structure variation in humans.

Over the first three years of activity the members of CoE Genomics have published more than 140 peer-reviewed research papers, including 12 papers in *Nature*, *Science* and *Nature Genetics*. The main results are revealing associations between genetic variations and common human features: obesity, body-mass index, height, waist-hip ratio, smoking behaviour, etc. These studies were performed in large consortia and included hundreds of thousands studied individuals, in order to achieve required power.

Progress in research also allowed to achieve important advancement in the understanding of the origin of the complexity of human matrilineally inherited mtDNA genome phylogeny and to dissect phylogenetically several hitherto unresolved major Eurasian patrilineal Y chromosomes.



Opening event of the Centre of Excellence in Genomics in Narva-Jõesuu on September 25-26, 2008

# EXCEGEN

The CoE Genomics is based on 3 research groups from Estonian Biocentre and University of Tartu:



## BIOINFORMATICS AND COMPUTATIONAL GENOMICS

Prof M. Remm ([maido.remm@ut.ee](mailto:maido.remm@ut.ee))

Main research projects of group: inheritance of Copy Number Variable sequences in families and populations, presence and inheritance of viral sequences in the human genome, fast detection and masking of repeated sequences, modelling the failure rate in genomic PCR and PCR primer design/annotation of new eukaryotic genome sequences (marine snail *Conus consors*), evolution of bacterial EFG protein families, detection and categorization of species-specific repeats in bacterial genomes (<http://bioinfo.ut.ee/>).



## BIOTECHNOLOGY

Prof A. Metspalu ([andres.metspalu@ut.ee](mailto:andres.metspalu@ut.ee))

The main goal of the Estonian Genome Center and the Dept. of the Biotechnology of the University of Tartu (as partners of the Centre of Excellence in Genomics) is to understand how genetic (and epigenetic) information and its variations influence individuals in their development and ageing, their wellness and disease, their behaviour and psychological characteristics, in relation to variation caused by the environment and lifestyle. We are using various 'omics' technologies in our new genotyping & sequencing core facility for analysis of whole genomes and exomes, both on individual levels, as well as at the population level. An important part of the research is the analysis of DNA, plasma and WBC samples combined with corresponding health records from the Estonian Biobank and its database, which represents 5% of the adult Estonian population (approx. 51 000 gene donors). The ultimate goal of the research is to apply the new knowledge for the benefit of patients by starting to implement personalized medicine in practice.



## EVOLUTIONARY BIOLOGY

Prof R. Villems ([richard.villems@ebc.ee](mailto:richard.villems@ebc.ee))

The main aim is to understand how the present-day genetic diversity of *Homo sapiens sapiens* arose. Though not solely, we concentrate on a world-wide variation of haploid genomes – on maternally inherited mitochondrial DNA (mtDNA) and paternally inherited Y chromosome. We are particularly interested in the early phase of the spread of modern humans from Africa to Eurasia, Australia, and to the New World. We are equally interested in the consequences of major environmental events like the last and previous glacial maxima and lesser ice ages on the demographic history of human populations: colonisations and re-colonisations that inevitably have had a crucial impact. Furthermore, a wide range of equally exciting events like neolithisation along with the ever-debated questions about the spread of genes and languages, language change in particular, as well as gender-related differences in the demographic history. In sum, what we are interested in is phylogeography, to be understood in terms of demographic history, a plethora of stochastic processes and, sure enough, natural selection. To a certain extent, the last sentence can equivalently be reversed: it is (demographic) history, etc. to be understood by phylogeography (<http://evoltsioon.ut.ee/>).

# CENTRE OF EXCELLENCE IN BIODIVERSITY RESEARCH

[http://fibir.ut.struktuur.ee/index.aw/set\\_lang\\_id=2](http://fibir.ut.struktuur.ee/index.aw/set_lang_id=2)

Frontiers in Biodiversity Research (FIBIR) consists of 6 research groups:

## PLANT ECOLOGY

Prof M.Zobel ([martin.zobel@ut.ee](mailto:martin.zobel@ut.ee))

## BOTANY

Prof M.Pärtel ([meelis.partel@ut.ee](mailto:meelis.partel@ut.ee))

## MYCOLOGY

Prof U.Kõljalg ([urmas.koljalg@ut.ee](mailto:urmas.koljalg@ut.ee))

## CONSERVATION BIOLOGY

Dr A.Lõhmus ([asko.lohmus@ut.ee](mailto:asko.lohmus@ut.ee))

## PHYSIOLOGICAL BEHAVIOURAL ECOLOGY

Prof R.Mänd ([raivo.mand@ut.ee](mailto:raivo.mand@ut.ee))

## ANIMAL SYSTEMATICS AND COMPARATIVE ECOLOGY

Prof T.Tammaru ([toomas.tammaru@ut.ee](mailto:toomas.tammaru@ut.ee))

The centre of excellence FIBIR aims to unify the six research teams into a synergistic network through lateral integration among the top-level scientists and groups. In particular, we aim to elucidate general trends in the variation of biological and functional diversity in ecosystems with different evolutionary history and under different human pressure, to distinguish the ecological and evolutionary processes behind diversity patterns, and to integrate ecological knowledge in order to develop principles of sustainable biodiversity conservation and management, and to enhance ecologically sustainable economic growth.



Establishment of a field experiment to study symbiotic soil fungi in a forest ecosystem

**Host organisation**  
University of Tartu

**Postal address**  
University of Tartu, Department of Botany,  
Institute of Ecology and Earth Sciences  
Centre of Excellence FIBIR  
Lai Street 40  
Tartu 51005, Estonia

**Head of the centre**  
Prof Martin Zobel  
Executive director Dr Edgar Karofeld  
Phone: +372 737 6223

# FIBIR



Calcareous grasslands are biodiversity hotspots in northern Europe

In particular, FIBIR aims collaborative activities on four general topics:

## MACROECOLOGY OF BIOLOGICAL DIVERSITY

Current community theory is strongly inclined towards local scale interaction-based explanations for biodiversity patterns, although recent theoretical developments have started to shift the paradigm, claiming that the legacy of the past evolutionary history is the primary driver. We would like to address the empirical relationships between biodiversity and environmental parameters across habitats and regions of the world and disentangle the role of regional evolutionary history behind patterns.

## PHYLOGENETIC COMPARATIVE ECOLOGY

Recent decades have seen rapid development of the phylogenetic comparative method, which relies on localising evolutionary changes on the phylogenetic tree, and the search for associations between changes in the values of different traits. We would like to build a link between phylogenetic comparative ecology and experimental life history studies ecology in order to understand the relative roles of adaptations and constraints, and links between evolution and ecosystem functioning.

## COEVOLUTION, ECOLOGICAL INTERACTIONS AND BIODIVERSITY

Mutualism and parasitism are important driving forces for development of life history traits in plants, animals and microbes, as well as for speciation. Co-variation of diversity patterns of mutualistically-related taxonomic groups is poorly understood. Recently developed molecular tools allow basic research on many types of interactions that cannot be manipulated in axenic conditions. We would like to address biodiversity patterns of mutualistically related organisms, focusing on vertebrate-parasite and plant-symbiotic fungus relationships.

## CONSERVATION BIOLOGY

The key question how biodiversity can be integrated with models of economic development still has no satisfactory answer. We are aware of the huge variation of biotic responses to anthropogenic pressures, but there is currently no framework to incorporate these variations into simple environmental management decisions. FIBIR members have recently been involved in several discussions of environmental and conservation strategies and policies in Estonia, as well as in studies focusing on biodiversity monitoring and management under different land use conditions. We would like to integrate the groups of FIBIR studying different organisms in order to develop general principles of biodiversity monitoring and sustainable management. We shall work in the close contact with stakeholders, notably governmental and non-governmental organisations of nature conservation and environmental protection.

Centre of Excellence for Translational Medicine: Translational research for improvement of diagnostics and treatment of neuroimmunological diseases (CETM) is based on a former centre of excellence in Estonia – Centre of Molecular and Clinical Medicine. Reorganised and renamed in July 2008, it has now got the status of National Centre of Excellence for years 2008-2015. Moreover, CETM is funded under the FP7 REGPOT project: Advancing scientific performance and regional potential of Estonian biomedical research 2008-2011.

The mission of CETM is to raise the international competitiveness of Estonian medical research and to concentrate our skills as well as the funds to cutting-edge areas. With the project, the centre has taken a step towards a multidisciplinary translational approach and to link our two main research fields, neuroscience and immunology.

