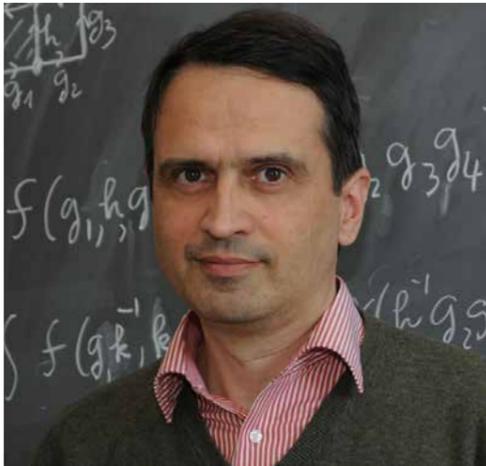


Report 2013 / 2014

ETH Institute for Theoretical Studies





time interviews of candidates for Junior Fellowships starting in the Fall 2014 took place. Since January of this year the Institute has a physical home, the red house in Clausiusstrasse 47, with a new seminar room hosting up to 25 people. Terry Hwa, a theoretical physicist and biologist of the University of California, San Diego, came to Zurich in January 2014 as the first Senior Fellow. Accordingly, the focus of the activities of the ETH-ITS in the spring was on biology and physics, with a lecture course of Hwa and two of the talks of the ITS Science Colloquium dedicated to theoretical biology.

Further talks, on quantum information, on mathematics and neuroscience and on quantum measurements and probability theory broadened the scope of the ITS Science Colloquium, stimulating interactions between disciplines. Three Senior Fellows (Gilles Brassard, Henryk Iwaniec and Dmitry Chelkak), and two Junior Fellows (Emily Clader and Zur Luria) will join the Institute in the summer and two further Senior Fellows will come in January 2015. Also, the Institute will host activities in Zurich of SwissMAP, the new National Centre of Competence in Research of the Swiss National Science Foundation on the Mathematics of Physics, a collaborative project with the University of Geneva.

While the first year was to a large extent focussed on building up the Institute, it was an enriching experience for me to meet members of the Advisory Committee, speakers at the ITS Science Colloquium, prospective Senior and Junior Fellows and interested ETH researchers, and see that there is both interest and potential for thinking across boundaries between theoretical disciplines at ETH, which is an essential ingredient for a successful future of the Institute.

Giovanni Felder, Institute's director

Foreword

Since 1 June 2013, ETH Zurich has an interdisciplinary institute dedicated to research in mathematics, theoretical natural sciences and theoretical computer science, the ETH Institute for Theoretical Studies. Thanks to this initiative, made possible by a generous donation of the Walter Haefner Foundation and Dr. Max Rössler, the lively research community of ETH Zurich in these areas gets the opportunity to collaborate in Zurich with international top scientists spending their sabbaticals as Senior Fellows at the Institute and to recruit talented young postdocs as Junior Fellows dedicating their time to research in topics they choose.

The international Advisory Committee of the institute met for the first time in November 2013, and made its recommendations for the programme of the next years. Around the same



Senior Fellow Terry Hwa (2nd from left) speaks with local scientists in the garden of the Institute

Junior and Senior Fellows

The ETH Institute for Theoretical Studies (ETH-ITS) is an interdisciplinary institute dedicated to research in mathematics, theoretical computer science and theoretical natural sciences. It hosts up to six Senior Fellows and up to twelve Junior Fellows. Junior Fellows are talented young postdocs spending up to three years at ETH Zurich under the supervision of a mentor who is an ETH professor. They are selected by the director, who is assisted by the scientific Advisory Committee, by a nomination procedure. Candidates for Junior Fellowships can be nominated by faculty members and senior researchers of universities and research institutions.

