5 steps into the future

Skolkovo Institute of Science and Technology

skoltech

5

SPECIAL ISSUE DEDICATED
TO THE 5TH ANNIVERSARY OF
THE SKOLKOVO INSTITUTE OF SCIENCE
AND TECHNOLOGY (SKOLTECH)
2017

#GREATSCIENCE #LABS #SPACESYSTEMS #BIOTECH #COGNITIVESCIENCES #SCIENTIFICRESULTS #MULTIDISCIPLINARYAPPROACH #EXCELLENTEDUCATION
#BIOINFORMATICS #MATERIALSSCIENCE #OILRECOVERY #DATASCIENCE #PHOTONICS #CHANGINGTHEWORLD #DRONES #QUANTUMMATERIALS
#ENERGYGRIDS #DNAEDITING #NANOTECHNOLOGIES #PEOPLECREATE #FORUMS #SCIENCEDRIVENBUSINESS #INNOVATIONS #NEWMATERIALS #STARTUPS
#ROBOTS #NEWUNIVERSITY #THEBESTCAMPUS #SKOLKOVOECOSYSTEM #WOMENINSTEM #LABTOMARKET #TECHENTREPRENEURSHIP #FABLAB #SKOLTECH


2022
200 professors
360 postdocs and researchers
1200 MSc and PhD students
great science
excellent education
changing the world
people create
new university

DEAR FRIENDS,

“Skoltech is a young university, but it has already become an important element of the Russian educational system insofar as it is implementing a new model of education. It is important for Skoltech to transfer scientific developments into practical technological solutions.

In five years, Skoltech has become a mature, modern institute, where open and enterprising students from all over the world study. These students regularly win prestigious international competitions, and many of them have already launched their own startups.

In parallel, Skolkovo is creating a new education hub built on partnerships between three leading universities: Skoltech, the Moscow School of Management Skolkovo and the New Economic School. Cooperation between these institutions is developing in three vectors: science and technology, management and economics. I am sure that the interactions between these three institutions will produce results not only for students and professors, but also for the Russian economy as a whole. The Skolkovo hub is an intellectual core, a model that can be replicated, a space where new ideas and projects are born and developed.

Very soon, the institute will move to an incredible new campus, which will open even more possibilities. I congratulate you on your five-year anniversary!”

ARKADY DVORKOVICH
CHAIR OF THE SKOLTECH BOARD OF TRUSTEES, DEPUTY PRIME MINISTER OF THE RUSSIAN FEDERATION

“When I tell people who are not in the know what Skolkovo is, listing off the elements of its ecosystem, I always say Skolkovo Institute of Science and Technology first. I do it on purpose because I firmly believe that Skoltech is the cornerstone of our project: the integral part of it that plays a special role in the formation of an innovation-friendly environment. Skoltech is, first and foremost, young people: talented, knowledgeable, and daring. Almost all of them are involved in practical, innovative activity, while many have already created real, “grown-up” startups with sizeable revenue. That means that the technologies they’ve developed have proven to be marketable.

Second, Skoltech is professors and lecturers, many of whom are outstanding, world-famous scientists. Around 70% of the faculty members are our fellow citizens, having returned to their homeland after working in the leading international scientific and academic institutions. Third, Skoltech is amazingly well-equipped and staffed research centers and laboratories which, as a matter of fact, have been created in partnership with large industrial companies like Rosatom, Gazprom Neft, Rosseti, Tatneft, Russian Helicopters, and others.

Usually, universities build experience and acquire traditions over decades or even centuries. And nonetheless, in only five years Skoltech has become one of the leaders of national higher education. You don’t have to take my word for it—for proof, just refer to the objective indicators that measure university rankings. There are 4.4 published works per faculty member in publications indexed by the Scopus international database, comparable to the leading global universities. According to the Nature Publishing Group index, Skoltech occupies the third place in Russia when it comes to publications in life sciences journals. In this respect, it trails after such giants as the Russian Academy of Sciences and Moscow State University.

I would like to wish staff at the Skolkovo Institute of Science and Technology a no less impressive continuation and even more explosive successes in its anniversaries to come. Your research and discoveries, your graduates with all the knowledge and skills necessary to create the digital economy of the future, are what our country needs, and what the world needs.”

