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Institute of Science and Technology

Foreword

When I was asked to write a foreword for this issue of our newsletter, I felt that with my new responsibility as the Dean of the Graduate School the topic is in some way predefined: Science and education. Both topics almost as old as humankind; generation after generation the world around us has been explored and knowledge passed to the students. I started to wonder about this legacy, drawing from advice of the best, those who succeeded in doing excellent science and raising a progeny of excellent scientists. Nowadays, in contrast to their times, advice is easy to find. There is no need to go to the library, no need to search for books. It is a calm Sunday afternoon when I am typing keywords to retrieve their wisdom. And, here they are, the sharp remarks, deep thoughts, and reflections from the scientific role models. I am having a great time reading and thinking about them. As the evening is approaching my notes are getting longer and I am facing a challenge to select the ones I find most meaningful to share.

I agree so much with Albert Einstein's statement: "Education is not the learning of facts but the training of the mind to think", or Claude Lévi-Strauss's note, "A scientist is not a person who gives the right answers but who asks the right questions". Also, we all should remember the words of Galileo Galilei that "Science may set limits to knowledge, but should not set limits to imagination!" And, maybe because of my personal background, I could not ignore the words of John Amos Comenius, the philosopher and pedagogue, who is considered the father of modern education: "Three things that give the student the possibility of surpassing the teacher; ask a lot of questions, remember the answers and teach."

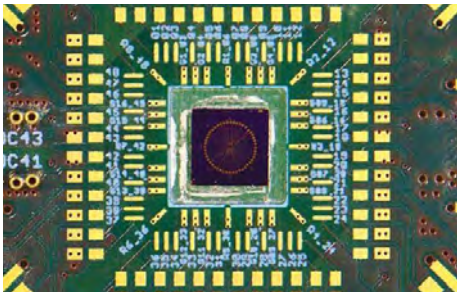
These and more quotes could be mentioned, all inspiring and motivating. However, there is no universal recipe for how to become a good scientist and whatever wise words we hear and guidance we get, at the end of the day, it is always up to us, our efforts and our endeavor to make it happen. All of us, whether we are scientists, students, part of the administration, or from the graduate school office, do our best to create a living and learning environment where we can all pursue our dreams and reach our goals. With best wishes for a successful academic year to all of you,

Eva Benková, Dean of the Graduate School

László Erdős becomes Fellow of the American Mathematical Society

Forty-five international mathematicians have been named Fellows of the prestigious American Mathematical Society (AMS) for 2022. Amongst them is professor László Erdős, whose group at IST Austria investigates the fundamental mathematics of random matrices and disordered quantum systems.

"This is also a success of the IST practice to regularly nominate eligible colleagues," credits the new Fellow his colleagues. "Our external award committee is responsible for that and it is doing a great job! For getting any award, the first step is being nominated." Earlier this year, Erdős already received the Erwin Schrödinger-Prize from the Austrian Academy of Sciences (ÖAW) and earned one of the highly competitive ERC grants.



New dossier on quantum computing

Quantum computing has been a hot topic for the last few years promising great advancements in material science, medicine, and our fundamental understanding of the world. At the moment, we are still in a very early phase of development, laying the groundwork for future technologies. This new dossier from IST Austria provides a short introduction to the underlying physics of quantum computing, why it could become as powerful as promised, and a brief overview of the current state of development.

Researchers at IST Austria like Georgios Katsaros, Johannes Fink, and Andrew Higginbotham are working on untangling the fundamental riddles underlying quantum computing. In the dossier, they share some insights into their work and their own perspectives on this still nascent field.

To see what a chicken has to do with this, check out the quantum computing dossier here!

Seeburg Prize awarded to Peter Jonas

For his contributions to the understanding of synaptic communication and information processing in neuronal microcircuits, Professor Jonas has now been awarded the Peter Seeburg Integrative Neuroscience Prize. Jonas seeks to understand how synapses shape higher-order computations in the mammalian brain. His focus has progressed in a bottom-up manner, from the level of receptors and channels, to synapses, to circuits and in vivo recordings.

The prize recognizes outstanding advances in the understanding of executive brain functions and cognitive processes. It is presented for the first time at this year's annual meeting of the Society for Neuroscience (SfN) and comes with $100,000 prize money endowed by the Schaller-Nikolich Foundation. The prize is named after Peter Seeburg (1944–2016), who was a leading neuroscientist and pioneer in molecular biology.

Research Highlights

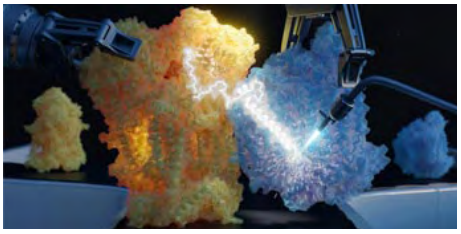
Stop and Grow

Plants need the hormone auxin to grow. In their roots, however, it inhibits growth. Researchers at IST Austria discovered a new mechanism allowing roots to quickly react to obstacles and find suitable soil. With their study published in the journal *Nature* the team fundamentally increases the knowledge on root development, which could help agriculture find better performing plants.

