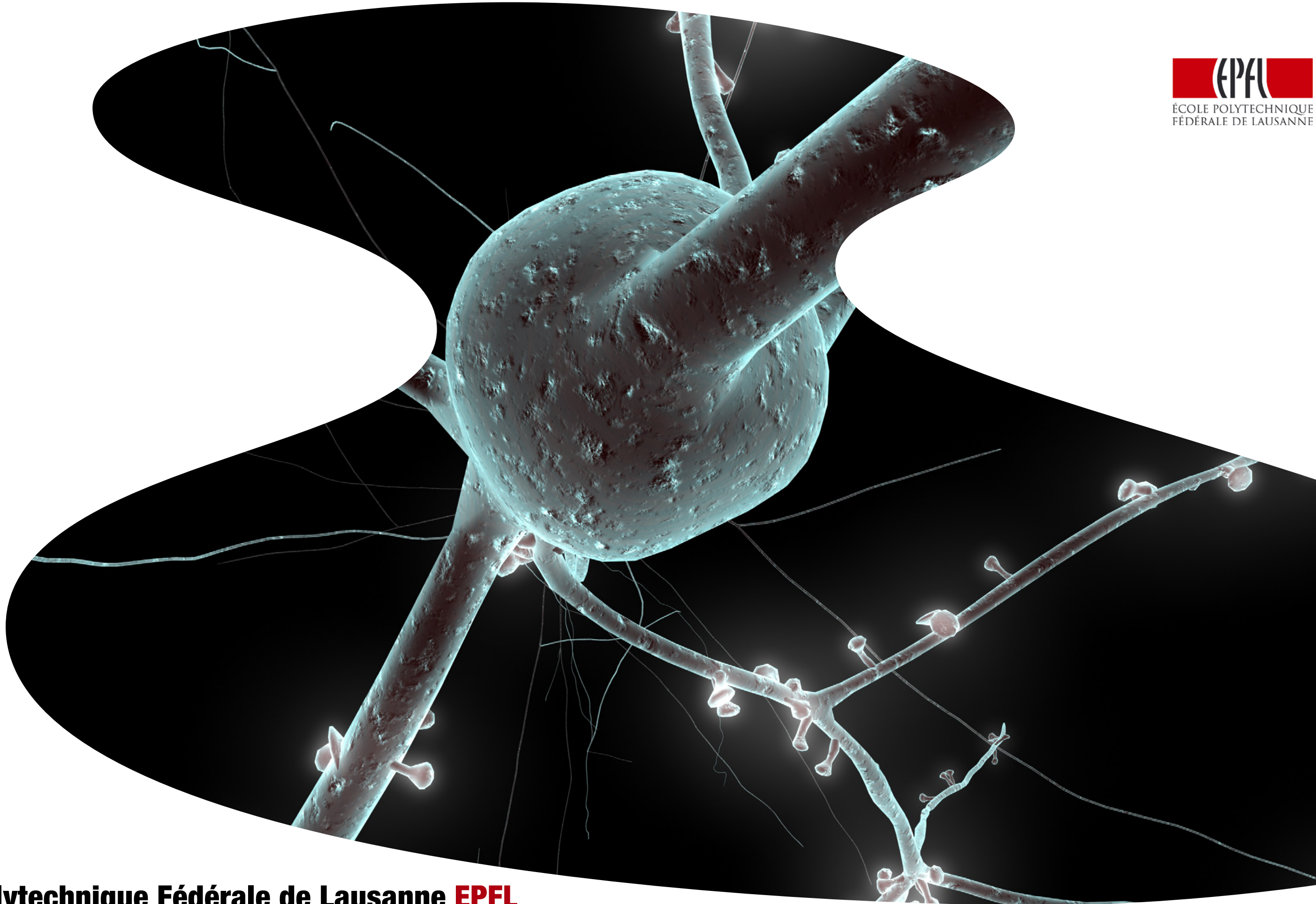


École Polytechnique Fédérale de Lausanne EPFL

Research Highlights 2013

Research at the EPFL

Beyond the quality of teaching and technology transfer activities, EPFL has now reached an enviable position for the quality of its research. More than any ranking could try to measure, a proper feeling for such an increase in excellence can be obtained by looking at the quality of the faculty who are willing to join EPFL, and their enthusiasm about coming here. Their dedication is key to the success of our school and the services of DAR can only be proud to be working within such a leading university.

It is necessarily unfair to try to point out one field or another and this report has chosen in some non-democratic / non-impact-factor based fashion one highlight from each of our schools. We hope that this report will be of interest to many people. As you will see, EPFL research spans a diverse range of areas, from cancer research to image recognition, molecular dynamics calculations to realization of high efficiency solar cells, as well as architectural wonders.

