NEWSLETTER 35th edition | Winter 2020

IST AUSTRIA
Institute of Science and Technology

Foreword

2020 has been a difficult year across the globe, and we have witnessed clearly the outsize role science plays in a pandemic. Indeed, as the year draws to a close, it is due to science that an effective vaccine is on the way.

While physical activities and events went online wherever possible this year, IST Austria has continued to do what it set out to accomplish: increase our staff and resources, and create and accumulate new knowledge. 29 PhD students graduated; 61 new students arrived from 27 different countries; 6 new professors started work on campus; 1 new spin-off company was created; research on campus was funded by 3 new ERC grants as well as multi-million euro grants from the Werner Siemens and NOMIS foundations; recent publications described a quantum radar prototype, how immune cells find their way to fight infections, and biology-inspired deep learning techniques for autonomous driving. Science progresses, even during a pandemic.

Scientists have also used their creativity and passion to help: at IST Austria, we set up a technology platform called AVID (Anti-Viral IDeas) for a wide variety of projects such as algorithms that improve the security of contact-tracing apps, the 3D printing of face-fitting masks and emergency ventilators, and the analysis of behavioral changes during lock-downs. What makes me personally most proud is that our scientists, staff, and alumni started several new initiatives to reach out to schoolchildren through educational games and online teaching. If you wish to support these activities, please contact science.education@ist.ac.at.

I wish you health, resilience, and a new year that brings cause for newfound optimism!
Thomas A. Henzinger | President, IST Austria

Julian Fischer wins "Förderungspreis" of the Austrian Mathematical society

On September 26th, Julian Fischer received the Förderungspreis of the Austrian Mathematical Society. The "Förderungspreis" is the highest award of the Austrian Mathematical Society for early- to mid-career researchers. It is awarded each year to a mathematician up to ten years past PhD, who completed a substantial part of their scientific achievements within Austria and who has distinguished themselves to an above-average extent through their mathematical research.

Julian Fischer who has been a professor at IST Austria since 2017 works in the area of partial differential equations, applied and numerical Analysis. "It is a great honor to receive this award from the ÖMG. As the award criteria explicitly emphasize my scientific work accomplished within Austria, it also testifies once more to the outstanding environment for fundamental research created by IST Austria."

Scientific Board member Angelika Amon passed away

Cell biologist and cancer researcher Angelika Amon tragically passed away. While being a distinguished scientist herself, Angelika also paved the way for future generations. As a member of IST Austria's Scientific Board, she helped to establish the highest scientific standards and she was a strong supporter of women in science.

She is the only Austrian to receive two of the most important prizes in the life sciences: the Breakthrough Prize 2019 and the HFSP Nakasone Award 2020. Since the founding of IST Austria, Angelika Amon was a close associate, welcome guest, and critical evaluator. Only a month ago, she gave an online lecture at IST and fascinated us with her research on cellular aging.

Angelika Amon helped to shape our institute and inspire many scientists to come. Thank you very much, Angelika. Our deepest sympathies go out to her family and friends.

Tamas Hausel appointed member of the Academia Europaea

Tamas Hausel combines methods from algebraic geometry, representation theory and combinatorics to develop tools to study the topology of spaces arising from string theory and quantum field theory. Based on his academic achievements, Professor Hausel has been elected as a member of the Academia Europaea in the section Mathematics.

Hausel says about the appointment: "I feel honored that I was elected to join the Academia Europaea. It has an impressive list of members, an attractive pan-European ethos and roots in Cambridge and the Royal Society, where I spent some of my earlier academic career."

In addition to Tamas Hausel, six other professors are already members of Academia Europaea: computer scientist and president Thomas Henzinger, neuroscientists Joszef Csicsvari, Ryuichi Shigemoto and Peter Jonas as well as mathematicians Herbert Edelsbrunner and László Erdős.

Research Highlights

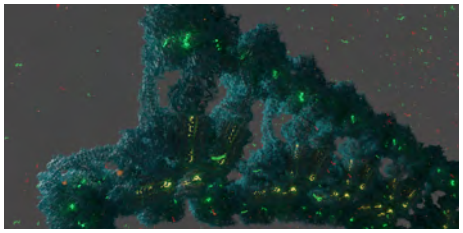
New Deep Learning Models: Fewer Neurons, More Intelligence

An international research team including TU Wien, MIT, and the Henzinger Group from IST Austria has developed a new artificial intelligence (AI) system based on the brains of tiny animals, such as threadworms. This novel AI-system can control a vehicle with just a few artificial neurons. The system has decisive advantages over previous deep learning models: It copes much better with noisy input, and, because of its simplicity, its mode of operation can be explained in detail. It does not have to be regarded as a complex "black box", but it can be understood by humans. This new deep learning model was the October cover story of *Nature Machine Intelligence*.