VICTOR VEKSELBERG
PRESIDENT OF THE SKOLKOVO FOUNDATION

CONTRIBUTORS

EDITOR IN CHIEF
ALEXANDER ZOLOTAREV

PRODUCER
INESSA GRIGALYUNENE

ART DIRECTOR
EKATERINA KHOLMOGOROVA

EXECUTIVE EDITOR
ELENA BARINOVA

EDITOR
KSENIA NAUMOVA

WRITER AT LARGE
INGRID BURKE

STAFF PHOTOGRAPHER
VITALY SHUSTIKOV

PROOFREADER
GALINA DANILOVA

PHOTOS
ELIZAVETA AZAROVA
EVGENY PELEVIN
PAVEL SAMOKHVALOV
MAXIM STULOV/VEDOMOSTI
EVGENY TSIKUNOV
EVGENY GURKO
VIKTOR FEDORCHUK

ILLUSTRATIONS
YULIA BLUCHER
ALEXANDRA KUZNETSOVA
MARINA MALYSHEVA
ALEKSANDRA SLOWIK

INTERVIEWS
ALINA CHERNOVA
POLINA IVAKINA
DIANA ROSHCHINA
ALEXANDER MURAKHOVSKY
VALERY SOBOLEV

TRANSLATION
NATALIA MAXIMOVA
GRACE CUDDIHY
HARRISON GRADY
FRANCES RANSOME

143026, Moscow, Nobel str. 3
Tel. +7 (495) 280 14 81

www.skoltech.ru

Circulation 500 copies

CONTENTS

STRATEGY

Skoltech: Past. Present. Future

–ALEXANDER KULESHOV–

The Skolkovo Institute of Science and Technology, one of the most important parts of the Skolkovo project, was formally established six years ago. Then, five years ago, in 2012, the first students were accepted, but for natural reasons the institute could only fully begin its work in mid-2015. By that time, many bureaucratic problems had been resolved; we had obtained facilities to accommodate our educational and research processes, assembled a critical mass of highly qualified faculty and acquired the minimal amount of equipment necessary to begin meaningful activity. Here, I would like to express my gratitude to the first Rector of Skoltech, Professor Edward Crawley, who was able to overcome a colossal amount of professional and bureaucratic obstacles at the outset. That took willpower and professionalism, which Ed, as it turned out, had in abundance. Skoltech's global mission is to foster a scientific and technological elite for Russia and the world, to train specialists and create technologies as a basis for our country's transition to a new type of economy, becoming an active participant in the global digital revolution currently under way.

In order to achieve this, it was necessary to create the first "third generation" university in Russia; a University 3.0. What exactly is new about this? What distinguishes third-generation universities from traditional educational institutions that have, over the centuries, successfully fulfilled their functions of mass and elite education, of fundamental and applied research?

Skoltech's primary task is to locate and foster next-generation leaders who are talented, well educated, ambitious and capable of looking beyond the limits of today's reality

A qualitative distinction between third-generation universities and traditional universities consists in the former's organic integration of an innovative element into research and educational activity, and the training of multidisciplinary research teams. In other words, training specialists who are not only capable of carrying out research and development in cooperation with specialists of different fields of knowledge, but also seeing market potential in their activity and possessing the ability to transform these results into industrial, high-demand products.

In addition, it is important to understand how technology-fueled lifestyle shifts have gathered momentum in the past ten to twenty years: professional skills considered essential only several years ago are becoming unnecessary as we speak. Professionals with entrepreneurial talent are beginning to play a leading role in the world. I will not list the household names of all of the people who have transformed the world before our eyes. Their main distinction from the managers of former generations is their combination of professional talents and knowledge with leadership skills, technological ingenuity and incredible bravery and willpower, self-confidence and determination to take their ideas to fruition, making the world a better place.

Of course, humanity has not changed much over the past several centuries and people have always been this way, but in today's world an environment has emerged that gave them the opportunity to fulfill themselves. And one of our country's main tasks is to try to create that type of environment and foster those kinds of people here in Russia. Skoltech is a pioneering organization for our country, and in the not-too-distant future I hope that it will become one of the leading scientific educational organizations in the world as well. We have every reason to think it will: our publishing activity has already reached the levels of the leading young international universities and we conduct applied research in the fields of biotechnology, energy, data science,

Skolkovo.AI CONFERENCE
Skoltech President, RAS Academician Alexander Kuleshov pictured opening the plenary session

Taking into account technological advances and experience, six priority areas have been formed as part of the third stage of the institute's development in 2018-2020: Data Sciences and Artificial Intelligence; Life Sciences and Biomedicine; Modern Methods of Engineering and the Non-Conventional Materials; Energy Efficiency; Quantum Technologies; and Advanced Studies

and quantum technologies, which should lead to world-class breakthroughs not only from a purely scientific perspective, but also in the creation of new products that will change life in our country and the world.