Considering the quality of our professors, the main duty of the research services is to allow them the maximum possible freedom to teach, search and transfer knowledge to the outside world. The services of the research deanship are meant to help our professors to the best of our abilities in the different steps linked with their scientific research. I want to thank here wholeheartedly the personnel of the different services of DAR for their constant dedication to the assistance of all researchers at EPFL.

Prof. Benoit Deveaud-Plédran
EPFL Dean of Research

School of Architecture, Civil, and Environmental Engineering ENAC

Faculté de l'Environnement Naturel, Architectural et Construit ENAC
enac.epfl.ch

The mission of the School of Architecture, Civil, and Environmental Engineering ENAC is to provide excellent undergraduate and graduate level education and conduct research into innovative solutions for the world's most pressing environmental issues: population growth and the emergence of megacities; increasing land, energy, and transportation needs; maintenance and improvement of the built environment; conservation of natural resources and biodiversity; and the management of natural and manmade hazards.

Designing Spaces for Cohabitation in the 21st Century

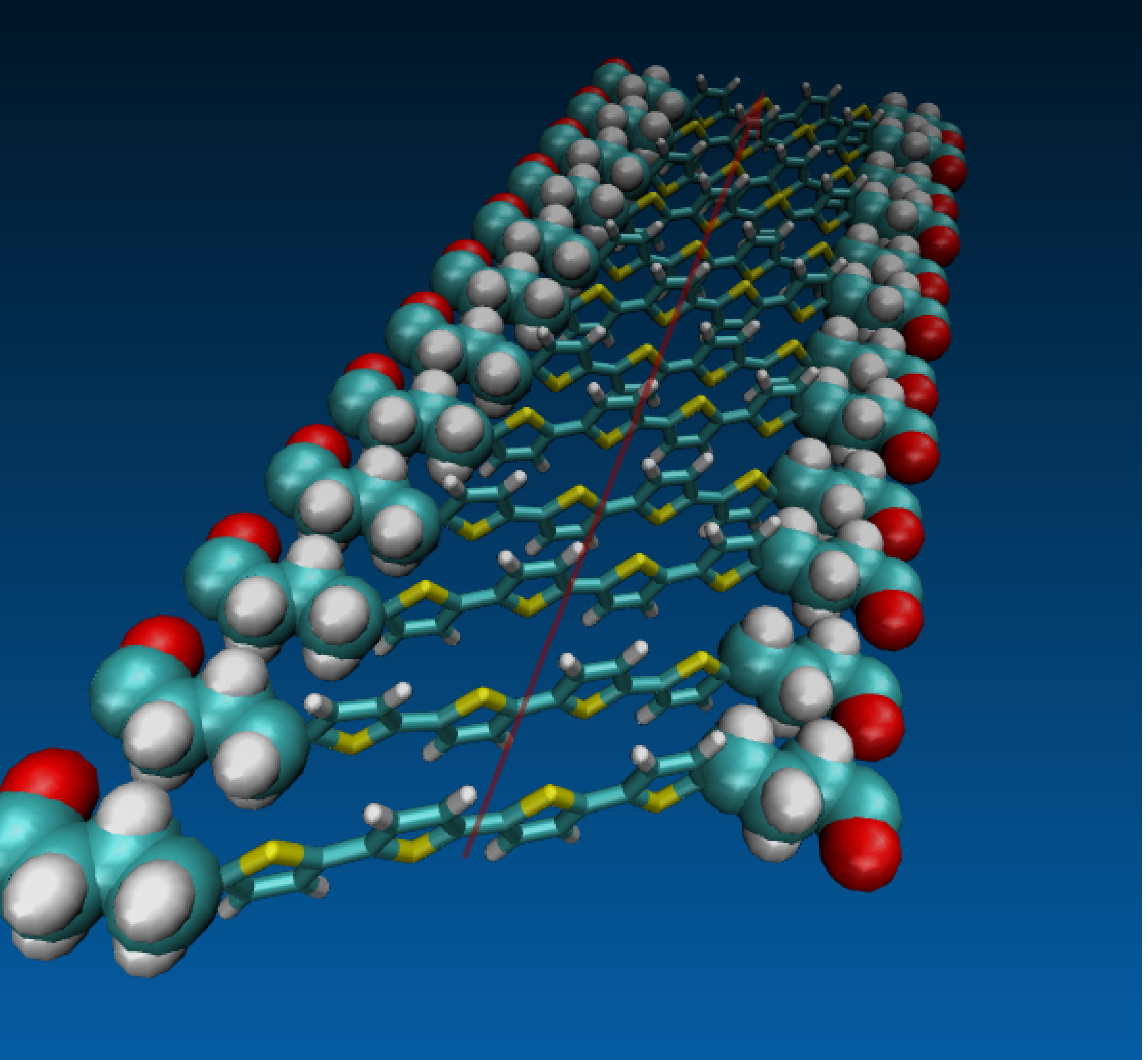
Space is at the core of many environmental problems. From everyday objects to large infrastructures the way we construct things has an impact on issues at global scale.