Senior Fellows are leading international researchers in mathematics, theoretical computer science and theoretical natural sciences, spending up to a year at the Institute on a sabbatical leave from their home institutions. They dedicate their time to research and participate in the activities of the Institute and of the ETH Zurich, for example by giving a course on research topics. They are invited by the President of ETH Zurich on the recommendation of the Advisory Committee. Candidates are often suggested by members of the Advisory Committee or ETH faculty, but they can also apply directly.

www.ethz.ch/eth-its/fellows.html →

Organization of the ETH Institute for Theoretical Studies

Director

Giovanni Felder

Coordinator

Christina Buchmann

Advisory Committee

Noga Alon (Tel Aviv University), Luis Álvarez-Gaumé (CERN), Gianni Blatter (ETH Zurich), Artur Ekert (Oxford University), Matthias Gaberdiel (ETH Zurich), Shafi Goldwasser (MIT and Weizmann Institute), Martin Hairer (Warwick University), Gerhard Huisken (Mathematisches Forschungsinstitut Oberwolfach), Elon Lindenstrauss (Hebrew University, Jerusalem), Rahul Pandharipande (ETH Zurich), Tristan Rivière (ETH Zurich), Nicola Spaldin (ETH Zurich), Angelika Steger (ETH Zurich).





The first Senior Fellow

Professor Terry Hwa joined the Institute for Theoretical Studies as a Senior Fellow in January 2014. He has a joint appointment at the Department of Physics and at the Section of Molecular Biology of the University of California, San Diego. Educated as a theoretical physicist, his main current interests are in the emerging field of quantitative and systemic biology. He is an advocate of the «vertical approach» to biology, developing quantitative links from molecules all the way to cell physiology. In the spring semester 2014 he gave a course on quantitative biology (see box) at ETH Zurich, that was also broadcast to the ETH campus in Basel.

Terry Hwa has been using his sabbatical leave at the ETH-ITS to explore two new scientific directions in theoretical biology. One is how to integrate large volume of data (the so-called «omics data») on molecular interaction into a model/theory for the macroscopic state of a growing cell. This is analogous to developing a statistical mechanical approach linking molecular collision to the thermodynamics of a gas. Hwa has a number of hypotheses and is pushing for discriminatory data to guide the direction of pursuit. These data are being generated by the labs of Ruedi Aebersold and Uwe Sauer at IMSB on the Honggerberg campus. The other direction



Terry Hwa lecturing on Quantitative Biology

Hwa is exploring is a quantitative study of the ecology of microbial communities. He has been discussing with the laboratories of Wolf Hardt and Uwe Sauer (ETH Honggerberg), Christophe LaCroix (Food Sciences, ETH Zentrum), Martin Ackermann (Environmental Sciences, Eawag), as well as other laboratories outside of Zurich, in an effort to establish a consortium that is needed to generate the necessary data to formulate a descriptive theory of the microbiome in the human gut.

Course description Quantitative Biology

Biology is undergoing a historical transformation from a component-centric focus on characterizing the parts to a system-level quest to understanding the rules of how a limited number of parts work together to perform complex functions. Progress in this newly emerging subject requires a combination of expertise in biology, chemistry, engineering, and physics. In this course, Professor Hwa presented such an integrative approach, focusing primarily on gene regulation in bacteria. Starting from the molecular components and the physics/chemistry of their interactions, he built up a comprehensive and quantitative approach to bacterial gene regulation including transcriptional and post-transcriptional control of individual genes, as well as feedback and stochastic effects in genetic circuits. They were integrated into the control of bacterial growth and metabolism. Whenever possible, natural examples (mostly taken from *E. coli*) were used to illustrate the principles, and to convey the immense complexity of experimental biology often under-appreciated by people of quantitative background.

www.ethz.ch/eth-its/activities →



The ITS Science Colloquium

The ITS Science Colloquium is a programme of talks about theoretical science usually of a transdisciplinary nature. Its aim is to expose students and researchers in mathematics, theoretical computer science and theoretical natural sciences to new questions and research subjects of common interest to different disciplines. A variety of topics was presented in the past academic year.