That is why Skoltech's primary task is to locate and foster next-generation leaders who are talented, well educated, ambitious and capable of looking beyond the limits of today's reality, confident visionaries and dreamers who I am certain will define our future.

One of Skoltech's most important goals in the near future is to reduce our dependence on government financial support, which, in our view, is eminently attainable. We have already achieved a lot to that end.

But not everything has gone as smoothly as we would like. One of the fundamental problems, the very existence of which we cannot and will not tolerate, is brain drain.

Of course, science is international and we certainly welcome internships, student exchanges at various levels of postgraduate study, and travel to conferences, because today that is the only way to foster the world-class leaders that our country is in such great need of. But nonetheless, it must be understood that our goal is to foster the scientific and technological elite of our country. We are fully aware that the majority of Skoltech graduates are in demand at the best international universities and companies, but we want them to give back the entire force of their intellect and education obtained at Skoltech here and now. For that reason, in the "big Skolkovo" ecosystem ("Skolkovo is not a territory, but an ideology," said Zhores Alferov, Nobel laureate and Co-Chairman of the Skolkovo Foundation Scientific Advisory Council) we need to do everything in our power to establish an atmosphere of creativity for our students, an atmosphere of passion for success, an atmosphere of professional mutual understanding, without which no technological achievements are possible today.

Skoltech is a pioneering organization for our country, and in the not-too-distant future I hope that it will become one of the leading scientific educational organizations in the world

Elements of an Ecosystem

ALEXANDER CHERNOV

SENIOR VICE-PRESIDENT FOR EXTERNAL COMMUNICATIONS OF THE SKOLKOVO FOUNDATION

In a very short time, Skoltech managed to carve out an absolutely unique niche in the Russian higher education system. Our country has many universities where students can receive a quality education in engineering and economics. But at present, it appears to be the case that Skoltech alone can provide its students with the complete scope of knowledge needed by researchers, developers and managers involved in technological entrepreneurship. These are the professions that are critical for Russia's innovative development, and for the creation of the digital economy.

RUPERT GERZER

SKOLTECH PROVOST, DIRECTOR OF THE CENTER FOR TRANSLATIONAL BIOMEDICINE, PROFESSOR

The City of Moscow is currently in the process of establishing the Moscow International Medical Cluster, as well as a new Biotech Park at the Skolkovo Innovation Center. Skoltech strongly supports these initiatives and is prepared to spearhead close collaborations with the new international healthcare providers in all respective fields. The institute is currently intensifying its translational biomedicine activities. Skoltech will also offer joint educational programs. This initiative will have a strong impact on the future fields of Skoltech activities.

ALEXEI SITNIKOV

VICE PRESIDENT FOR COMMUNICATIONS AND COMMUNITY DEVELOPMENT

Skoltech is an essential element and the intellectual nucleus of the Skolkovo ecosystem. Professors, researchers, and students actively participate in the Innovation Center's key events: the annual Open Innovations Forum, the Startup Village festival held each summer, and the Skolkovo Jazz Festival. Next year, Skoltech will move into its new home, possibly the most state-of-the-art university campus in the world, built by the acclaimed architectural firm Herzog & de Meuron. Today, Skolkovo is actively pursuing a new initiative: the Skolkovo educational hub. It is composed of three universities located in close proximity to one another: Skoltech, the Moscow School of Management Skolkovo, and the New Economic School. They collaborate on educational and research programs for the benefit of the Russian economy, and for the benefit of the country as a whole.

ALEXANDER SAFONOV

VICE PRESIDENT FOR DEVELOPMENT

One of Skoltech's priorities is to engage young talent in the world of big science and cutting-edge technologies. We place an enormous emphasis on work with highly gifted junior high and high school students. Cooperation has already been developed with the Sirius Educational Center and the Skolkovo International Gymnasium, which started the academic year in a beautiful new building not far from Skoltech. University graduate students and professors give lectures and immerse students in project work. In addition, Skoltech conducted a pilot school in physics, molecular biology, and bioinformatics for undergraduate students this past summer. Several dozen brilliant students from various Russian and international cities participated. Classes were led by world-class professors not only from Skoltech, but also from some of our international partner universities, like the Massachusetts Institute of Technology, the Weizmann Institute, Stony Brook University, and many others. We will definitely continue this work in the future.