Research groups:

#### VIROLOGY

Prof I.Lutsar ([irja.lutsar@ut.ee](mailto:irja.lutsar@ut.ee))

#### NEUROPHARMACOLOGY

Prof A.Zharkovsky ([aleksander.zarkovski@ut.ee](mailto:aleksander.zarkovski@ut.ee))  
Prof A.Kaasik ([allen.kaasik@ut.ee](mailto:allen.kaasik@ut.ee))

#### CLINICAL METABOLOMICS

Prof M.Zilmer ([mihkel.zilmer@ut.ee](mailto:mihkel.zilmer@ut.ee))  
Prof U.Soomets ([ursel.soomets@ut.ee](mailto:ursel.soomets@ut.ee))

#### MOLECULAR PATHOLOGY

Prof P.Peterson ([part.peterson@ut.ee](mailto:part.peterson@ut.ee))

#### IMMUNOLOGY

Prof R.Uibo ([raivo.uibo@ut.ee](mailto:raivo.uibo@ut.ee))

#### PHYSIOLOGICAL GENOMICS

Prof E.Vasar ([eero.vasar@ut.ee](mailto:eero.vasar@ut.ee))  
Prof S.Köks ([sulev.koks@ut.ee](mailto:sulev.koks@ut.ee))

The first three years have been highly rewarding for CETM. Definite increase could be seen in the quality of scientific output: this includes a total of 22 papers in journals with impact factor greater than 5. Besides articles in *Cell*, *Nature Reviews Immunology*, *PNAS*, *Human Molecular Genetics*, *Journal of Biological Chemistry*, a good number of publications authored by CETM members appeared in prominent medical journals like *Journal of Experimental Medicine*, *Blood*, *Brain*, *Hypertension*, *Cardiovascular Research*, *Journal of Infectious Diseases*, *Internal Medicine*.

Simultaneously with high impact publications, a reasonable number of PhD dissertations (altogether 15) relating to research projects of CETM have been commenced. The number of currently ongoing PhD projects is 31.

Concerning the major scientific findings one should start from the evidence established by P.Peterson and collaborators that the epigenetic code regulates self-antigen expression and negative selection of T-cells in thymus. Although it has been shown before that AIRE binds to chromatin, they have defined the precise target of AIRE interaction – one of the elements in core nucleosome – the histone H3. This finding has provided us with an explanation for how AIRE, as a single factor, activates the regions of inactive chromatin leading to expression of hundreds of genes. Moreover, the same research group has demonstrated that autoimmunity to Th17 cell cytokines causes chronic mucocutaneous candidiasis. The major importance of this finding is in the idea that chronic mucocutaneous candidiasis susceptibility can be primarily a result of immune attack on IL-17 and IL-22-expressing cells. These findings may help to explain the mucocutaneous rather than systemic focus of the candidiasis in these patients. The research performed by Allen Kaasik and collaborators underlines the evidence about the role of mitochondrial autophagy in neurodegenerative diseases. These data suggest that overactivated mitochondrial removal could be one of the main contributing factors for mitochondrial loss. These results also demonstrate that mitochondrial loss has a prominent role in the observed mitochondrial defect. They propose that increased mitochondrial removal could be one of the links that connects intracellular accumulation of  $\alpha$ -synuclein with the mitochondrial loss observed in Parkinson's disease. Moreover, the scientists belonging to the centre have studied the function of unknown proteins like MYG1, the epigenetic mechanisms behind cocaine-induced sensitisation and published a number of reports describing the behavioural and other defects in *Wfs1* and *Lsamp* deficient mice.

The research groups involved into the centre have demonstrated the neuroprotective properties of novel non-hematopoietic erythropoietin mimetic, have studied the metabolic mechanisms in effects of antihypertensive drugs and have demonstrated that *CCL3L1* copy number decreases the likelihood of HIV seropositivity also in intravenous drug abusers. Besides that the researcher of centre are also involved into the study of etio-pathogenetic mechanisms of chronic autoimmune disease Type 1 diabetes.



Biomedicum



New building



LSM5 Duo Confocal microscope



Open array system

CETM research groups are cooperating with more than 50 international and national research teams. In the majority of cases cooperation is maintained on the bilateral level and happening independently from the principal activities and support of CETM. Nevertheless, close collaboration between the research teams within CETM frequently leads to involvement of clinical research teams from University of Tartu as well as the major hospitals of Estonia. One has to underline the collaboration with other centres of excellence in Estonia. The major partners are: CoE in Genomics, CoE in Chemical Biology and CoE in Computer Science. Several research groups of centre have established the collaborative links with the competence centres of Reproductive Medicine and Biology, and Healthy Dairy Products. Among the foreign partners the major role is played by centres of excellence – Finnish CoE in Molecular

and Integrative Neuroscience Research, Finnish CoE in Molecular Systems Immunology and Physiology Research and CoE in Diabetes of Leiden University Medical Centre.

Last but not least, we have the ongoing plan to extend the competences of CETM by including new members. We have opened visiting professorships to Prof V.Veksler (INSRM 769) and Prof T.Timmusk (Tallinn University of Technology). From 2012 we plan major changes at the level of key senior staff. Dr T.Teesalu working currently in Sanford-Burnham Institute for Medical Research will join us as a professor with his independent research group funded by Wellcome Trust and ERC starting grant. Dr M.Hickey (PhD from Cambridge, 10 years in Neurology Department in UCLA) and Dr C.A.Hundahl (University of Copenhagen) will join us as senior researchers funded by Doctoral School of Clinical Medicine.

Centre of Excellence in Cultural Theory (CECT) contributes to raising the methodological and theoretical level of cultural research, and the sustainability of cultural research in Estonia. By juxtaposing and comparing data, theories and analytical methods, through creation of an interdisciplinary environment, development of cooperation, and by becoming acquainted with other spheres of research, we strive towards significant changes in self-understanding of disciplinary fields and understanding of general theoretical models in cultural research.

Eight research groups of CECT comprise research staff, PhD students and supporting personnel working at University of Tartu as well as Tallinn University, thus supporting inter-university cooperation.

## ARCHAEOLOGY

Prof V.Lang ([valter.lang@ut.ee](mailto:valter.lang@ut.ee))

Group concentrates on composing a new generalised interpretation of Estonian archaeology in a 6-volume set, starting from the Stone Age and focusing on periods that have been less studied and analysed, e.g. archaeological treatment of the medieval and modern times was thus far fully missing. Hence, preparatory work includes thorough archaeological research, both archaeological excavations and work with finds and sites in the archives.

## SEMIOTICS

Prof K.Kull ([kalevi.kull@ut.ee](mailto:kalevi.kull@ut.ee))

Studies originate from the need of bringing the advancement of social and human sciences to greater congeniality with the developmental speed of culture and society. This implies updating the analysis of complex or hybrid cultural phenomena (identities, events, various artistic synthetic activities, new media and multimedia texts) and increasing the cooperation capability of disciplines studying culture, society and nature. Three areas of analysis (semiotics of culture, socio-semiotics and semiotics of nature) are combined to analyse the set of signification, communication, representation and translation mechanisms as meaning-generation.

## ETHNOLOGY

Prof A.Leete ([art.leete@ut.ee](mailto:art.leete@ut.ee))

Group is involved in research of different ethnic-cultural levels of identity, by applying theoretical and methodological approaches drawn from ethnology and social anthropology. The goal is to study how and through which means an individual or a social group constructs, arguments and defends its own self-conception, thus the dynamic aspect of identity is of great relevance in the framework of this theme.

## LANDSCAPE STUDIES

Prof H.Palang ([palang@tlu.ee](mailto:palang@tlu.ee))

Group aims at exploring landscape practice as a strategic dimension for the study of complex interactions between landscape and heritage, using combined approaches of (cultural) geography, ethnology/anthropology and folklore studies. Inscribed ruptures/discontinuities in landscapes caused by societal changes are studied through the process – how societal changes are transmitted into changes in the landscape (practice change) and the consequences – how the changing practices are reflected in patterns, processes, functions, contexts.

## FOLKLORISTICS

Prof Ü.Valk ([ulo.valk@ut.ee](mailto:ulo.valk@ut.ee))

Group has undertaken to analyse and discuss folklore as a tradition-oriented creative process, whose meanings and functions depend on the social context. The concept of tradition memory will explain the relationship between individual memory and collective tradition, referring to the expressive potential of human mind, actualised in remembering and performing. Studies are focused on biographical narratives, retold memories, folk songs, laments, legends and folktales. Genres are interpreted as frames of performance and interpretation that shape the understanding of folklore. Past and present folklore is studied in its social dimensions.

## RELIGIOUS STUDIES

Prof R.Altnurme ([riho.altnurme@ut.ee](mailto:riho.altnurme@ut.ee))

Research is devoted to examining the genesis of the contemporary religious situation in Estonia. Estonia is an extremely secularised European country, characterised by diminishing institutionalisation of religion (de-institutionalisation) and decline of Christian practices and beliefs (de-Christianisation). The methods of social history, cultural anthropology and modern textual analysis are combined with social sciences methods, mainly qualitative.