At ALICE EPFL architects and scientists work together in trans-disciplinary projects placing space within the focus of human and technological processes. ALICE strives for open processes and non-deterministic, synthetic design methodologies – driven by the will to integrate analytical, data based approaches and design thinking into actual project proposals.

In 2010 ALICE launched an ongoing research project entitled CH2048. Based on analytical data and scientific assessment, ALICE is using prospective future-oriented visions in order to question whether demographic flux could act as a lever towards more sustainable territorial developments. Evaluating new ways of living together, researchers are assessing a sequence of growth scenarios for the Swiss population by the year 2048 (8, 12 and 16 million inhabitants). Density, contrast and mix-used configurations are premises to this research process. It involves a careful study of socio-spatial parameters, innovative planning tools and urban energy consumption at several scales of the Swiss territory.

In the last years the lab has been able to obtain broadly cited results through its synthetic Design Research activities employing scientific knowledge about design processes and scientific findings from other fields. Exhibited at the Venice Biennale in 2008, projects such as the London 'overflow' pavilion have received several awards. The 2009 'evolver' project in Zermatt continues to be widely published and was number 7 of the top-ten visited sites in designboom* blog-magazine worldwide in 2011. In 2012 ALICE realized research projects such as Luna, an ephemeral stage for the St Prex Classics festival as well as the Montreux Jazz Heritage Lab – and continues to strive for ever more challenging projects in its Design Research approach.

Prof. Dieter Dietz
Institute of Architecture IA
alice.epfl.ch



School of Basic Sciences SB

Faculté des Sciences de Base SB

sb.epfl.ch

The mission of the School of Basic Sciences SB is to create new knowledge that forms the basis of next generation technologies, find scientific solutions to real-world problems, educate and train the next generation of scientists and engineers, and foster innovation for economic growth via activities ranging from curiosity driven research to device oriented applications.

To fulfill its mission, SB hires world-class researchers and teachers, maintains state-of-the-art scientific infrastructure, and encourages bottom-up participation of all our faculty in the day-to-day management as well as in the strategic planning of our school.

The Challenges of Modeling Organic Molecular Materials

The field of electronics is a veritable economic powerhouse, driving technological breakthroughs affecting all aspects of everyday life. Aside from silicon and inorganic congeners, growing interest exists for developing a new generation of electronic devices based on π-conjugated polymers and oligomers. These species potentially result in reduced fabrication costs along with novel functionalities (e.g. mechanical flexibility, transparency, impact resistance). The performance of such organic devices (e.g., charge-carrier mobility in field-effect transistors) depends heavily upon the organization and electronic structure of π-conjugated molecules or chains at the molecular level. To achieve the full potential of such materials, technological developments require fine-tuning of the specific intermolecular interactions spanning small ranges of distances, lateral displacements, and π-conjugated moiety orientation. The discovery pace of novel materials can be accelerated, considerably, by using efficient computational schemes where key characteristics are evaluated in silico.

Researchers from Prof. Corminboeuf's group at ISIC work on developing and applying electronic structure methods that provide accurate descriptions of the structural organization, electronic properties, and electron dynamics of π-conjugated frameworks. The apparent simplicity of the chemical composition of π-conjugated systems contrasts the complexity of their electronic structure, where the most commonly used framework (i.e., density functional approximations) suffer from obvious failures. To achieve accurate predictions of organic electronic materials, LCMD addresses lingering difficulties in describing charged radical oligomers (i.e., charge carrier), charge-transfer interactions, close π-stacking interactions, and near-degenerated electronic states.

In addition to methodological aspects, focus is placed on identifying key organic material structure-property relationships. In particular, ongoing work addresses issues regarding the sundry factors that govern the strength of interactions among π-conjugated moieties, the nature of charge carriers, and charge transfer rates.

All approaches and realizations are designed to tackle the most relevant aspects associated with functional organic molecule properties.