Together with co-first author Lanxin Li, Inge Verstraeten, former postdoc in the Friml Group, discovered two counteracting mechanisms allowing the roots of the mouse-ear cress, *Arabidopsis thaliana*, to very quickly modulate their growth.

Previously, it was believed that auxin worked through regulating gene transcription. Yet, what the team observed pointed into a different direction. "We increased the auxin level and immediately saw how the roots stopped growing. After washing it out, within seconds we saw that the roots were growing again," describes Inge Verstraeten. This immediate response of the roots was far too fast to be explained by activating genes in the plant cell's nucleus.

In the shoot, auxin makes the cell walls less rigid so the cell can take in more water and expand. It does so by causing molecules to pump protons into the cell walls leading to their acidification. In roots the researchers witnessed the opposite effect – an alkalinization of the cell walls. But when looking at the proton pumps in the cells' membrane the team was flabbergasted. Like in the shoot, protons were pumped into the cell walls, which should have led to the cell walls becoming more acidic instead of alkaline. Ruling out other options, the team was able to identify the enzyme and mechanism, by which auxin activates the proton pumps leading to the acidification of the cell walls. Via a different, so far still mysterious signaling pathway auxin promotes the efflux of protons, causing the alkalinization of the cell walls. The two mechanisms balance each other out enabling a fine-tuned growth modulation.



Boosting the cell's power house

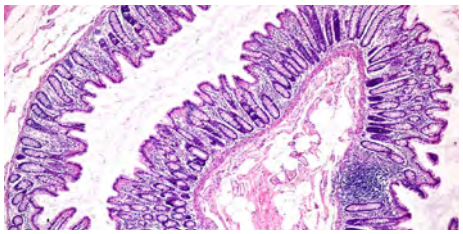
Severe fatigue, muscle weakness, even blindness – mitochondrial diseases have various symptoms. In fact, the majority of genetic diseases are caused by defects of the mitochondria. Hence, understanding these "power houses" of our cells is crucial for the development of new treatments. In a study published in *Nature*, researchers at IST Austria show for the first time the structure of a protein complex essential for the mitochondria to function.

In the cell's power plants, known as mitochondria, the energy contained in our food is converted into the molecule ATP. It serves as a kind of fuel that drives most cellular processes – from muscle contraction to the assembly of our DNA. Leonid Sazanov and Irene Vercellino are now the first scientists to precisely show what a protein assembly essential for this process looks like in mammalian cells.

Using cryo-electron microscopy they show the exact structure of the so-called supercomplex $CIII_2CIV$. This assembly of protein building blocks pumps charged particles, protons, through the mitochondrial membrane, which is needed to start the energy conversion process in the cells. It therefore fulfills a similar task as the starter battery of cars. Up to now, this supercomplex has only been described in plant and yeast cells where it takes on a very different form, as the researchers now discovered.

Previous studies already showed that the molecule SCAF1 plays a role in assembling the two protein complexes that together form supercomplex $CIII_2CIV$. Instead of interacting with the two protein complexes on the surface only, the molecule goes deep inside complex III while being attached to complex IV. Being assembled into a supercomplex speeds up the chemical reactions, which has great advantages for the animal. Mice and zebrafish missing the SCAF1 molecule are significantly smaller, less fit, and less fertile.

Together with their previous studies, the Sazanov group now determined the structures of all supercomplexes in mammalian mitochondria. Thus laying the foundation for new treatments for mitochondrial disease.



How Cells Feel Curvature

Cells in your body cannot see, but they can feel their surroundings and their own shape. Scientists at the University of Mons and the IST Austria showed via experiments and in theory how cells can sense the curvature of tissue around them and how this influences their inner workings.

A study in *Nature Physics* led by PhD student Marine Luciano and Professor Sylvain Gabriele in cooperation with IST Austria postdoc Shi-Lei Xue and Professor Edouard Hannezo has uncovered new findings. The researchers found the mechanisms that regulate the cells' behavior depending on the change of the environment's curvature.

Gabriele's team reproduced the folding patterns observed in living tissues in a very controlled way by developing a method to grow cells on curved surfaces using soft hydrogels. These specially constructed surfaces have valleys and mountains with sizes from a hundredth to a tenth of a millimeter. The experiments showed that cells grown on these surfaces tend to spread thinly on the mountains and gather in the valleys.