## CULTURAL COMMUNICATION STUDIES

Prof H.Harro-Loit ([halliki.harro@ut.ee](mailto:halliki.harro@ut.ee))

Interdisciplinary fundamental research in the field of cultural communication is aimed at mapping comprehension difficulties that hinder inter- and trans-disciplinary research and offering methodological solutions to overcome them. The innovative aspect emerges from formulating the methodological grounds for the complex approach to cultural communication, and evaluation of the effectiveness of applied analysis. The central concepts are complexity, reflexivity and dialogism, mediated communication and discourse practices.

Host organisation  
University of Tartu

Postal address  
University of Tartu, CECT  
Ülikooli 18  
Tartu 50090, Estonia

Head of the centre  
Prof Valter Lang  
Phone: +372 737 6535  
Fax: +372 737 6257

# CECT

## CONTEMPORARY CULTURAL STUDIES

Prof A.Aarelaid-Tart ([aarelaid@tlu.ee](mailto:aarelaid@tlu.ee))

Group focuses on the second wave changes in Estonian culture during the transition period in the 1990ies. The collapse of socialism laid a foundation to the spread of postmodern attitudes in the Estonian cultural space favouring fragmentation, yet creating possibilities for social coherence through emerging new identities. A post-Soviet being in the field of culture is a phenomenon primarily connected with the functions of social memory, in-depth analysis of collective memory constructions and their impact on policy decisions is necessary.

Primary channels for the activities of CECT are:

- ▶ scientific publications (incl. joint compendia in "Approaches to Culture Theory Series" and special issues)
- ▶ organising and attending scholarly events
- ▶ informing the general public of the research findings
- ▶ promoting graduate studies and cultural studies in school curricula

Main events organised by CECT include:

- ▶ annual international autumn conferences on general theoretical subjects, alternately in Tallinn and Tartu
- ▶ regular theoretical seminars as specialised discussion forums
- ▶ activities to promote the quality of graduate education within the EU FP7 Graduate School of Culture Studies and Arts (GSCSA) project in cooperation with Estonian Academy of Music and Theatre, University of Tartu, Tallinn University and Estonian Academy of Arts (2009-2015)
- ▶ research popularisation activities, generating possibilities to connect teaching at school with cultural studies: series of seminars for school teachers "The Teacher as the Mediator of Cultural Memory", publications for teachers.



Field studies in Urveste Parish



GSCSA and CECT winter school 2011 in Tartu

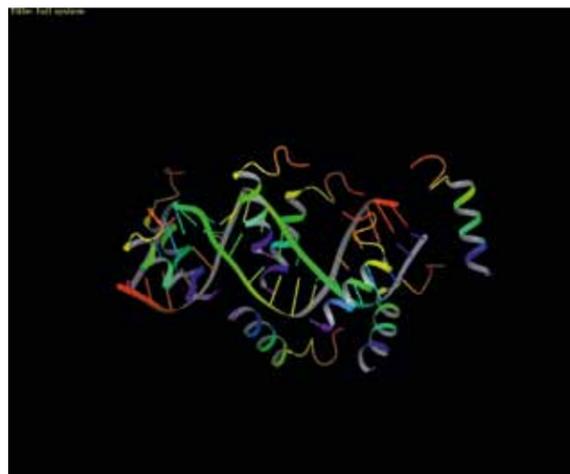
The Centre of Excellence in Chemical Biology (CECB) brings together expertise in modelling and synthesis of chemical compounds, in addition to the biology of viruses, bacteria and eukaryotic cells. CECB consists of six research groups: molecular modelling, chemical synthesis, peptide research, DNA viruses, RNA viruses and antibiotics. Through collaboration of these groups, chemical biology approaches are being applied to the study of infectious diseases and treatment of malignant tumors.

CECB includes around 50 researchers from University of Tartu (UT), Tallinn University of Technology (TUT) and Estonian Biocentre (EBC).

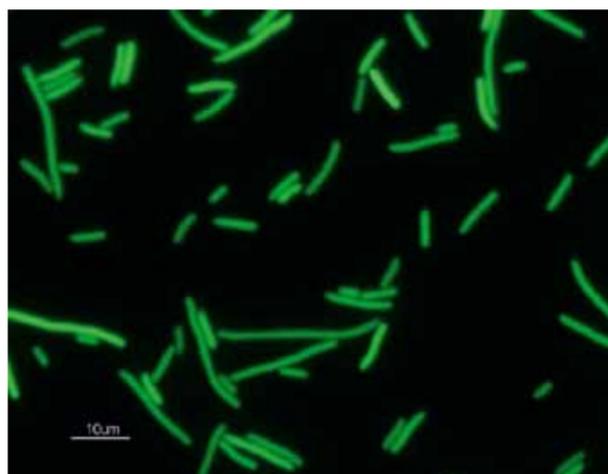
Two core facilities developed by CECB at UT provide services for researchers at CECB as well as in a wider range of academic and industrial sectors, both national and international.

The applied virology facility develops virus-based systems for biotechnological applications. The facility also runs flow cytometry equipment. (Contact: R.Kurg, reet.kurg@ut.ee)

The proteomics facility provides mass spectrometry based services with a special focus on quantitative proteomics. (Contact: L.Arike, liisa.arike@ut.ee)



Computer modelling of a macromolecular complex of potential therapeutic value. The large double helical structure in the middle shows a small RNA molecule intended to modulate gene expression of the host. The RNA is packed with cell penetrating peptides for efficient delivery



Cells of a bacterium, *Escherichia coli*, treated with the antibiotic erythromycin. In response to drug treatment, some of the cells filament; this response in turn could modulate the sensitivity of bacteria to the antibiotic

## CECB

### MOLECULAR MODELLING

Prof M.Karelson (mati.karelson@ttu.ee)

Group comprising researchers from UT and TUT focuses on the design of bioactive compounds.

### CHEMICAL SYNTHESIS

Prof M.Lopp (lopp@chemnet.ee)

Group is located at TUT, focuses on the development of new methods for asymmetric organic synthesis and application of these tools in the design of new bioactive compounds.

### PEPTIDE RESEARCH

Prof Ü.Langel (ulo@neurochem.su.se)

Group is located at UT, involved in developing cell penetrating peptide-based methods for delivery of bioactive compounds into target cells.

### DNA VIRUS RESEARCH

Prof M.Ustav (mart.ustav@ut.ee)

Group studies the mechanisms of papilloma virus replication and stable maintenance in host cells. This knowledge is applied in the development of new tools for gene vaccination, gene therapy and production of therapeutic molecules. The group contains researchers from UT and EBC.

### RNA VIRUS RESEARCH

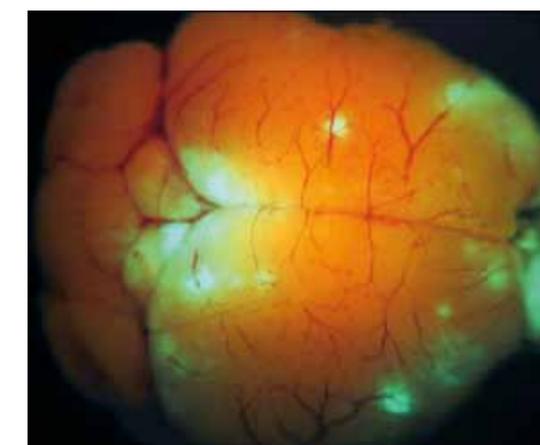
Prof A.Merits (andres.merits@ut.ee)

Group is located at UT, focuses on viruses with RNA genomes, including important human pathogens such as Chikungunya virus, hepatitis C virus and HIV. This knowledge is applied in the development of new antiviral therapies.

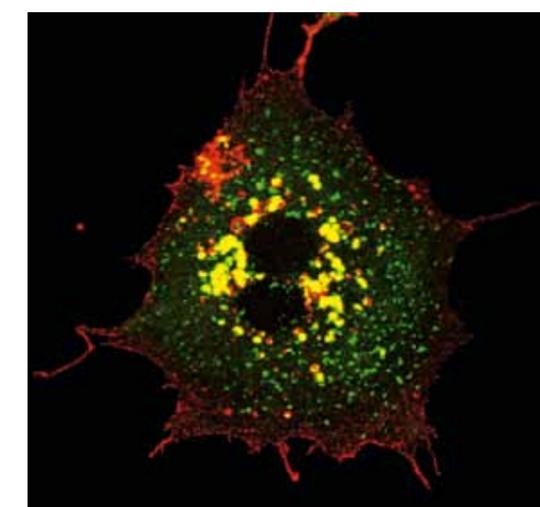
### ANTIBIOTICS RESEARCH

Prof T.Tenson (tanel.tenson@ut.ee)

Group is located at UT, studies the mechanisms of antibiotic action, resistance mechanisms and spread of antibiotic resistance.