Prof. Clémence Corminboeuf
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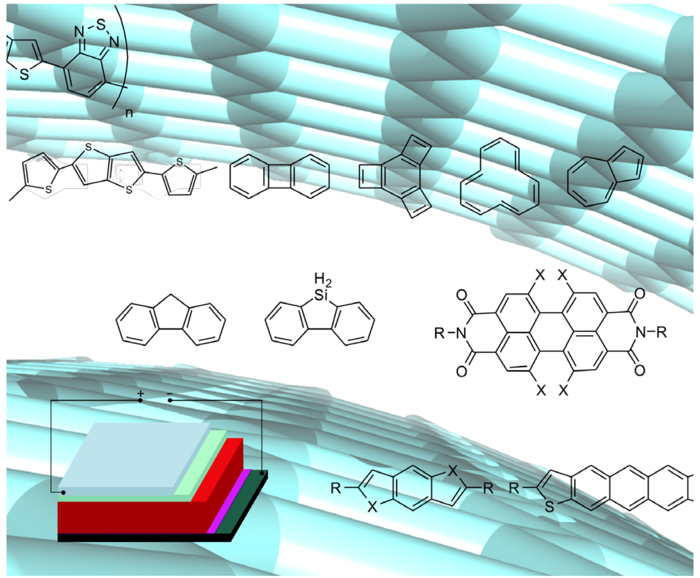
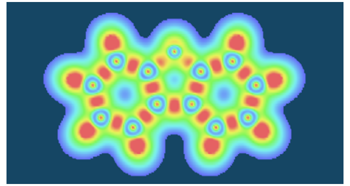
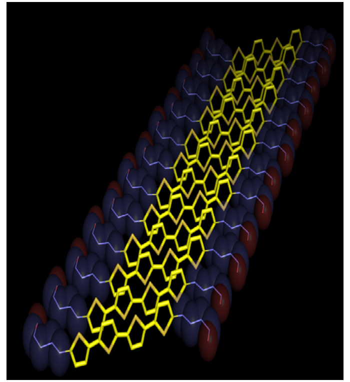






School of Engineering
STI

Faculté des Sciences et Techniques de l'Ingénieur STI
sti.epfl.ch

The high quality of the scientific publications and the large number of successful patent applications that emanate from the School of Engineering STI laboratories attest to the recognition of the international academic community and the interest of industrial partners in its work.

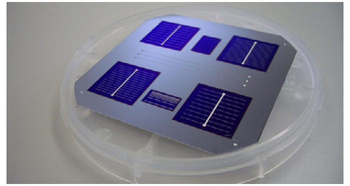
With 1275 employees, 1020 undergraduates, 547 Masters students and 657 doctoral candidates, and an annual budget of 80 million Swiss Francs, STI possesses both the competencies as well as the means to bring a broad range of multidisciplinary projects to a successful conclusion.

Advanced Silicon Photovoltaics for a Solar-Powered Future

Solar cells have the potential to renewably supply the electricity demands of our modern society. Despite the entry of many new materials into the photovoltaics market, silicon remains the most promising material for a solar-powered future. The Photovoltaics and Thin-Film Electronics Laboratory PV-Lab of IMT, headed by Prof. Christophe Ballif, focuses on the development of new processes and device structures for silicon solar cells and specialty detectors. Our research ranges from fundamental materials science to industrially feasible demonstration modules

Key topics include the realization of high-efficiency thin-film silicon solar cells (based on amorphous and microcrystalline silicon) as well as the fabrication and characterization of high-efficiency silicon heterojunction solar cells (obtained by sandwiching crystalline wafers between nanometer-thick amorphous silicon layers, De Wolf et al., Phys. Rev. B 2012). To realize state-of-the-art devices, the lab specializes in the development of ultra-transparent conductive oxides, advanced light-trapping structures (Battaglia et al., ACS Nano 2012), and tailored plasma processes for semiconductor layer deposition and interface treatment (Cuony et al., Adv. Mat. 2012). Solar product development is also a core activity, with a focus on reliability and innovative design. In 2012, we patented a novel terracotta-colored module that mimicks traditional roof tiles and opens unique opportunities for integrating modules into roofs and building.

Other recent highlights include top-notch thin-film silicon solar cells with initial efficiencies up to 14.1% (on glass, Boccard et al., Nanolett. 2012) and 13.7% (on plastic foil, Söderström et al., J. Appl. Phys. 2012), as well a screen-printed silicon heterojunction solar cell that broke the 22% efficiency barrier with production-like manufacturing processes (Descoeudres et al., IEEE J. Photovoltaics 2012). Ongoing industrial collaborations ensure that our findings are on their way to solar roofs and solar farms!



Prof. Christophe Ballif
Institute of Microengineering IMT
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School of Computer and Communication Sciences IC

Faculté Informatique et Communications IC

ic.epfl.ch

The School of Computer and Communication Sciences is one of the main European centers for education and research in the field of computer, information and communication sciences. Its research includes interdisciplinary projects with a wide variety of programs across campus and with other universities and is funded by the Swiss Confederation, European Union, as well as a number of private foundations and industrial partners.

Research activities span the following areas: Algorithms & Theoretical Computer Science, Artificial Intelligence & Machine Learning, Computational Biology, Computer Architecture & Integrated Systems, Data Management & Information Retrieval, Graphics & Vision, Human-Computer Interaction, Information & Communication Theory, Programming Languages & Formal Methods, Security & Cryptography, Signal & Image Processing, Systems & Networks.