Similar to living brains, artificial neural networks consist of many individual cells. Also similar to many living systems, these artificial neural networks were, in the past, extremely complex. However, animals such as the nematode *C. elegans* live their lives with a small number of neurons, but still show interesting behavior, due to the efficiency of their nervous systems. The team's goal was therefore to imitate this phenomenon, and reduce complexity while enhancing interpretability.

"Inspired by nature, we developed new mathematical models of neurons and synapses," says IST Austria Professor and President Thomas A. Henzinger.

The new deep learning model was tested on a real autonomous vehicle. "Our model allows us to investigate what the network focuses its attention on while driving. Our networks focus on very specific parts of the camera picture: The curbside and the horizon. This behavior is highly desirable, and it is unique among artificial intelligence systems," says Ramin Hasani, co-first author of the paper. "Moreover, we saw that the role of every single cell at any driving decision can be identified. We can understand the function of individual cells and their behavior. Achieving this degree of interpretability is impossible for larger deep learning models."

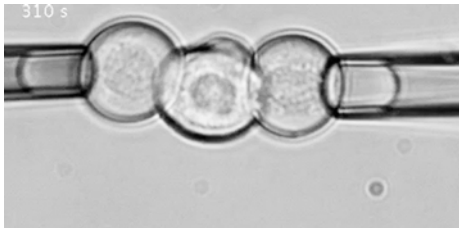


Structure of ATPase, the world's smallest turbine, solved

The chemical ATP, adenosine triphosphate, is the fuel that powers all life. ATP is found in all known forms of life, where it provides energy to drive muscle contraction, impulse propagation, and chemical synthesis. Despite ATP's central role, the structure of the enzyme generating ATP in mammals, F1Fo-ATP synthase, was previously unknown. Now, Professor Leonid Sazanov and his group have reported the first complete structure of the mammalian F1Fo-ATP synthase. This structure also settles a debate on how the permeability transition pore—a structure involved in cell death, cancer, and heart attacks—forms. The study was published in *Nature Structural & Molecular Biology*.

ATP synthase is also referred to as complex V of the respiratory chain, a series of protein complexes in the membrane of mitochondria. This respiratory chain creates a proton gradient that the ATP synthase uses to make ATP. Previously, Sazanov was the first to solve the protein structure of bacterial complex I and the structure of a mammalian complex I. In the new study, Sazanov and lab members Gergely Pinke and Long Zhou turned to mammalian complex V, the final unsolved structure in the mammalian respiratory chain. "F1Fo-ATP synthase is one of the most important enzymes on Earth. It provides energy for most life forms, including humans, but until now, we didn't fully understand how it worked," explains Sazanov.

Using the fully solved structure of F1Fo, Sazanov and his group can describe how the pore forms in F1Fo-ATP synthase: When calcium binds in the F1 subunit, a large conformational change is induced. The complex has to accommodate this change, and in doing so, pulls on the hook apparatus. The apparatus in turn pulls out the lipid plug on the bottom of the Fo, initiating pore opening. "When the pore is open for a longer period of time, the c-ring is destabilized and pore formation becomes irreversible," explains Sazanov. "This model is consistent with the available data from mutants. To be fully sure that this is how the permeability transition pore forms, one would need to solve the structure of ATP synthase during calcium-induced transitions, which we are doing now."



Sticking together

In unraveling how a single cell develops into a complex organism, one vexing question has remained for developmental biology: How do robust patterns form in the body? An answer has now been found for the zebrafish neural tube. In this paradigm of patterned tissues, the varying stickiness of cells combined with gradients of signaling molecules is responsible for generating a robust pattern. This was shown by a study published in *Science*, carried out jointly by the lab of Carl-Philipp Heisenberg at IST Austria and the lab of Sean Megason at Harvard Medical School.

The neural tube is organized into domains of cells with different identities and fates. In the French Flag model, a signaling molecule sets up a gradient across a field of cells. A cell "knows" its location within the field, and consequently its identity, by the amount of signaling molecule it receives. However, cells move around as an organism develops, disrupting the strict division into domains. An additional mechanism is needed to maintain the domains. Combining a range of genetic, developmental, and biophysical experiments, the team was able to solve the puzzle: adhesion, or the "stickiness" of cells, is the factor that keeps cells of the same domain together, and cells of different domains apart.

The researchers further found that the difference in stickiness corresponds to a differential expression of adhesion proteins in the domains. The different cell types express different classes of cadherins. When the researchers interfere with this expression and make cells express more or less of a certain cadherin, preferential adhesion and correct cell sorting are lost. "Our experiments show that a sorting process based on adhesion, together with a gradient of the signaling molecule Sonic Hedgehog, leads to a precise sorting of cells into domains based on their cell type," concludes Heisenberg. "By combining experiments from biophysics, genetics, and developmental biology, we were able to answer this long-standing question."