The brain of a mouse infected by Semliki Forest Virus, the viruses being indicated by the yellow-green plaques



A mammalian cell infected with Semliki Forest Virus, the viruses concentrating into yellow-green dots

# CENTRE OF EXCELLENCE IN RESEARCH ON ADJUSTING TO ENVIRONMENTAL CHANGES

<http://environ.emu.ee>

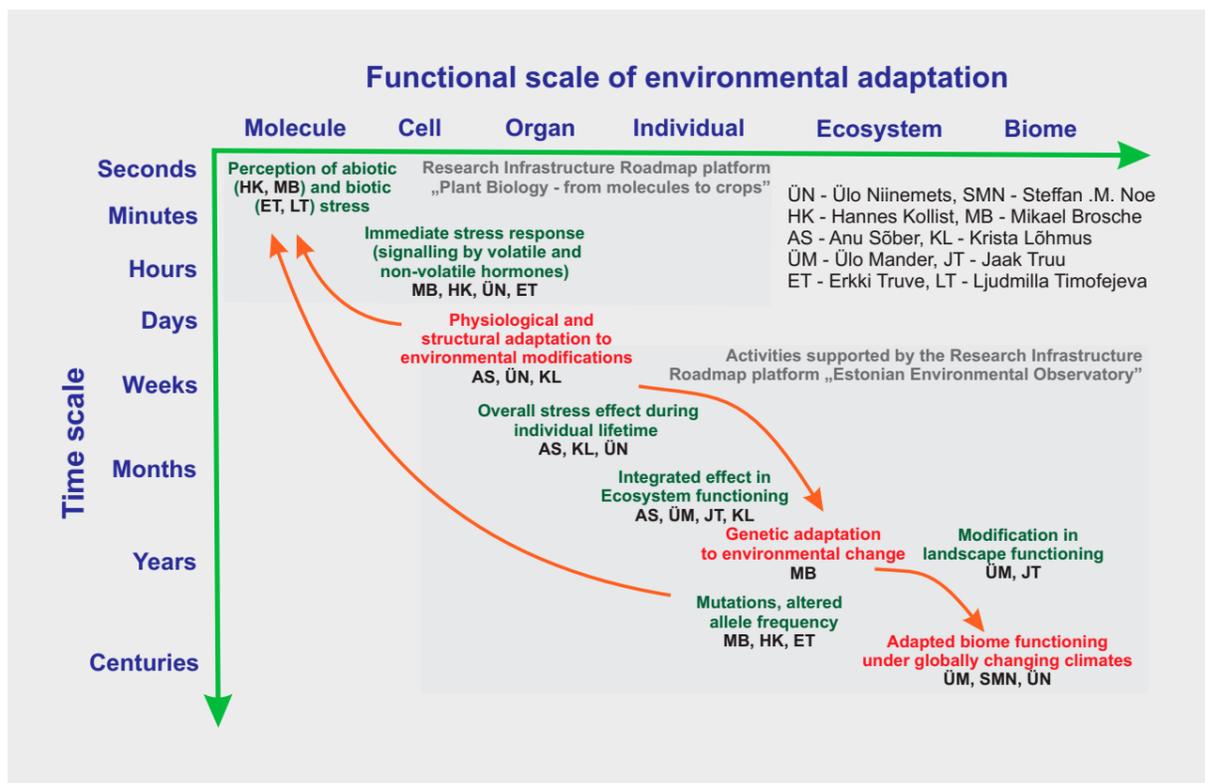
The Centre of Excellence in Environmental Adaptation (ENVIRON) was launched in August 2011 with support from the EU through the European Regional Development Fund for the period 2011-2015. The coordinating institution is Estonian University of Life Sciences. ENVIRON involves five research groups from three Estonian universities and includes more than 50 staff scientists and over 40 PhD students. Scientific activities are supported by an International Advisory Board: Prof S. Jansson (University of Umeå, Sweden), Prof M. Kulmala (University of Helsinki, Finland), Prof R. Matyssek (Technische Universität München, Germany), Prof J. Peñuelas (Universidad Autónoma de Barcelona, Spain), Prof C. Pieterse (Utrecht University, the Netherlands).

The overall objective of ENVIRON is to understand the mechanisms of environmental adaptation from molecular to global scales, and feedbacks between plant and ecosystem adaptation and climate change.

ENVIRON focuses on the process-oriented approach. The schematic overview below illustrates the key processes induced by the environmental stress, covered by the participating research teams. Different processes occur on different time scales, but are interdependent and form several feedback loops illustrating the need for integrated collaborative research at all levels.

Ecosystems have a high capacity to adapt to environmental perturbations, but most of the future projections of global change ignore adaptation responses. Interdisciplinary experimental and modelling approaches are used to analyse abiotic and biotic stress effects at molecular, physiological, individual and ecosystem levels, determine the limits of adaptation to multiple sequential and interacting stresses, and scale from molecular stress response mechanisms to adaptation of individuals, ecosystems and biomes. Apart from excellence in science, the consortium builds a foundation for sustainable management of natural resources in Estonia and other Nordic countries under globally changing conditions.

To meet the objectives, excellent lab facilities, including modern GC-MS, PTR-MS, HPLC equipment and unique plant gas-exchange monitoring systems, microscopy and plant molecular biology tools are available. A large-scale ecosystem infrastructure will be developed by "The Estonian Environmental Observatory" project in frames of the Estonian National Research Infrastructures Roadmap, including a SMEAR station (Station for Measuring Forest Ecosystem-Atmosphere Relations) and upgrading a FAHM (Free Air Humidity Manipulation) platform. These facilities collectively allow characterisation of plant stress responses in the lab and in the field and direct monitoring of soil-vegetation-atmosphere feedbacks.



**Host organisation**  
Estonian University of Life Sciences

**Postal address**  
Estonian University of Life Sciences,  
Institute of Agricultural and  
Environmental Sciences, ENVIRON  
Kreutzwaldi 1  
Tartu 51014, Estonia

**Head of the centre**  
Prof Ülo Niinemets  
Phone: + 372 7313187  
E-mail: [ylo.niinemets@emu.ee](mailto:ylo.niinemets@emu.ee)



Research groups:

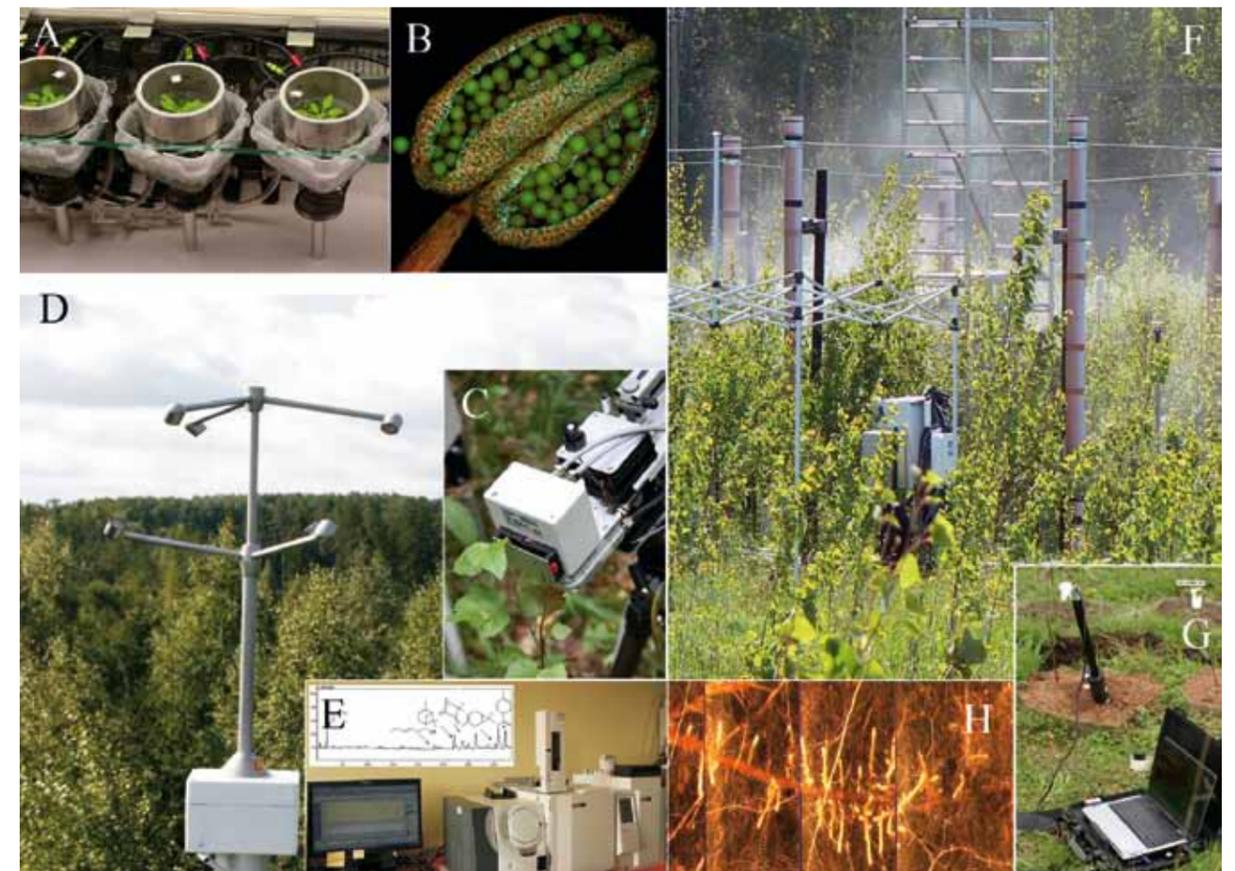
**PLANT PHYSIOLOGY AND  
BIOSPHERE-ATMOSPHERE INTERACTIONS**  
Prof Ü.Niinemets ([ylo.niinemets@emu.ee](mailto:ylo.niinemets@emu.ee))