Images and Visual Representation

The research of the Images and Visual Representation Group IVRG in the School of Computer and Communication Sciences IC is primarily concerned with color image processing and computer vision for computational photography and video to optimize the quality of natural image encoding and display. The developed imaging systems, algorithms, and models are based on low and high level processing features of the human visual system as well as the underlying physics of the acquired and displayed lightfield.

In general, we are interested in the question of "what is an image?" What are the fundamental components that "make" an image, and how does the change of one of those components influence the perception of it? How come we always know if we are looking at a "good" image or a "bad" image, even without being able to identify what is "good" or "bad" about it? Can we identify models and algorithms that define and predict these subjective criteria, and build systems that improve the visual experience? In the domains of photography and video, where we only acquire a reduced dimension of the original lightfield, there are still fundamental gaps in our knowledge of how much other concurrent physical stimuli as well as mental processes contribute to perception.

To develop meaningful computational photography and image quality models, systems and algorithms that better mimic visual perception needs the collaboration of several fields, including computer vision, image processing, psychology, physiology, and physics. IVRG is therefore collaborating with several experts from different fields and different institutions. Applications of the developed systems, methods and algorithms are in new camera technologies, cross-comparisons of different image capture, processing and display techniques, in image understanding, and in digital image production and archiving. For example, IVRG has developed demosaicing and high dynamic range image rendering algorithms that are based on a retinal processing model, new camera models that use silicon sensors' inherent sensitivity to near-infrared to improve image quality and image understanding, and automatic image enhancement tools that take into account the specific context of a photograph.

Prof. Sabine Süsstrunk
Institute of Communication Systems ISC
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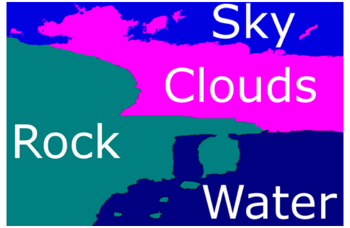


School of Life Sciences SV

Faculté des Sciences de la Vie SV

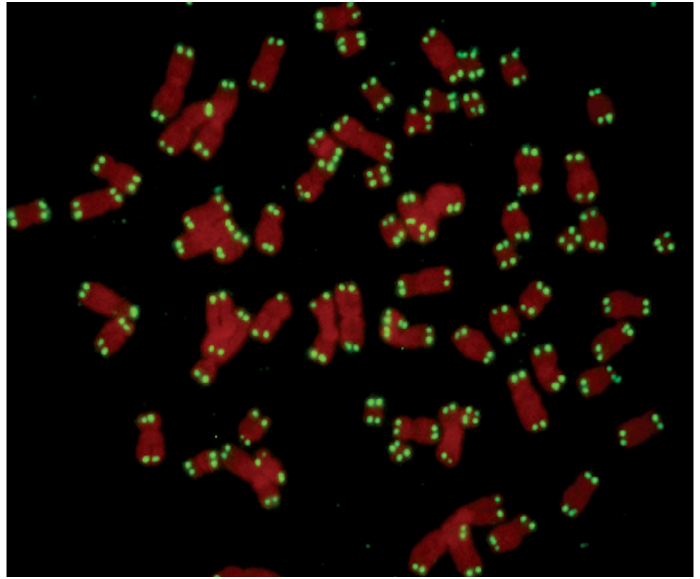
sv.epfl.ch

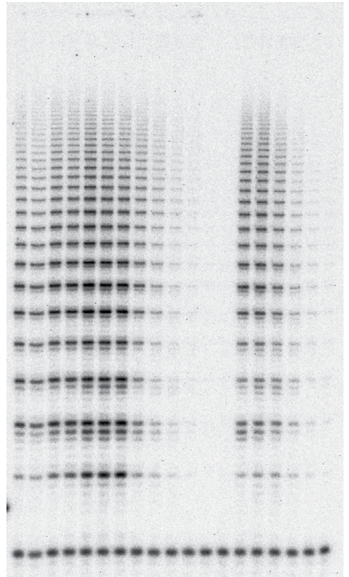
Today's challenges in medicine require broad transdisciplinary approaches, merging expertise in biology, medicine, physics, chemistry, mathematics, and engineering. Consequently, the School of Life Sciences SV trains scientist engineers whose combined skills in these fields are set to address fundamental biological questions and to attack major medical problems of our times. Researchers in SV apply this philosophy to broad fields including cancer, infectious diseases, neurological disorders, bioengineering, drug delivery, immunoengineering, or systems biology. These projects span a wide range of disciplines and methodologies through active collaborations with engineers across the rich technology campus of EPFL.