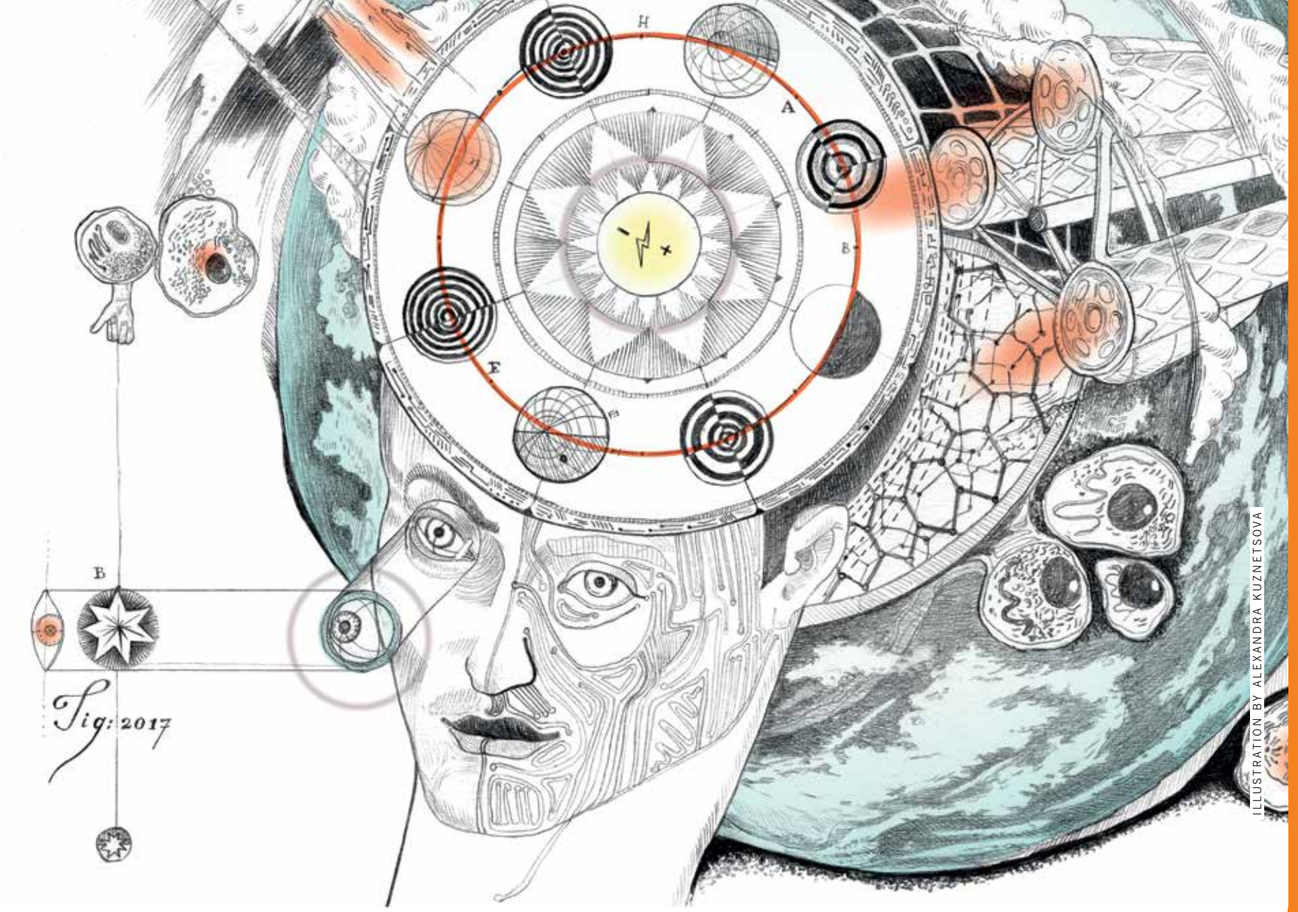


ILLUSTRATION BY ALEXANDRA KUZNETSOVA

#GREATSCIENCE
#LABS
#PUBLICATIONS
#CUTTINGEDGERESEARCH
#SCIENTIFICRESULTS

great science

#1

THE HUMAN BRAIN AND THE PRIMATE BRAIN ARE MORE DIFFERENT THAN WE THOUGHT

– Philipp Khaitovich –
– Olga Efimova –

An international group of scientists from Russia, China and Germany led by Skoltech Professor Philipp Khaitovich examined new gene expression features in different layers of the prefrontal cortex of the human brain and compared their findings with chimpanzee and macaque brains.

The scientists arrived at the conclusion that despite significant similarities between human and primate brains, the neocortex microarchitecture underwent rapid and substantial changes during the course of the human evolutionary process.

The study of human cognitive abilities is a key priority in the fields of medicine and neurobiology. But little is known about just how evolution changed the functional organization of the human brain.