**PLANT SIGNALS**  
Dr H.Kollist ([hannes.kollist@ut.ee](mailto:hannes.kollist@ut.ee))

**PLANT-PATHOGEN INTERACTIONS**  
Prof E.Truve ([erkki.truve@ttu.ee](mailto:erkki.truve@ttu.ee))

**PLANT ECOPHYSIOLOGY**  
Dr A.Söber ([anu.sober@ut.ee](mailto:anu.sober@ut.ee))

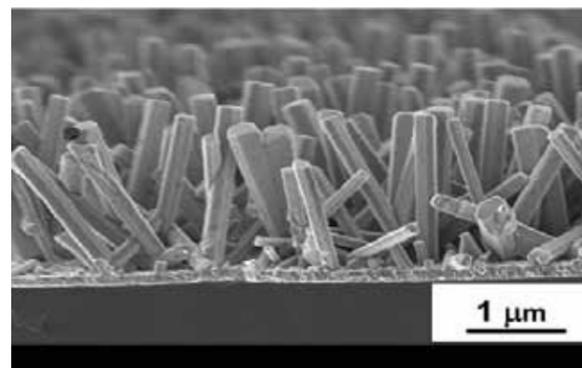
**LANDSCAPE ECOLOGY AND ECOTECHNOLOGY**  
Prof Ü.Mander ([ulo.mander@ut.ee](mailto:ulo.mander@ut.ee))



A – custom made *Arabidopsis* specific gas-exchange system for monitoring intact plant responses to various stimuli; B – ultrastructural studies of anthers in *Arabidopsis*; C – leaf level photosynthesis measurements with portable photosynthesis system; D – ecosystem level flux measurements (anemometer in an eddy flux tower); E – facility to measure constitutive and stress-elicited volatile compounds from plants; F –FAHM experiment; G, H – minirhizotron method: images of intact fine roots (H.-S.Helmisaari)

Current research of materials and processes delves progressively into micro- and nano- (on spatial scale) and to femtolevel (in time-domain). Mesoscopic systems and phenomena lie in between the macro world and atomic dimensions. Such spatial scale is a challenge for the current theories as both, the ones developed to describe macroscopic bodies as well as the theories for isolated atoms and molecules, fail. Meso-range of dimensions and processes hides potential for innovations for sensorics and informatics, and is also pertinent when talking of living systems (the size range between viruses and bacteria). New theories and closely related experimental studies are needed in order to 'bridge' the gap between the atomic and macro dimensions. The distinguishing feature of the research centre is unification of theoretical and experimental groups in solving one common task – how do atomic and macroscopic processes and properties interconnect on mesolevel?

Centre of Excellence Mesosystems – Theory and Applications (MESO) is focused on three closely interrelated topics: 'coherence' (superconductivity and superfluidity, ferromagnetic and ferroelectric ordering, plasmonic resonances), 'dynamics' (nonlinear models of energy localization and defect formation in microsols, transport processes in mesostructured systems) and 'structures' ('stripe structures' and incommensurate modulation, cracking of sol-gel films, molecular recognition, low-dimensional systems). These problems will be addressed by theoretical modelling, numerical simulations and various experimental techniques.



ZnO structural layer with nanorods from TUT group "Synthesis of functional structures"

Expected results of future research are development of methods of simulations of structure and dynamics of mesosystems, development of theory of nonlinear quantum optics and nonlinear plasmon-photonics on discrete photon level, prediction of new superconducting and magnetic mesosystems and new materials stable against radiational damage.

MESO is based on research cooperation of six research groups from three Estonian universities: University of Tartu (UT), Tallinn University of Technology (TUT) and Tallinn University (TLU).

### CONDENSED MATTER THEORY

Prof V.Hizhnyakov (hizh@fi.tartu.ee), UT

Group comprising 16 researchers and 3 PhD students is a renowned contributor to the theory of condensed matter and quantum fields. Recent successes include the discovery of percolative phase separation in high temperature superconductors (in collaboration with Nobel prize winner A.Müller); new general theory of vibronic transitions in solids; discovery of the effect of the zero-point motion of atoms in optical spectra of 4He and 3He droplets; prediction of vibrational solitons in metals and local modes associated with vibrational solitons; theory of the magnetic incommensurability in cuprates, modelling of defect formation and quantum diffusion in crystals.

### PHYSICS OF MESOSTRUCTURES

Prof J.Kikas (jaak.kikas@ut.ee), UT

Group comprising 24 researchers and 18 PhD students conducts material and optical research with experimental methods, develops advanced spectroscopic methods like spectral hole-burning and single molecule optical spectroscopy and their application to large variety of systems and processes ranging from complex biological structures to diamond-based materials. In recent years much attention is devoted to techniques utilising dopant molecules and ions in solids as nanoemitters/markers or as extremely selective and sensitive probes of local conditions. Novel techniques such as single-molecule imaging (SMI), confocal Raman and luminescence microscopy, photon correlation spectroscopy have been implemented, complemented by AFM and intensive numerical simulations. Pulsed laser deposition, sol-gel technology and focused ion beam lithography enable fabrication of a large variety of meso- and nanosystems.

# MESO

### CRITICAL PHENOMENA, ORDERINGS AND PHASE TRANSITIONS

Prof T.Örd (teet.ord@ut.ee), UT

Group comprising 7 researchers and 2 PhD students is mostly involved in the field of multi-band superconductivity. Successes include modelling of the properties of MgB<sub>2</sub> doping-created interband coupling mechanism for high-T<sub>c</sub> cuprates and study of superconducting fluctuations. The topics enfold nonlinear quantum optic effects and stochastic effects in phase transitions. Further research includes study of superconducting, magnetic and electronic mesoscale orderings; stochastic phenomena in multi-gap superconductors (Josephson junctions, vortex transport); phase transitions and nonlinear dynamics in spatially restricted systems and the development of new models of mesosystems.

### BIOORGANIC CHEMISTRY

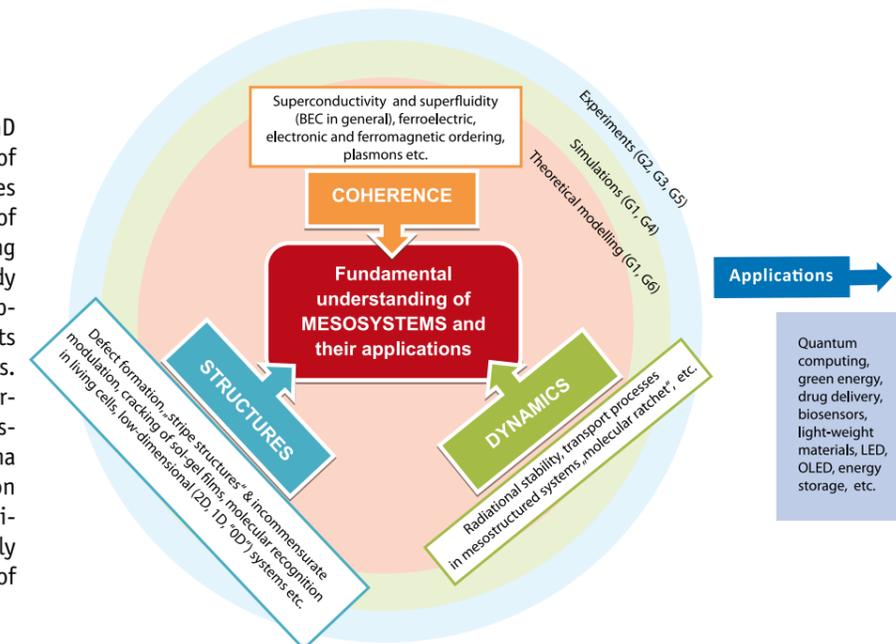
Prof A.Rinken (ago.rinken@ut.ee), UT

Group comprising 8 researchers and 4 PhD students is conducting studies on the mechanisms of the functioning of heptahelix receptors and their regulatory proteins, the key players in chemical signal transduction in nervous system. Original fluorescence based methods are implied together with new virus-based targets; novel synthetic strategies of substituted hydrazines – precursors for next generation drugs and materials are worked out; fluorescence applications form a base for developing new biosensors for determination of different substances.