PhD Call

IST Austria presents its PhD program to students worldwide in a virtual event

On December 3, the Virtual Student Open Day will connect potential students with the Institute of Science and Technology Austria. In its first online edition, the event enables direct contact between students and faculty across nations and continents.

IST Austria's faculty and student body will present the Institute's unique PhD program and its six different tracks: biology, neuroscience, mathematics, computer science, physics, and data science & scientific computing. Interested students can register here.

"Our students complete an innovative interdisciplinary training program consisting of both research and receive close mentoring by world-class faculty," explains Maria Trofimova, Head of the Graduate School Office.

One highlight of the PhD program is the initial stage of rotations and cross-disciplinary coursework. These rotations and courses enable students to get hands-on scientific skills from various research groups and find the best group for their PhD project, which they complete during the second phase.

"IST Austria is a melting pot for excellent scientists from different backgrounds, countries, and cultures. Students from all over the world can benefit from our scientific environment, diversity of disciplines and state-of-the-art infrastructure," explains President Thomas Henzinger.

Applications open for PhD program 2021

The international PhD program is open to all students with a Bachelor's or Master's degree. IST Austria welcomes students with different academic backgrounds who can bring their skills and experiences to the scientific setting. Next to undergraduate performance in the relevant field and transferable skills, diversity plays an important role. Applicants who switched fields are especially encouraged to apply.

The PhD call for 2021 is now open. The deadline for applications is January 8, 2021 (23:59 CET) for PhD entry in September 2021.

Further information, and details about registering for the PhD program for the PhD program can be found on the Graduate School website.

The recorded videos from the Virtual Student Open Day 2020 will be available for streaming on the IST Youtube channel after the event.

SSU spotlight

Helios G4 dual beam Xe FIB – UHR SEM installed in the I21 LBW

Plasma Xenon Focus Ion Beam (PFIB)

The Focus Ion Beam (FIB) is a technique that was developed for the first time in 1975. Since then this technique is often used in the semiconductor industry, material science, and the life sciences.

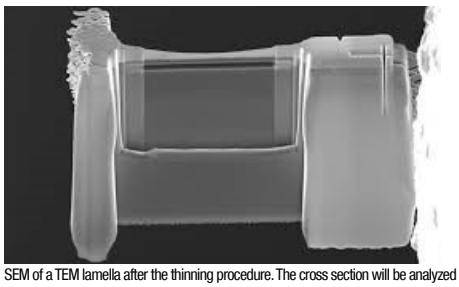
Xenon plasma FIB differs from gallium liquid metal ion FIB technology as it has the ability to focus more ions into the beam, thereby achieving higher ion beam currents than what is possible with a liquid metal ion source. Moreover, due to the inert nature of xenon, plasma FIB eliminates any risk of sample contamination by ion implantation.

A survey was performed at the end of 2019 and the beginning of 2020, to find the best system suitable for the specific needs of the actual faculty members. The survey and the performed tests led to the purchase of the Helios G4 PFIB system.

The PFIB dual beam system, installed at IST Austria, combines a FIB column with an Ultra high resolution – SEM (UHR-SEM). This system represents the state of the art in focused ion beam technology. A typical gallium FIB has a maximum current of 100 nA, whereas the xenon-based Helios G4 PFIB has a maximum current of 2.5 µA. As the cutting rate is proportional to the current, the Helios G4 allows to increase the cutting speed by a factor of 25 while maintaining a 15 nm resolution even at the highest cutting rate. While the UHR-SEM column allow us to reach a resolution of 0.7nm @1kV.

The system is also equipped with state-of-the-art detectors for Energy Dispersive X-Ray Spectroscopy (EDS) Detector, Electron Backscatter Diffraction (EBSD), Scanning Transmission Electron Microscopy (STEM) analysis, and a MultiChem injection system to deliver up to 6 gases in the chamber.

This system was installed due to the hiring of Kimberly Modic and the request from physics faculty members for super thin TEM lamellas for cross section analysis. In particular, Modic's research group focuses on state-of-the-art methods for detecting thermodynamic and transport properties in single crystals ranging from 100 microns to 1 mm in size.



SEM of a TEM lamella after the thinning procedure. The cross section will be analyzed in the TEM at the EM Facility

The Nanofabrication Facility is one of eight Scientific Service Units currently established at IST Austria. Its excellently trained staff provides scientists with high-end equipment and cutting-edge technology to address highly sophisticated research questions. It is their task to constantly develop and establish new techniques and methods to ensure that future needs and demands of the scientific community will be met efficiently and with high-quality standards. Further information can be found on the Scientific Service Units website.

Review Science-Industry Talk 2020

On November 10, IST Austria's Science-Industry Talk took place for the twelfth time in cooperation with the Federation of Austrian Industries. Over 140 people joined the live stream of the online event.