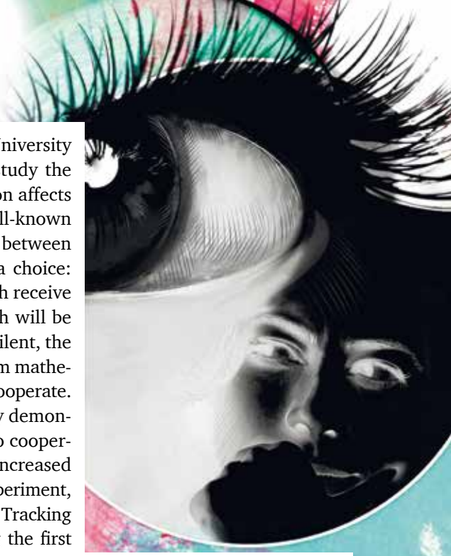
Each of the six layers of the prefrontal cortex carries out special functions in information processing, distributing different types of cells and organizing the links between them.

The scientists analyzed the RNA of sections of the prefrontal neocortex of the cerebral cortex of humans, chimpanzees and macaques. More than 2,320 genes were identified, new markers of neocortex layers unique to humans. Their research revealed some 367 human genes operate in a completely different layer of the neocortex than those of chimpanzees. Only 133 similar genes were discovered in chimpanzees, compared to macaques, despite the fact that considerably more time has passed since the evolutionary division of the chimpanzee and the macaque than of the chimpanzee and the human. Knowledge of the unique features of gene expression in different layers of the human prefrontal cortex make it possible to develop new means of regulating human cognitive functions, for instance, in cases of brain pathologies and aging.

THE RESULTS OF THIS STUDY HAVE BEEN PUBLISHED IN NATURE NEUROSCIENCE JOURNAL

ILLUSTRATION BY MARINA MALYSHEVA

ILLUSTRATION BY MARINA MALYSHEVA



EYE MOVEMENTS GIVE AWAY THE DECISIONS WE MAKE

– Tatyana Babkina –

Researchers from Skoltech and Tomsk State University in Russia and the University of Oregon in the United States used a mobile eye-tracking system to study the decision-making process. Scientists were able to observe how socialization affects decision-making and levels of cooperation between participants. The well-known game theory problem, the “Prisoner’s Dilemma,” involves cooperation between two players. Two people are caught after committing a crime. Each is faced with a choice: testify against his or her accomplice, or keep silent. If both remain silent, they will both receive the minimum term of six months behind bars. If both testify against each other, both will be imprisoned for two years. But if one testifies against the other, and the other remains silent, the betrayer is released, and the silent one is sentenced to 10 years in prison. It would seem mathematically correct to always betray. But people are social by nature, that is, inclined to cooperate.

Early joint studies by Skoltech and the Moscow Institute of Physics and Technology demonstrated that a group of strangers participating in the Prisoner’s Dilemma only opted to cooperate in about 20% of cases. However, even brief social interactions between players increased cooperation rates to levels similar to those achieved between friends. During the experiment, the behavior of participants was studied using a mobile eye-tracking system (SMI Eye Tracking Glasses v. 1.8). Scientists compared the oculomotor activity of 12 participants during the first part of the experiment when they did not yet know each other, and during the second part, following social interactions. They determined that an increase in the total time period of looking and the time of gaze fixation on non-cooperative advantages are inherent to “defectors” — people who choose a betrayal strategy. Following social interactions, the perception of material stimuli changes: the decision-making process is accompanied by the increased frequency of fixations on specific strategies and a reduction of their duration, as well as greater frequency of coordinated eye movements and their decreased total length.

THE RESULTS HAVE BEEN PUBLISHED IN PLOS ONE JOURNAL

INORGANIC PEROVSKITE SOLAR CELLS ARE BECOMING MORE EFFICIENT

– Pavel Troshin –

Scientists from Skoltech, the Institute of Problems of Chemical Physics of the Russian Academy of Sciences and Moscow State University have explored the potential of fully inorganic perovskite solar cells. The fabricated devices delivered power conversion efficiency (PCE) of 10.5%.

"These results demonstrate the high potential of inorganic integrated halides, which creates potentially new possibilities for the design of new photovoltaic materials for effective and stable perovskite solar cells," says Pavel Troshin, a professor with Skoltech's Center for Electrochemical Energy Storage.

Thus far, PCE power conversion in hybrid organic-inorganic perovskite solar cells has reached 22%. The high effectiveness, low costs and simplicity of producing hybrid perovskite solar cells make it one of the most promising technologies of photovoltaic cells. But hybrid integrated iodoplumbates easily undergo rapid thermal and photochemical decomposition, which challenges their practical implementation in solar modules.