### SYNTHESIS OF FUNCTIONAL STRUCTURES

Prof M.Krunk (malle.krunk@ttu.ee), TUT

Group comprising 6 researchers and 6 PhD students is active in the field of chemistry and deposition of metal oxide and of binary and ternary metal sulfide thin films by wet chemical methods such as sol-gel spray and chemical spray pyrolysis.



Main strength of this group is chemical analysis of formation, structure and thermal behaviour of intermediate complexes as precursors for the films. It has obtained notable success on the preparation of metal oxide and metal sulfide thin films for electronics, sensorics and photovoltaics; has invented the technology for manufacturing ZnO layers comprising nanorods/nanowires by chemical spray pyrolysis and solar cells based on those; is developing functional mesomaterials by wet chemical methods for light harvesting, plasmon photonics and biosensorics.

ZnO structural layer with nanorods from TUT group "Synthesis of functional structures".

### STOCHASTIC PROCESSES

Prof R.Mankin (romi@tlu.ee), TLU

Group comprising 12 researchers and 3 PhD students is directing its efforts towards developing a theoretical basis for various manifestations of stochastic processes and their applications in inter-disciplinary spheres. Possible applications range from superconductors to intercellular protein transport to methods of particle separation in nanotechnology, thus enabling to establish a fruitful collaboration with all other research groups in MESO. Main research topics are: anomalous transport; structure formation and phase transitions; influence of plasma on materials; noise-generated phenomena in superconductors; cell/nanoparticle sorting in molecular biology.

The interdisciplinary Centre of Excellence High-tech Materials for Sustainable Development (CoE) binds together the existing high-level expertise and research infrastructure of Institute of Chemistry and Institute of Physics at University of Tartu as well as Institute of Materials Science at Tallinn University of Technology – the leading exploratory establishments in Estonia in the field of science, materials technology and education.

Research groups:

#### ENERGY GENERATION AND STORAGE DEVICES

Prof E.Lust (enn.lust@ut.ee, <http://www.chem.ut.ee>)

#### SUPERACIDS AND -BASES

Prof I.Koppel (ilmar@chem.ut.ee, <http://www.chem.ut.ee>)

#### COATINGS AND SENSORS

Prof V.Sammelselg (vaino.sammelselg@ut.ee, <http://www.fi.ut.ee>)

#### SOLAR CELLS

Prof E.Mellikov (enn@staff.ttu.ee, <http://www.ttu.ee/departments-of-materials-science>)

CoE is focused on: a) design and development of materials synthesis and surface modification methods, b) development of time-resolved synchrotron, laser and neutron beam based methods for three-dimensional (3D) or two-dimensional *in situ* analysis of the kinetics of mass and charge transfer processes, and c) development of fundamental theory for analysis of processes at/inside micro-meso-porous (MMP) catalysts for novel power sources and thin-film anti-corrosion coatings (ACC) and solar cells (SC). New highly efficient ACC, dielectrics, graphene based materials, complex oxides for sensors, active catalysts, electrolytes and room-temperature ionic liquids based on superacids and superbases will be designed, synthesised, characterised and applied for future development of SC, electric double layer (EDLC) and hybrid supercapacitors (HSC), Li-ion batteries (LIB) and fuel cells (FC).

The activities of CoE are supported by small and medium scale research equipment upgrading projects and Estonian Science Infrastructures Roadmap projects common for all its partners. Significant attention of CoE will be paid to the development of 'human capital', including training of highly educated young scientists by involving post-doctoral researchers as well as MSc and PhD students in the research. Synergy of the activities of CoE and its Estonian and European business partners will considerably increase the R&D level and allows performing studies, which would not be efficient enough if carried out by the research groups separately but are, nonetheless, inevitable for the development of high-technology materials production and knowledge-based industry in Estonia and EU.

All actions of CoE are directed towards frontier research, its R&D strategic goals include:

- ▶ development of novel material technologies (new template synthesis methods for nanomaterials and novel electrolytes, new approaches for processing graphene-based structures, etc.)
- ▶ advancement of methods and approaches for characterisation of MMP and nano- and microstructured materials, in particular surface phenomena related to processing and application of these materials
- ▶ more efficient employment and modernisation of infrastructure of partner laboratories
- ▶ practical (commercial) application of new knowledge in thin-film SC, EDLC, HSC, FC and ACC with their integration into hybrid energy conversion and storage systems
- ▶ sustainable re-production of academic community and high-level young specialists for Estonian and EU economy
- ▶ expansion of cutting-edge studies applying facilities of CoE's international partners.

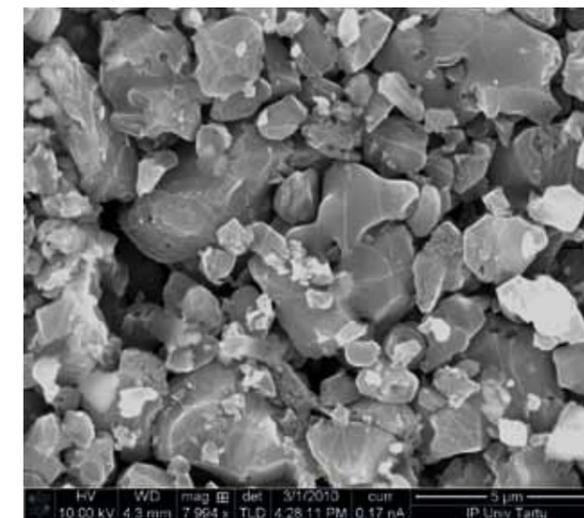
CoE addresses one of today's critical issues for the mankind – development of sustainable community based on environmentally friendly and highly effective hybrid energy technologies and its fields of expertise include:

- ▶ MMP materials, very high surface area carbons for EDLC and HSC, activated rare-earth complex oxides preparation for FC
- ▶ thin-film deposition methods, e.g. atomic layer deposition (ALD) and chemical vapor deposition (CVD) for preparing high-quality thin films for anti-corrosion coatings, chemical sensors and nanoelectronic devices
- ▶ thin-film materials and SC
- ▶ design and synthesis of superacidic and superbasic materials as catalysts and/or electrolytes for LIB and HSC.

Fundamental research is essential to generate necessary scientific understanding about the design, synthesis and modelling of nanostructured thin-film and MMP materials with hierarchical structure, thus CoE intends to develop advanced computational methods (density functional algorithms, quantum Monte Carlo techniques, *ab-initio* molecular dynamics, advanced mesoscale methods for soft-matter and fast multipole and multigrid algorithms); apply state-of-the-art material synthesis methods: ALD (allowing subnanometre thickness and structure control of synthesised material layers), CVD (suited for synthesis of graphene), electron beam deposition, magnetron sputtering, selective oxidation/reduction for processing and modification of materials.

Besides common techniques (dual focused ion and electron beam scanning microscopy, high-resolution scanning transmission electron microscopy, electron backscatter diffraction, secondary ion mass spectrometry), new dedicated large-scale international synchrotron radiation and neutron facilities are utilised. In perspective: developing

novel time resolved small angle X-ray and neutron scattering with picosecond resolution, element specific X-ray absorption spectroscopy, X-ray Raman spectroscopy with 3D depth resolution, and X-ray free-electron laser instrumentation for the analysis of nanoparticles properties during material synthesis; applying X-ray spectroscopy with sub-micrometer spatial resolution combined with AFM/STM – X-ray beamline for monitoring dynamical, structural and electronic processes with atomic resolution for analysis of chemical catalysis and electrocatalysis processes at solid | gas and solid | liquid interfaces; developing extended X-ray absorption fine structure and near edge structure methods to determine the d-metal atom oxidation state, coordination numbers, bond distances and mean-square disorder, local symmetry and electronic structure for catalysts surfaces under real electrochemical conditions.



Scanning electron microscope image of TiC derived carbon electrode

# DARK MATTER IN (ASTRO)PARTICLE PHYSICS AND COSMOLOGY

**Host organisation**  
National Institute of Chemical  
Physics and Biophysics

**Postal address**  
National Institute of Chemical  
Physics and Biophysics  
Rävala 10  
Tallinn 10143, Estonia

**Head of the centre**  
Dr Martti Raidal  
Phone: +372 645 4711

The scientific aim of the Centre of Excellence (CoE) is to combine the existing competence in particle physics theory and in experimental high energy physics in Estonia with the existing competence in cosmology and in simulations of the large scale structure of the Universe with the purpose to explain the origin and properties of dark matter of the Universe and to contribute to the discovery of dark matter in terrestrial and satellite based experiments.