At IST Austria, Xue and Hannezo developed a key theoretical model that explains the experimental distribution of cells on the surfaces. They used the simple physical principle of energy minimization. Their cell model is inspired by the physics of foam and led to the understanding how the curvature governs the distribution of cells on the surface and therefore also their shape and density in an area. It was already known that cells could sense the density of other cells around them and that this governs their biochemical machinery. Therefore, biochemicals like the Yes-associated proteins (YAP) – key markers of stem cells – are influenced by the curvature via density sensing.

This interdisciplinary study incorporating physical chemistry, cell biology, and theoretical physics sheds light on a cellular mechanism that has been poorly understood so far.

Science beyond language barriers

The project "Wissen schafft's" wants to raise broader interest in STEM subjects, especially among children and young people, with a series of educational videos, available in five languages. The team strives to help develop a deeper basic understanding for new findings and innovations that arrive in our day to day-lives through science and research, and thus contribute to an enlightened society of tomorrow.

The team behind „Wissen schafft's" is a group of young international scientists from different STEM disciplines, most of whom are currently working at IST Austria. They are not only enthusiastic about their own fields of research, but also about science communication. The first season of their videos, available on YouTube, revolves around cell biology and virology. The videos explain the basics of vaccines, how they work and why they are important.

Nicole Amberg, Postdoc in the Hippenmeyer Group and initiator of the project: "I think as a scientist, it is extremely important to contribute something to society. And when, if not now in the pandemic, would be the best time to really get into contact with the general public?"

Equal opportunities in a diverse society

Acknowledging that we live in a diverse and inclusive society, the international project team aims to avoid language barriers in knowledge transfer and thus developed a multilingual portfolio of their first season of videos. Besides German, they started with four languages that are common in Austria: Turkish, Serbian/Bosnian/Croatian, Farsi and Arabic. The translation of the videos was financially supported by IST Austria.

"I am delighted to see this project taking off. This initiative shows the clear desire of scientists to establish a stronger connection with the public and it will serve as example of how rewarding and beneficial such connection can be. I'd like to thank the entire team for their enthusiasm and initiative," compliments Gaia Novarino, Vice President for Science Education.

With this multilingual approach, "Wissen schafft's" aims to promote equal opportunities across language barriers. Understanding something can not only spark interest and curiosity for a topic, but also lead to career prospects in the field of STEM. For Nicole Amberg, it's the best job in the world: "There could be nothing better than working in STEM. You can solve problems, you can find out new things that nobody explored before. I can't imagine anything more rewarding than making new discoveries."

For the team it's clear: Those who understand can make informed decisions for themselves and for society. "Wissen schafft's" wants to make all of this possible for children, young people and their families in Austria and beyond. The first-season of videos with the main focus on immunology and vaccines can be found in all five languages on the YouTube channel of "Wissen schafft's". More information about "Wissen schafft's", their mission and other projects can be found on their website.

Contributors to the project at IST Austria: Nicole Amberg, Ste Tavano, Aysan Cerag Yahya, Cihan Önal, Kristina Lukic, Mojtaba Tavakoli, Shadi Gharagozlou, Aline Monzer, Marwan Elkrewi, Laura Burnett, Philipp Velicky, and Daniel Jirovec.

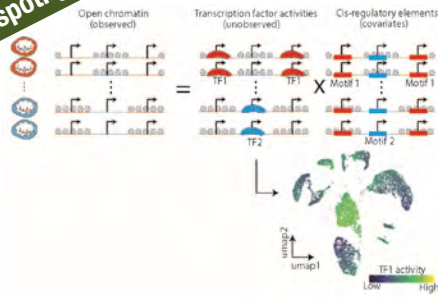


Fig. 1: Schematic of a TF activity model to infer transcriptional regulators in single cells.

Bioinformatics Services

The main purpose of the Bioinformatics Services is to make the handling and analysis of biological data as streamlined as possible for IST researchers.

To this end, Bioinformatics Services focuses on three main areas:

1. Consultation for experimental design leading to bioinformatic data analyses. For example, advising the Guet group on sequencing to cost-effectively characterize *E. coli* genomes or discussing with the Heisenberg group about sequencing for analyzing zebra fish gene expression.

2. Performing bioinformatic data analyses. Here they helped the Novarino group analyze single-cell gene expression data from mouse brains, assisted the de Bono group in gene expression and mutagenesis identification analyses in *C. elegans* round worms, as well as worked with the Sweeney group to analyze single-cell gene expression data in Xenopus frogs.

3. Helping IST Austria researchers adapt bioinformatic data analysis workflows for the IST High Performance Computing (HPC) cluster. The Bioinformatics Services sped up the Novarino group's analysis of gene regulation data and worked with the Kondrashov group to more quickly identify mutations associated with improved growth of bacterial colonies.