The most effective approach in the creation of stable perovskite materials appears to be the full replacement of organic with inorganic cations. For instance, inorganic solar cells demonstrated a conversion efficiency of just 2-3%, but this study recognized the possibility of substantially increasing these figures.

"We have conclusively demonstrated the possibility of creating highly effective solar cells with a planar heterotransition based on CsPbI3 films obtained through the thermal co-evaporation of cesium and lead iodides," says Pavel Troshin.

THE RESULTS OF THIS STUDY HAVE BEEN PUBLISHED IN NATURE JOURNAL

ILLUSTRATION BY MARINA MALYSHEVA

ILLUSTRATION BY MARINA MALYSHEVA

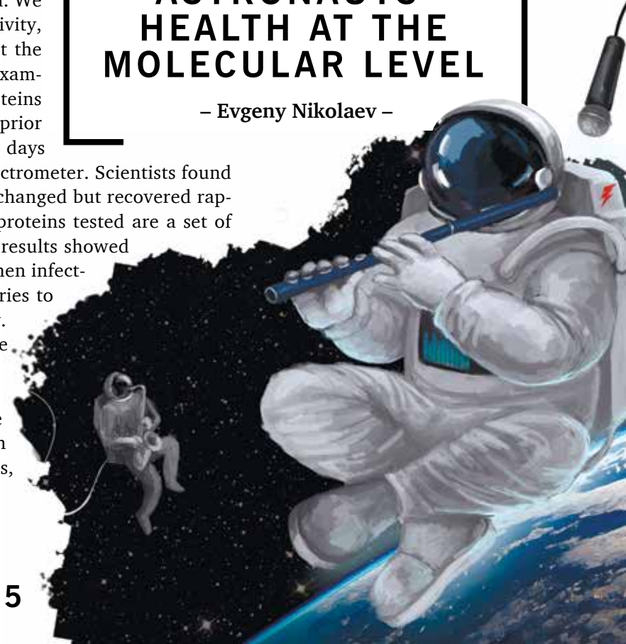
WEIGHTLESSNESS AFFECTS ASTRONAUTS' HEALTH AT THE MOLECULAR LEVEL

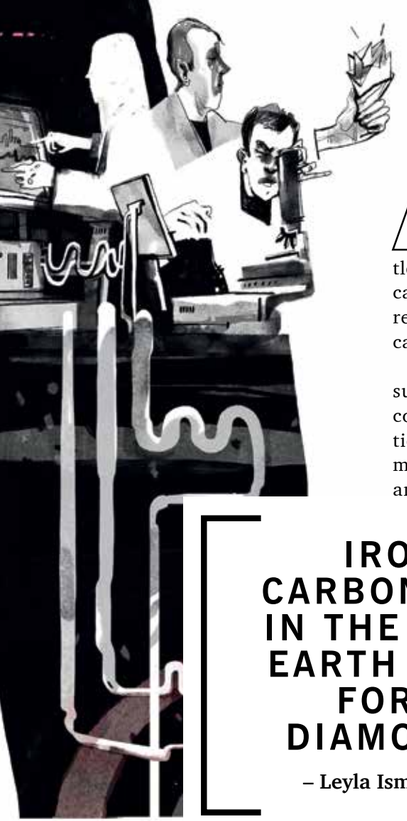
– Evgeny Nikolaev –

Scientists from Russia and Canada analyzed the effect of spaceflight conditions on protein make-up in blood samples of 18 cosmonauts who lived on the International Space Station for an extended period of time. Professor Evgeny Nikolaev of Skoltech and the Moscow Institute of Physics and Technology initiated the research. We know that space conditions influence metabolism, muscle activity, the respiration system, and many other bodily functions, but the molecular mechanisms behind these processes have yet to be examined. The research team analyzed concentrations of 125 proteins in the blood plasma of astronauts, who were tested 30 days prior to their flights, directly after their return to Earth, and seven days later. Protein concentrations were measured using a mass spectrometer. Scientists found proteins with concentrations that remained unchanged, that changed but recovered rapidly to normal levels, and that recovered very slowly. "The proteins tested are a set of biomarkers used to identify noncommunicable diseases. The results showed that in weightlessness, the immune system acts like it does when infected, because the human body doesn't know what to do and tries to turn on all possible defense systems," said Professor Nikolaev.