CoE Dark Matter in (Astro)particle Physics and Cosmology combines two research groups from two Estonian research institutions:

## HIGH ENERGY AND PARTICLE PHYSICS (HEP GROUP)

Dr M.Raidal (martti.raidal@cern.ch), National Institute of Chemical Physics and Biophysics (NICPB)

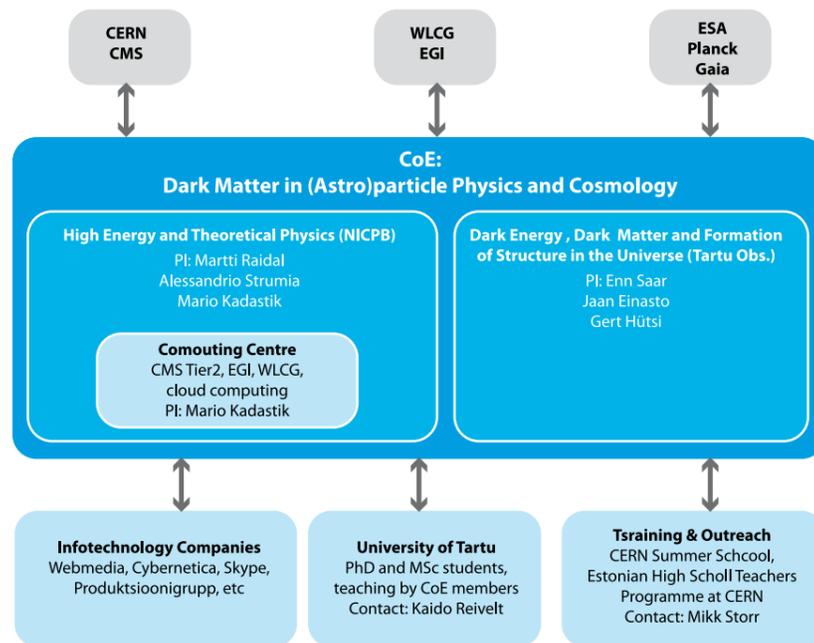
## DARK ENERGY, DARK MATTER AND THE FORMATION OF STRUCTURE IN THE UNIVERSE (COSMOLOGY GROUP)

Dr E.Saar (saar@aai.ee), Tartu Observatory (TO)

The former group hosts the largest Estonian scientific computing centre, which also belongs to the CoE – M.Kadastik (mario.kadastik@cern.ch).

Precise determination of the energy budget of the Universe is one of the greatest scientific achievements of the last decade. According to the WMAP satellite only 4% of the mass in the Universe is in the known form of baryonic matter. What are the constituencies of dark matter and dark energy that make up 20% and 76% of the Universe, respectively, remains a complete mystery. The question of origin of mass is the most important fundamental scientific question to be answered in this decade.

While Higgs boson, the last missing ingredient of the Standard Model that gives mass to all known particles, can be found or excluded by the CERN Large Hadron Collider (LHC) experiments alone, discovering dark matter, studying its origin, properties and distribution in the Universe requires a global multidisciplinary approach. This includes, in addition to direct dark matter searches at the LHC, also dark matter direct searches in low energy experiments like XENON100, DAMA, CoGeNT and CDMS II, indirect searches for dark matter annihilation or decay products in satellite based experiments like PAMELA, Fermi and AMS II, searching for the imprints of dark matter annihilations in the Cosmic Microwave Background to be measured with unprecedented precision by the Planck Mission, etc. Only a combination all those experimental efforts in cosmo-logy and particle physics with the results of computer modelling of the formation of large scale structure of the Universe and with theoretical interpretation of the results will make the discovery of dark matter possible.



The structure and main scientific partners of the CoE

# DARK MATTER

The main purpose of the CoE is to create an environment for interdisciplinary approach to dark matter research and to promote collaboration between research groups studying different aspects of dark matter. The members of the CoE belong to four large international collaborations, the Compact Muon Solenoid experiment at the LHC, the Worldwide LHC Computing Grid coordinated by CERN, the European Grid Initiative of the European Union and the Planck Mission of European Space Agency. Both groups belonging to the CoE include a number of international researchers, postdocs and graduate students working on scientific programs of those international collaborations.

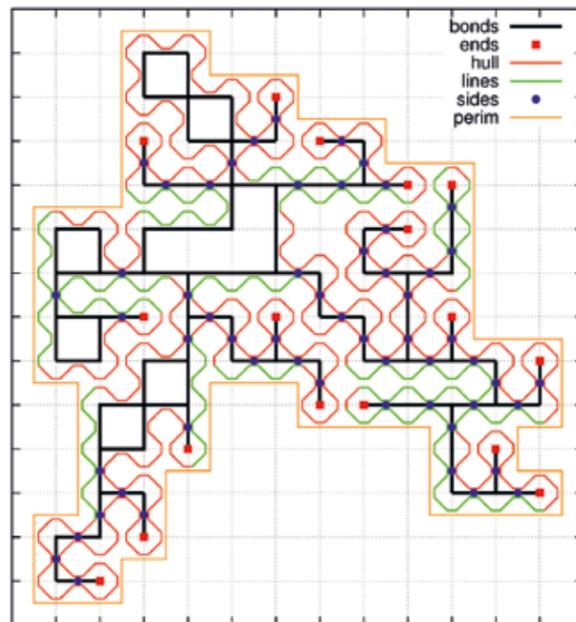
All those activities, participation of Estonian researchers in CERN, European Space Agency, Worldwide LHC Computing Grid and European Grid Initiative, are the objects of Estonian Science Roadmap. Therefore the CoE directly contributes to the formulation and to execution of the Estonian and European research strategies.

The CoE members have been and still are involved in the development of Grid and Cloud computing infrastructure in Europe and in Estonia for years. The CoE participates in several European Union distributed computing infrastructure projects and have similar projects with Estonian info-technology companies including Webmedia and Skype.



CoE members in front of the CERN Compact Muon Solenoid

The underlying idea for founding Centre for Nonlinear Studies (CENS) in 1999 was to bring together the scientific potential of Estonia engaged in interdisciplinary studies of complex nonlinear processes. CENS has succeeded twice, in 2002-2007 and in 2011-2015 to be included into the programme of the Estonian Centres of Excellence in Research. Earlier results are described in "CENS Highlights, 2007". For Annual Reports since 1999, see the homepage.



For fractal sets (here, a percolation cluster), different subsets can have equal fractal dimensionalities; our novel algorithm makes use of this fact to improve dramatically the efficiency of Monte-Carlo simulations

CENS is the Estonian hub of competence, research and training in nonlinear phenomena – the intrinsic component of real world that brings in universal phenomena (solitons, coherence, chaos, hierarchies, self-emergence, etc.) which need specific tools for their analysis and control. The research is interdisciplinary and cross-disciplinary. The present CENS includes the following research groups from the Institute of Cybernetics at Tallinn University of Technology (IoC at TUT) and the University of Tartu (UT):

### NONLINEAR DYNAMICS (IOC AT TUT)

Prof J.Engelbrecht ([je@ioc.ee](mailto:je@ioc.ee))

Group deals with (i) nonlinear wave motion in solids; (ii) soft matter physics; (iii) photoelasticity. Attention is on hierarchical behaviour of microstructured solids under dynamical impact and corresponding inverse problems; solitons and solitary waves; turbulent mixing; processes with power laws; nonlinear photoelastic tomography.

### WAVE ENGINEERING (IOC AT TUT)

Prof T.Soomere ([tarmo.soomere@cs.ioc.ee](mailto:tarmo.soomere@cs.ioc.ee))

Group has competence in nonlinear wave theory and modelling of fluids with the focus on applications in the marine and coastal environments. Attention is to wave excitation and propagation over the sea surface; impact of waves in coastal regions; unified framework for wave-driven phenomena.

### SYSTEMS BIOLOGY (IOC AT TUT)

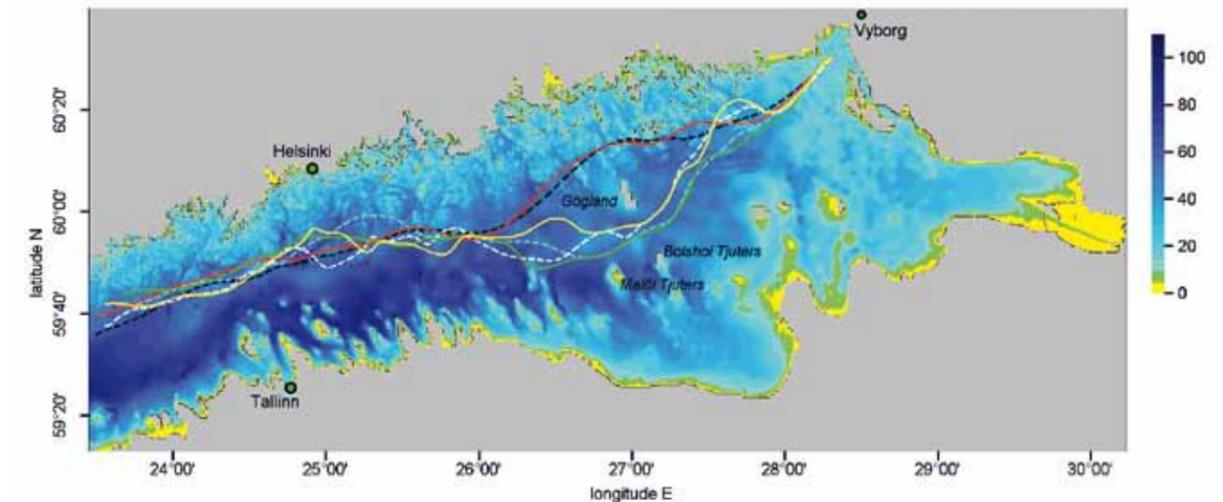
Dr M.Vendelin ([markov@sysbio.ioc.ee](mailto:markov@sysbio.ioc.ee))

The Systems Biology group is focused on unravelling the intricacies behind regulation of intracellular processes in cardiac muscle cells. Efforts are mostly concentrated on studying regulatory mechanisms of metabolic processes in the heart, expanding our knowledge of cardiac energetics and contractile function, and shedding light on novel aspects of excitation-contraction coupling in rat, trout and mouse hearts. Both experimental and computational approaches are applied in investigating these topics.