Dissecting the Telomere Clock in Cancer

Cancer develops due to the accumulation of mutations in our genome, which resides in the form of DNA in 46 chromosomes. The physical ends of chromosomes, known as telomeres, play critical roles in suppressing cancer development because of two main reasons. First, telomeres suppress mutations protecting chromosomes from degradation and from chromosome rearrangements typically seen in cancer. Second, telomeres serve as cellular clocks limiting cellular lifespan. The DNA ends at telomeres shorten every time a cell duplicates and upon reaching a critically short length, telomeres instruct the cell to not divide any further. Thus, precancerous cells which loose normal growth constrains due to mutations in growth control genes, will stop expanding due to short telomeres before forming large life-threatening tumors. In tumors, however, the telomere clock is overcome through mutations that cause expression of an enzyme, called telomerase, which re-elongates the shortened telomeres. Through telomerase expression, cancer cells become immortal which represents a cancer hallmark.

The ISREC laboratory led by Prof. Joachim Lingner investigates the mechanisms by which telomeres are maintained by telomerase in cancer. The laboratory discovered cellular mechanisms which occur to assemble telomerase and deliver it to telomeres in order to mediate their extension. A recent key finding of this team was also to identify protein factors that bind to elongated telomeres in order to terminate telomere elongation by telomerase (Chen, Nature 2012). The laboratory also discovered that telomeres contain not only telomeric DNA and proteins but also long noncoding RNA molecules that regulate telomere length (Azzalin, Science 2007; Pfeiffer, PloS Genetics 2012). Detailed mechanistic insight into how telomeres are maintained should facilitate the development of rational therapies that target the telomere clock to abolish cancer cell growth.





Prof. Joachim Lingner
Swiss Institute for Experimental Cancer Research ISREC
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College of Management of Technology CDM

Collège du Management de la Technologie CDM
cdm.epfl.ch

The mission of the College of Management of Technology CDM is to conduct research and provide education at the frontier of management science, finance, and economics. Our research activities span a comprehensive range, from asset pricing, corporate finance, entrepreneurship, financial mathematics, industrial organization, innovation, operations research, strategy, supply chain management, to quantitative risk management. In addition, we offer first-class teaching programs at master's, doctoral and executive level designed to provide scientists and engineers with a solid knowledge of management and finance. The CDM is a strong asset to EPFL, infusing the campus with entrepreneurial spirit and cross-disciplinary research partnerships.

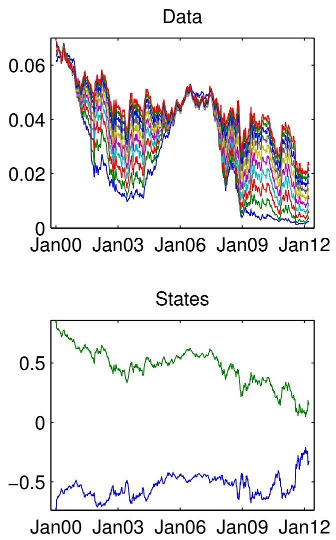
Deciphering the Term Structure

The term structure plays a central role in the functioning of the interbank market, which enables banks to extend loans to households and firms, hence fostering economic growth. The recent financial crisis has revealed the multivariate risk nature of the term structure, which includes interest rate, credit, inflation and liquidity risk. This has generated a strong interest in tractable stochastic models for the movements of the term structure that can match all determining risk factors.

The Swissquote Chair in Quantitative Finance and researchers from the Swiss Finance Institute at EPFL have recently developed a novel stochastic model for a term structure analysis which offers valuable information about market participants' perceptions of future interbank risk. That is, the risk of losses resulting from lending in the interbank money market. Their analysis provides a framework for pricing, hedging, and risk-management of interest rate derivatives in the presence of significant term structure risk. It can also provide a valuable tool for central banks and regulatory authorities in anticipating future stress in interbank markets and guiding appropriate policy responses.

The term structure is a function which displays the relationship between the yield of a zero-coupon bond, which is a certain form of loan, and its term to maturity. It thus also represents a key factor for the valuation and management of long term insurance liabilities, such as pensions. Traditional models fail to capture the current historically low interest rate environment.

Professor Filipovic is presently developing a new class of term structure models based on polynomial preserving processes, which are defined as Markov processes whose generator leaves the space of polynomials of any fixed degree invariant. As a consequence polynomial preserving processes yield closed form polynomial-rational expressions for the term structure. These models can deal with low interest rate regimes as we presently encounter. The methods will also be applied to model other important economic variables such as energy or volatility risk.