Evolution hasn't prepared us for the changes that take place in the human body during spaceflight. It is unknown if the human body has mechanisms responsible for rapid adaptation to such serious changes in its living conditions. The results of the study indicate that these mechanisms likely do not exist, which is why adaptations take place in all major types of human cells, organs, and tissues.

THE RESULTS OF THIS STUDY HAVE BEEN PUBLISHED IN NATURE SCIENTIFIC REPORTS JOURNAL





IRON CARBONATES IN THE DEEP EARTH HELP FORM DIAMONDS

– Leyla Ismailova –

An international group of scientists including researchers from Russia (Leyla Ismailova, research scientist at the Skoltech Center for Hydrocarbon Recovery), France, Germany, Italy and the United States, discovered surprising particularities in the behavior of iron carbonates in conditions of high temperatures and extremely high pressure in the Earth's mantle. Diamonds extracted from depths of some 700 km. bear inclusions that contain carbonates, providing direct evidence that carbonates exist at such depths. Scientists revealed that under these extreme conditions, carbonate structure is reorganized: the carbon carries an extra carbon atom, forming a tetrahedral shape.

Pressure deep in the Earth is equivalent to more than one million times the pressure of Earth's atmosphere, and temperatures reach 2,200° Celsius. Most chemical compounds cannot exist under such conditions. To simulate deep mantle conditions, the team generated high pressure and temperatures using laser-heated diamond anvil cells. The team then used synchrotron X-rays to examine the content and the structure of the samples at the European Synchrotron Radiation Facility in France and the Advanced Photon Source in the United States, which made it possible to analyze the composition and structure of the samples.

The results of their work indicate that one of the new crystal structures is uncommonly stable and retains its structure under the conditions present in the earth's mantle, to depths of 2,500 km – close to where the mantle meets the earth's core.

Through the process of self-oxidation, carbonates can remain preserved deep in the Earth's mantle, thereby contributing to diamond formation.

THE RESULTS OF THIS STUDY HAVE BEEN PUBLISHED IN NATURE COMMUNICATIONS JOURNALV

ILLUSTRATION BY YULIA BLUCHER

ILLUSTRATION BY YULIA BLUCHER

SCIENTISTS EXPLORE A NEW MECHANISM FOR LIVER CELL REGENERATION

– Yuri Kotelevtsev –

Scientists from Skoltech, the University of Edinburgh's Centre for Regenerative Medicine in Scotland, and the Massachusetts Institute of Technology in the United States have, for the first time, demonstrated the role of cholangiocytes (epithelial bile duct cells) in liver regeneration. The results of their study are highly useful for regenerative medicine and the fight against liver disease.

The liver is one of the few organs in the human body that is capable of regenerating. In the event of liver damage as a result of trauma or chronic disease, the main liver cells – hepatocytes, which are responsible for all basic liver functions – are able to regenerate by dividing into new hepatocytes. Stimulation of liver regeneration is an acute problem for medical practitioners and researchers, but the details of this mechanism and whether other types of hepatic cells are involved in the process of the formation of new hepatocytes remains unclear.

An international group of scientists used transgenic mice as test subjects; in doing so, they managed to simulate liver damage common to humans. At the same time, the ability of hepatocytes to divide was intentionally reduced in order to evaluate the contribution of other liver cells to regeneration. As a result it was shown that bile duct epithelial cells – cholangiocytes – are involved in the regeneration of hepatocytes. Also, scientists suggest that the potential for regeneration in hepatocytes derived from cholangiocytes may be higher than in normal hepatocytes.

"The Scottish Center for Regenerative Medicine... is beginning work aimed at isolating and transplanting autologous cholangiocytes to patients with cirrhosis," said Yuri Kotelevtsev, deputy director of the Skoltech Center for Translational Biomedicine.

THE RESULTS OF THIS STUDY HAVE BEEN PUBLISHED IN NATURE JOURNAL

NEW TROJAN HORSE ANTIBIOTIC TO HELP TREAT BACTERIAL INFECTIONS

– Konstantin Severinov –

Scientists from Skoltech and the Institute of Gene Biology (Russian Academy of Sciences) in collaboration with their colleagues from Belgium, led by Skoltech Professor Konstantin Severinov, have described a new antibiotic that, like the Trojan Horse, penetrates inactive bacterial cells and, once inside, becomes toxic and destroys them. The substance described by the scientists was found in the bacteria Bacillus amyloliquefaciens.

The new antibiotic has a number of advantages over previously studied Trojan horses. "At first the antibiotic was predicted by means of bioinformatics," said Severinov, who serves as director of the Skoltech Center for Data Intensive Medicine and Biotechnology. "The new compound acts through a Trojan horse mechanism but has a unique chemical structure that allows the new drug to inhibit the growth of cells that have acquired resistance to certain antibiotics. These findings highlight the importance of DNA sequence mining for uncovering novel bioactive compounds and may lead to the development of new antibacterial drugs in the future."