The Bioinformatics Services team strives to serve as a communication hub within and beyond IST Austria for all questions related to bioinformatic data analysis. To accomplish this, Bioinformatics Services and other members of Scientific Service Units at IST Austria have formed a Bioinformatic Round Table to discuss data integration challenges coming from different facilities.

Introducing Jake: A staff scientist in computational biology

Jake develops statistical and machine learning methods, with particular interest in single-cell genomics technologies. He is available to discuss designing new single-cell experiments (e.g. scRNA-seq, scATAC-seq, scChIC-seq), as well as developing methods to reveal gene regulatory principles in single cells.

Examples of current methods being developed in collaboration with IST:

- Neuronal differentiation dynamics across species (Sweeney lab)
- Combining spatial information with single-cell genomics (Shigemoto lab)
- TF activity models for single-cell chromatin data (see Figure 1)

More information on Bioinformatics Services can be found on the Scientific Computing webpage.

PhD Call 2022 open!

IST Austria's 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 experience to the table in a scientific setting.

All our PhD students are fully funded, at internationally competitive salary levels, and receive full social security coverage.

The PhD call for 2021 is now open. The deadline for applications is January 8, 2022 (23:59 CET) for PhD entry in September 2022.

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

Panel Event "WoMen in Science: Change the World!"

This year, IST Austria has started a campaign called "WoMen in Science", highlighting the importance of gender balance in research and innovation.

As part of this campaign, IST Austria was happy to host a panel event featuring talks, video interviews, and panel discussions trying to answer questions like: "Why do we need gender balance?", "How can we reach and maintain it?" and "What can science institutions do?".

More information on the "WoMen in Science" campaign and its activities can be found on the event's webpage.

COLLOQUIUM SPEAKERS

PAST SPEAKERS: Vidya Madhavan, University of Illinois Urbana-Champaign (Oct 11) | Lillian Pierce, Duke University (Oct 18) | Yang Dan, University of California, Berkeley (Nov 15) | Aviv Regev, Massachusetts Institute of Technology (Dec 6)

FUTURE SPEAKERS: Lenka Zdeborova, EPFL (Jan 24) | Sarah Cohen, UNC at Chapel Hill (Mar 21) | Catherine Dulac, Harvard University | (Oct 3)

SELECTED RECENT PUBLICATIONS

Benedikter, N. P. (2021). Bosonic collective excitations in Fermi gases. Reviews in Mathematical Physics. World Scientific.https://doi.org/10.1142/s0129055x20600090

Benedikter, N. P., Nam, P. T., Porta, M., Schlein, B., &; Seiringer, R. (2021). Correlation energy of a weakly interacting Fermi gas. Inventiones Mathematicae. Springer.https://doi.org/10.1007/s00222-021-01041-5

Diringer, A. A., &; Gulden, T. (2021). Impact of drive harmonics on the stability of Floquet many-body localization. Physical Review B. American Physical Society.https://doi.org/10.1103/PhysRevB.103.214204

Aichholzer, O., Akitaya, H. A., Cheung, K. C., Demaine, E. D., Demaine, M. L., Fekete, S. P.,https://doi.org/10.1016/j.comgeo.2020.101700__Schmidt, C. (2021). Folding polyominoes with holes into a cube. Computational Geometry: Theory and Applications. Elsevier.https://doi.org/10.1016/j.comgeo.2020.101700

Pitrik, J., &; Virosztek, D. (2021). A divergence center interpretation of general symmetric Kubo-Ando means, and related weighted multivariate operator means. Linear Algebra and Its Applications. Elsevier. https://doi.org/10.1016/j.laa.2020.09.007

Ojavee, S. E., Kousathanas, A., Trejo Banos, D., Orliac, E. J., Patxot, M., Lall, K.,https://doi.org/10.1038/s41467-021-22538-w__Robinson, M. R. (2021). Genomic architecture and prediction of censored time-to-event phenotypes with a Bayesian genome-wide analysis. Nature Communications. Nature Research.https://doi.org/10.1038/s41467-021-22538-w

Takeo, Y. H., Shuster, S. A., Jiang, L., Hu, M., Luginbuhl, D. J., Rülicke, T.,https://doi.org/10.1016/j.neuron.2020.11.028__Luo, L. (2021). Glu- and Cbln1-mediated competitive synaptogenesis shapes the dendritic arbors of cerebellar Purkinje cells. Neuron. Elsevier.https://doi.org/10.1016/j.neuron.2020.11.028

Zhang, T., Liu, T., Mora, N., Guegan, J., Bertrand, M., Contreras, X.,https://doi.org/10.1016/j.celrep.2021.109208__Hassan, B. A. (2021). Generation of excitatory and inhibitory neurons from common progenitors via Notch signaling in the cerebellum. Cell Reports. Elsevier.https://doi.org/10.1016/j.celrep.2021.109208

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

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