Prof. Damir Filipovic
Swiss Finance Institute SFI
sfi.epfl.ch

Vice Presidency for Academic Affairs VPAA
vpaa.epfl.ch
Integrated Systems Center CTSI
Nano-Tera.ch Centre NANO-TERA
Swiss Space Center CTS
Center for Neuroprosthetics CNP
Center on Risk Analysis and Risk Governance CRAG

Vice Presidency for Innovation and Technology Transfer VPIV
vpiv.epfl.ch
MetaMedia Center CMM
Energy Center CEN
Transportation Center TRACE
EPFL-ECAL Lab EPFL-ECAL-L
EcoCloud Center ECOCLOUD

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Civil Engineering Institute IIC
Institute of Urban and Regional Sciences INTER
Environmental Engineering Institute IIE
Hosted Units EH-ENAC

School of Basic Sciences SB
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Mathematics Institute of Computational Science and Engineering MATHICSE
Mathematics Institute for Analysis and Applications MATHAA
Mathematics Institute for Geometry and Applications MATHGEOM
Institute of Chemical Sciences and Engineering ISIC
Institute of Physics of Energy and Particles IPEP
Institute of Condensed Matter Physics ICMP
Institute of the Physics of Biological Systems IPSB
Institute of Theoretical Physics ITP
Max Planck - EPFL Centre for Molecular Nanosciences and Technology CMNT
European Centre of Atomic and Molecular Computations CECAM
Bernoulli Center CIB
Biomedical Imaging Research Center CIBM
Interdisciplinary Center for Electron Microscopy CIME
Center for Research In Plasma Physics CRPP
PRN Quantum Photonics PRN-QP

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Institute of Electrical Engineering IEL
Institute of Mechanical Engineering IGM
Institute of Microengineering IMT
Institute of Materials IMX
Interinstitutional Center of Translational Biomechanics CBT
Competence Centre for Materials Science and Technology CEPF CCMX
Center of MicroNanoTechnology CMI
Molecular and Hybrid Materials Characterization Center MHMC
PRN - Robotics PRN-ROBOTICS

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Institute of Computing and Multimedia Systems ISIM
Institute of Communication Systems ISC
Mobile Information and Communication Systems MICS
Center for Advanced Digital Systems CSDA
Center for Neural Information Processing CTIN
Center for Global Computing CGC
Institutional Partners PI-IC

School of Life Sciences SV
sv.epfl.ch
Brain Mind Institute BMI
Interschool Institute of Bioengineering IBI-SV
Swiss Institute for Experimental Cancer Research ISREC
Global Health Institute GHI
Center for Neuroscience and Technology CNT
Center for the Study of Living Systems CAV
NCCR Molecular Oncology PRN-MO
PRN The Synaptic Bases of Mental Diseases PRN-SYNAPSY

College of Management of Technology CDM
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Management of Technology and Entrepreneurship Institute MTEI
Swiss Finance Institute at EPFL SFI
Management of Technology EPFL - UNIL CMT

College of Humanities CDH
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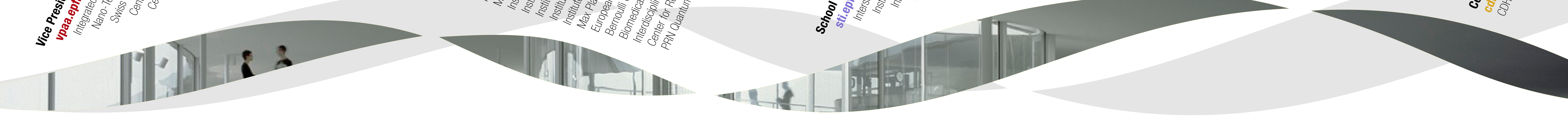