**Host organisation**  
Tallinn University of Technology

**Postal address**  
Tallinn University of Technology,  
Institute of Cybernetics, CENS  
Akadeemia 21  
Tallinn 12618, Estonia

**Head of the centre**  
Prof Jüri Engelbrecht  
Phone: + 372 620 4160  
Fax: + 372 620 4151



Optimum fairways from the Baltic Proper to Vyborg according to the spatial distributions of the probability for coastal hits (solid lines) and of the particle age (dashed lines)

### OPTICS (UT)

Prof P.Saari ([peeter.saari@ut.ee](mailto:peeter.saari@ut.ee))

Optics group has competence in ultrafast optics, optical and nonlinear spectroscopy and localised waves. Attention is to application of localised waves in femtosecond optics and nonlinear spectroscopy as well as extending operational characteristics of laser-based optical tomography.

### NONLINEAR CONTROL THEORY (IOC AT TUT)

Dr Ü.Kotta ([kotta@ioc.ee](mailto:kotta@ioc.ee))

Group has competence in dynamical control systems on time scales. Attention is focused on novel algebraic methods and symbolic software tools for solving fundamental problems for nonlinear control systems towards unification of discrete- and continuous-time control.

CENS has personnel of 75, of whom 30 are PhD students. In 2011, the researchers from 10 countries work in CENS.

The International Advisory Board is the direct link to the international community and an international network with many research centres working on same problems has been developed.

Synergy and added value is created in understanding universal nonlinear phenomena: mathematical models and methods of analysis; interaction of waves in a wide range of scales; solitons; solitary and localised waves; emerging features; nonlinear feedback; irreversibility; control over physical phenomena. Such studies are in the forefront of science, more specifically in studies of complex systems. There are many practical applications in materials science, environmental protection, health care, and information technology. Research is supported by several international agencies and programmes: Wellcome Trust, Bonus+ Baltic Way, Roboswarm, FuturICT, Humboldt Foundation, etc.

# CENTRES OF EXCELLENCE IN RESEARCH FOR YEARS 2008-2015 IN ESTONIA

Estonia is similarly to the rest of the world progressing towards establishing a system of Centres of Excellence in Research (CoEs), whose primary purpose is to generate new ideas. When administering the development of CoEs, resources are channelled into those areas of research, development and innovation, which have the potential for producing significant results in the context of global frontline research. This measure is focused on furthering performance at the highest standard of excellence in research and its implementation is expected to create a financial incentive to produce outstanding results on a world scale.

In Estonia the activities to promote and support CoEs are focused on several targets:

- ▶ creating a favourable work environment necessary for high-performance research
- ▶ establishing expedient conditions for integrating Estonian CoEs into the worldwide network and coherent collaboration between research groups in conformity with EU research policy
- ▶ encouraging and facilitating co-operation between top-level research groups working in similar or complementary fields
- ▶ developing an efficient communication mechanism between public-sector research institutions and enterprises for elaboration, development and implementation of innovative ideas.

The operation of the CoEs in Estonia for the period 2008-2015 is co-funded through EU structural instruments, which means that 85% of the eligible costs incurred by a CoE is covered by the European Regional Development Fund (ERDF), 10% by the state budget and the remaining 5% of eligible project expenditure has to be self-financed by the grant recipient. The Archimedes Foundation is the implementing agency for the "Development Centres of Excellence" measure in Estonia. The ERDF resources intended for this measure are almost 41.8 million euros, which represents 13.46% of the total ERDF budget available for R&D&I support measures. Likewise, financial assistance from the ERDF is provided for R&D activities, procurement of research equipment and modernisation of infrastructure in the priority areas specified in the Estonian R&D&I Strategy.

The Operational Programme (OP) "Development of Economic Environment" prepared pursuant to the Estonian National Strategic Reference Framework (NSRF) for the programming period 2007-2013 outlines five main priorities for action, incl. Priority 2: Improving the competitiveness of Estonian R&D through the research programmes and modernisation of higher education and R&D institutions. Enhancing the competitive ability of Estonian R&D at a global level is highlighted as one of the objectives in this priority area,

whereas publications by research staff members of CoEs reflected in the ISI Web of Science database were chosen as its impact indicator. The same document brings forth the number of CoEs financed by ERDF (7 in total) as the output indicator of this priority.

Regulation on Terms and Conditions for the "Development of Centres of Excellence in Research" measure actions applicable to the operation of a CoE co-financed from the Structural Funds and the Cohesion Fund was adopted on January 18, 2008 by Minister of Education and Research. According to the definition provided by the Regulation, a Centre of Excellence in Research is a consortium of several research groups internationally renowned in their area of activity. Its goal is to improve the quality and efficiency of scientific studies through co-operation between top-rank research groups. A research group is composed of Theme Leader and all Principal Investigators for a targeted financing research theme, however, it is constituted by members of some other currently running top level research project in case a particular area is not represented by a targeted financing research theme.

Two open calls for proposals for establishing new Centres of Excellence have been finalised in the programming period 2007-2013. The number of proposals submitted by prominent Estonian research teams under the First Call for Proposals in 2008 amounted to 24 with a total sum of over 140 million euros. 7 CoEs were finally selected by an Evaluation Panel consisting of both local and foreign experts (the first 7 in booklet). In 2011 a mid-term evaluation was carried out for the CoEs that had received funding under the First Call for Proposals. The Second Call for Proposals for CoEs was announced in 2011. From among 17 proposals with a total amount of over 49 million euros, received under the Second Call for Proposals, the Evaluation Panel decided to award funding to 5 CoEs (the last 5 in booklet).

The activities of CoEs supported under the First Call for Proposals are expected to be executed in the period 2008-2015 and the average grant amount for a CoE is over 4 million euros. The average number of involved research groups for a CoE is six.

CoEs approved for funding under the Second Call for Proposals are co-financed through structural instruments over a period of 5 years (2011-2015) and the average grant amount for a CoE is 2.6 million euros. The average number of involved research groups for a CoE is 5.

*Mariann Saaliste*

Head of Bureau of R&D Economic Environment  
Development  
Implementing Agency of Structural Support,  
Archimedes Foundation

## HISTORY



### 2001-2002

#### ESTONIAN CENTRES OF EXCELLENCE:

- ▶ Estonian Biocentre
- ▶ Institute of Physics of the University of Tartu
- ▶ Centre of Excellence of Analytical Spectrometry
- ▶ Centre of Basic and Applied Ecology
- ▶ Centre of Behavioural and Health Sciences
- ▶ Centre of Cultural History and Folkloristics in Estonia
- ▶ Centre of Excellence for Gene and Environmental Technologies

#### ESTONIAN PROSPECTIVE CENTRES OF EXCELLENCE IN RESEARCH:

- ▶ Centre for Biodiversity and Systematics
- ▶ Centre of Excellence in Increasingly Complex Molecular Systems
- ▶ Centre of Molecular and Clinical Medicine
- ▶ Research Unit for the Estonian Language Technology
- ▶ Research Centre for Isotope Geology and Palaeoclimatology
- ▶ Centre for Nonlinear Studies
- ▶ Cosmology Centre



### 2003-2007

#### ESTONIAN CENTRES OF EXCELLENCE:

- ▶ Centre of Excellence for Gene and Environmental Technologies
- ▶ Centre of Excellence of Analytical Spectrometry
- ▶ Centre for Nonlinear Studies
- ▶ Estonian Centre of Behavioural and Health Sciences
- ▶ Institute of Physics of the University of Tartu
- ▶ Centre of Excellence in Chemistry and Materials Science
- ▶ Centre of Molecular and Clinical Medicine
- ▶ Centre of Basic and Applied Ecology
- ▶ Centre of Cultural History and Folkloristics in Estonia
- ▶ Centre for Dependable Computing