Artur Ekert addressed the timely question of privacy in communication, and explained how to securely transmit encoded information even if you don't trust the manufacturer of the

encoding device. The ambitious question "What is mathematics?" was addressed by Rafael Núñez from various points of view, from neurosciences to anthropology. In the two talks on biology, by Terry Hwa and Stanislas Leibler, several examples of the emergence of simple laws describing quantitatively complex biological systems were presented, calling for a new approach to this science. Denis Bernard showed how the statistics of repeated quantum non-demolition measurements can be understood by combining probability theory and foundations of quantum mechanics, leading to the notion of quantum stochastic processes.

Programme 2013/2014

11.11.2013	Artur Ekert, Oxford	The ultimate limits of privacy
20.02.2014	Rafael Núñez, UCSD	What is mathematics? And why is the time now ripe for addressing this question scientifically?
20.03.2014	Terry Hwa, ETH-ITS and UCSD	Quantitative biology: frontier at the interface of the physical and life sciences
17.04.2014	Denis Bernard, ENS Paris	A random walk on quantum noise and measurement
02.05.2014	Stanislas Leibler, IAS Princeton and Rockefeller University	On the (un)reasonable (in)effectiveness of mathematics in biology

www.ethz.ch/eth-its/activities →



The Institute is housed in Clausiusstrasse 47



The seminar room of the Institute



Outlook 2014/2015

Five new scholars will join the Institute for Theoretical Studies in the summer 2014. Gilles Brassard, a computer scientist working in quantum information science, number theorist Henryk Iwaniec and Dmitry Chelkak, a specialist in statistical mechanics and probability theory, will come as Senior Fellows to the ETH-ITS, together with the first two Junior Fellows Emily Clader, a researcher in geometry, and Zur Luria, working in combinatorics and probability theory. They will join Terry Hwa, the first Senior Fellow, who will then spend the fall at his home university, to come back in the spring 2015. Two more Senior Fellows will come in January 2015: mathematician Alex Lubotzky and computer scientist Adi Shamir. A third Junior Fellow working on mathematical aspects of General Relativity, Alessandro Carlotto, who just got his PhD from Stanford University, postponed his stay and will come in September 2015 after spending a year at Imperial College.

1 Gilles Brassard, professor of computer science at Université de Montréal, is a researcher in quantum information science. He was among the founders of this discipline, having coauthored some of the fundamental papers in the subject. For example in his 1984 paper with C. H. Bennett he introduced the first quantum cryptography protocol and in 1993, Brassard and collaborators discovered the principle of quantum teleportation. His present research interests are at the boundary between quantum physics and computer science. He joined the ETH-ITS as a Senior Fellow in June 2014 and will stay until the end of the year.

2 Henryk Iwaniec, New Jersey State Professor of Mathematics at Rutgers University, is a specialist in analytic number theory. He is well-known for his development of

analytic tools to obtain deep results in the theory of automorphic forms and number theory, in particular on the distribution of prime numbers among the natural numbers. He will stay at the Institute for Theoretical Studies for one year from August 2014 and will give a course at ETH in the spring semester 2015.

3 Dmitry Chelkak, senior research fellow at the Steklov Institute of the Russian Academy of Science and the Chebyshev Laboratory of the St. Petersburg State University, works on complex analysis, probability theory and statistical mechanics. His recent research is about the critical behaviour of the Ising model of magnetic surfaces. He and his collaborators proved that the correlations in the Ising model exhibit conformal invariance in the scaling limit. He will spend a year at the ETH-ITS starting in September 2014.

4 Emily Clader received her PhD in mathematics in May 2014 at the University of Michigan with a thesis on the Landau-Ginzburg/Calabi-Yau correspondence under the supervision of Yongbin Ruan. She works on mathematical questions of geometry with close connections with physics, such as mirror symmetry and the theory of Gromov-Witten invariants. She will come as a Junior Fellow in September 2014.

5 Zur Luria is about to receive his PhD from Hebrew University, Jerusalem. He works in combinatorics and probability theory, particularly on higher dimensional versions of combinatorial notions. With his advisor Nathan Linial he gave an upper bound on the number of higher dimensional permutations. He will also start his Junior Fellowship in September 2014.



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Redaktion	Giovanni Felder
Fotos	Christina Buchmann
Layout	Muriel Sager
Druck	ETH Druckzentrum