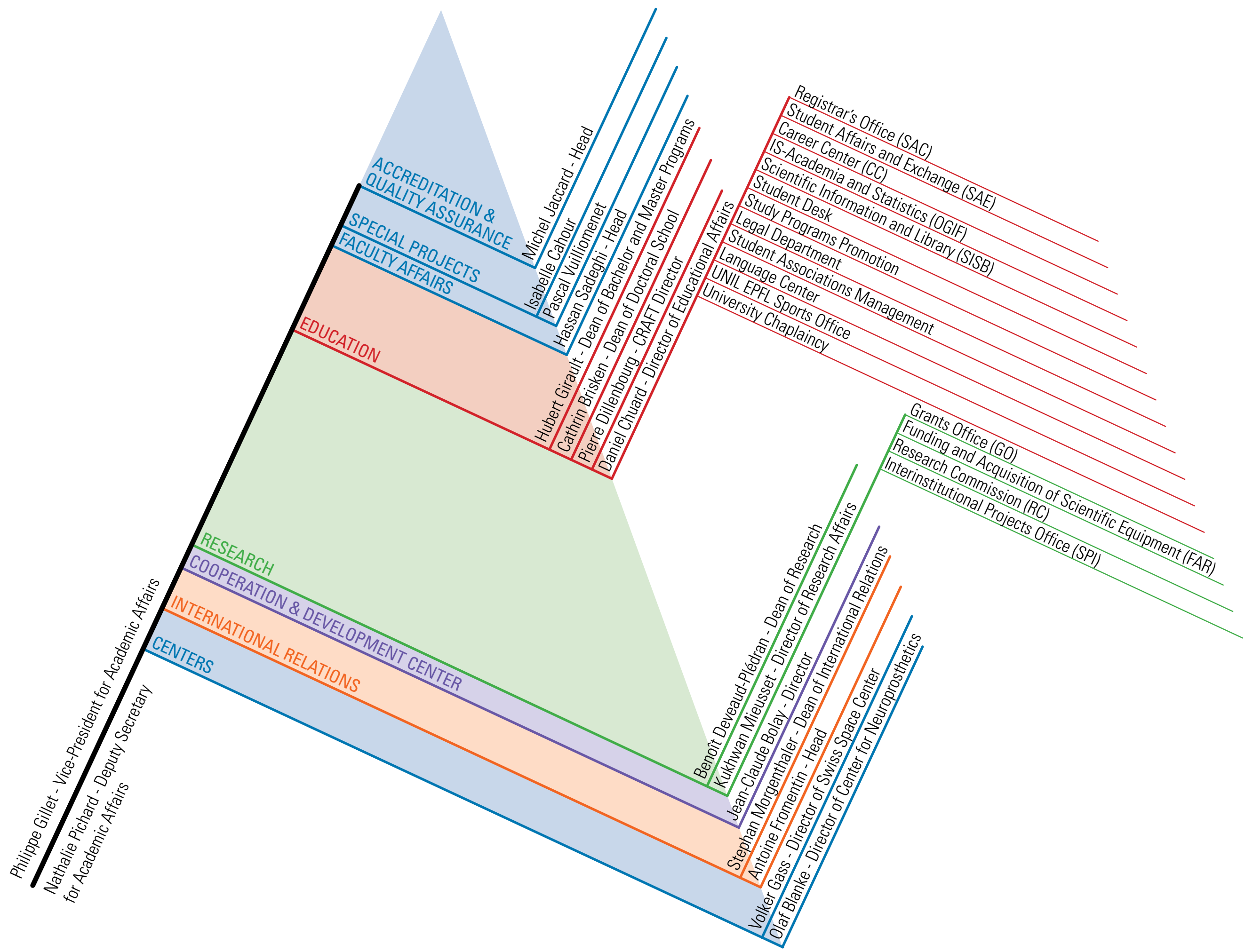

Vice Presidency for Academic Affairs Structure

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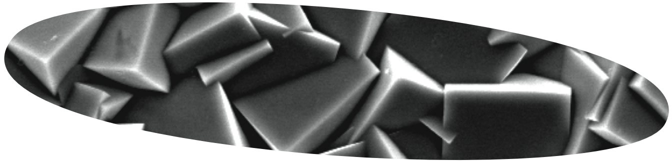

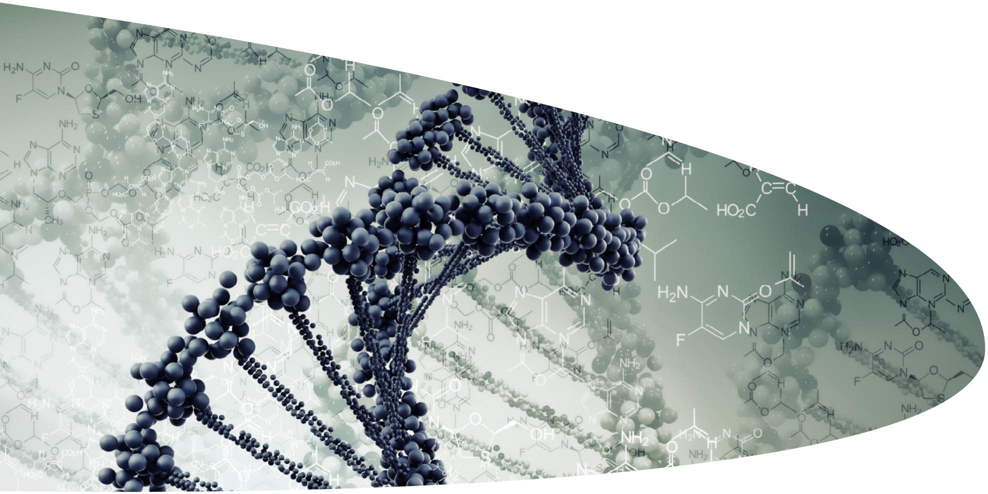

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