In a panel discussion, Matthias Evers, Senior Partner at McKinsey, Dorothee von Laer, founder of ViraTherapeutics, Erich Tauber, co-founder and CEO of Themis Bioscience GmbH and Ingrid Kelly Spillmann from IST Austria technology transfer team discussed their views on how to strengthen the European technology transfer ecosystem. They also talked about the role of IST Austria, IST Park, and IST Cube and highlighted several best practice cases of successful knowledge transfer from research into applications.

The recorded stream and the presentations on research carried out on campus as well as the current work at IST Park can be found on YouTube.

Game: Virus Alert in Stayhompton

"Virus Alert in Stayhompton" is a freely available board game for young people age 12 and up, developed with scientists from IST Austria, the Max Planck Institute for Evolutionary Biology, and the science education NGO eduB. By simulating the spread of a fictitious virus in a small town, the players learn how the spread of viruses can be contained by limiting contact to others.

The game is freely available as a download in English and German and can also be ordered via mail (German only). A video of the game and its backstory can be found on Youtube.

COLLOQUIUM SPEAKERS

PAST SPEAKERS: Florence Bertails-Descoubes, INRIA (Oct 19) | Michael J. Shelley, Flatiron Institute, Simons Foundation (Nov 9) | Tom Mitchell, Carnegie Mellon University (Nov 16) | Amir Yacoby, Harvard University (Nov 23) | Thierry Giamarchi, University of Geneva (Nov 30)

FUTURE SPEAKERS: Maria Chudnovsky, Princeton University (Dec 7) | Elchanan Mossel, Massachusetts Institute of Technology (Dec 14) | Tom Mrsic-Flogel, University College London (Jan 11) | Rong Li, National University of Singapore (Jan 18) | Asya Rolls, Technion - Israel Institute of Technology (Mar 1) | Cristina Marchetti, University of California, Santa Barbara (May 17)

SELECTED RECENT PUBLICATIONS

Li, Y., Wang, Y., Tan, S., Li, Z., Yuan, Z., Glanc, M., … Zhang, J. (2020). Root growth adaptation is mediated by PYLs ABA receptor-PP2A protein phosphatase complex. Advanced Science, 7(3). https://doi.org/10.1002/advs.201901455

Tkadlec, J., Pavlogiannis, A., Chatterjee, K., &; Nowak, M. A. (2020). Limits on amplifiers of natural selection under death-Birth updating. PLoS Computational Biology, 16.https://doi.org/10.1371/journal.pcbi.1007494

Xiao, G., &; Zhang, Y. (2020). Adaptive growth: Shaping auxin-mediated root system architecture. Trends in Plant Science, 25(2), 121–123.https://doi.org/10.1016/j.tplants.2019.12.001

Rybicki, J., Abrego, N., &; Ovaskainen, O. (2020). Habitat fragmentation and species diversity in competitive communities. Ecology Letters, 23(3), 506–517.https://doi.org/10.1111/ele.13450

Baskett, C., Schroeder, L., Weber, M. G., &; Schemske, D. W. (2020). Multiple metrics of latitudinal patterns in insect pollination and herbivory for a tropicaltemperate congener pair. Ecological Monographs, 90(1). https://doi.org/10.1002/ecm.1397

Laukoter, S., Beattie, R. J., Pauler, F., Amberg, N., Nakayama, K. I., &; Hippenmeyer, S. (2020). Imprinted Cdkn1c genomic locus cell-autonomously promotes cell survival in cerebral cortex development. Nature Communications, 11.https://doi.org/10.1038/s41467-019-14077-2

Piriya Ananda Babu, L., Wang, H. Y., Eguchi, K., Guillaud, L., &; Takahashi, T. (2020). Microtubule and actin differentially regulate synaptic vesicle cycling to maintain high-frequency neurotransmission. Journal of Neuroscience, 40(1), 131–142.https://doi.org/10.1523/JNEUROSCI.1571-19.2019

Nibau, C., Gallemi, M., Dadarou, D., Doonan, J. H., &; Cavallari, N. (2020). Thermo-sensitive alternative splicing of FLOWERING LOCUS M is modulated by cyclin-dependent kinase . Frontiers in Plant Science, 10.https://doi.org/10.3389/fpls.2019.01680

Lopez Alonso, J. M., Feldmann, D., Rampp, M., Vela-Martín, A., Shi, L., &; Avila, M. (2020). nsCouette – A high-performance code for direct numerical simulations of turbulent Taylor–Couette flow. SoftwareX, 11.https://doi.org/10.1016/j.softx.2019.100395

Geher, G. P., Titkos, T., &; Virosztek, D. (2020). Isometric study of Wasserstein spaces - the real line. Transactions of the American Mathematical Society, 373(8), 5855–5883.https://doi.org/10.1090/tran/8113

A full list of publications from IST Austria can be found in the IST Austria Research Explorer.

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