Antibiotic resistance is one of the biggest problems in modern healthcare. One of these antibiotics is microcin C, a prototypical Trojan horse antibiotic produced by several strains of E. Coli bacteria to fight other bacteria. Inside the sensitive target cell, microcin C breaks down, producing a toxic substance that inhibits protein synthesis and prevents cell growth. The new compound described in this study is similar to microcin C, but one of its main particularities is its specialized chemical modifications that reduce the probability of antibiotic resistance development.

The research, carried out in Severinov's laboratory, expands the known range of antibiotics produced by bacteria and makes possible the development of new antibiotics.

THE RESULTS OF THIS STUDY HAVE BEEN PUBLISHED IN THE JOURNAL OF THE AMERICAN CHEMICAL SOCIETY

ILLUSTRATION BY ALEKSANDRA SLOWIK

ILLUSTRATION BY ALEKSANDRA SLOWIK

SKOLTECH SCIENTISTS LEARN TO MANIPULATE HUMAN GAZE IN THE IMAGES

– Victor Lempitsky –
– Yaroslav Ganin –

Scientists from the Skoltech Computer Vision Group, led by professor Victor Lempitsky, have developed an algorithm that can change the direction of the gaze in images and video in real time.

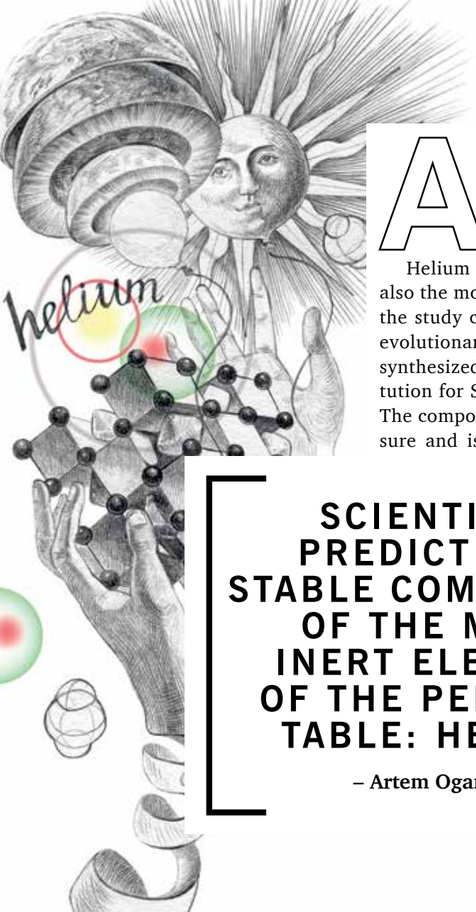
During video conferences (for example, on Skype), both parties are usually looking at the screen but not at the camera, leading to a slightly downward gaze. Often this inhibits the sensation of a real conversation. A similar problem is faced by television announcers, who must simultaneously read texts and look at the audience.

The system developed by the Skoltech scientists requires only a basic digital camera. It is based on deep neural networks (deep learning), a machine learning method that recently led to several breakthroughs in computer vision, speech recognition and natural language processing.

"First, we localize the eye region in the input frame. This data, along with the angle used to correct the direction of the gaze, enter into the deep neural network," explains study author Yaroslav Ganin. "This in turn produces a so-called 'displacement field,' that is, a deformation that needs to be applied to the input image to receive the correct image. Hence the name of the method: DeepWarp."

DeepWarp is one of several projects developed by Victor Lempitsky's group, dedicated to image synthesis using neural networks. This field has enormous practical potential. For instance, the gaze manipulation project can be used in the photo and motion picture industry as a post-processing tool.

THE RESULTS OF THIS STUDY HAVE BEEN PRESENTED AT THE 14TH EUROPEAN CONFERENCE ON COMPUTER VISION IN AMSTERDAM



SCIENTISTS PREDICT TWO STABLE COMPOUNDS OF THE MOST INERT ELEMENT OF THE PERIODIC TABLE: HELIUM

– Artem Oganov –

An international team of researchers led by Skoltech Professor Artem R. Oganov (head of the Computational Materials Discovery laboratory at the Moscow Institute of Physics and Technology) has predicted two stable helium compounds– Na_2He and Na_2HeO. This work could hold clues about the chemistry occurring in planetary depths or even stars where helium plays a key role.

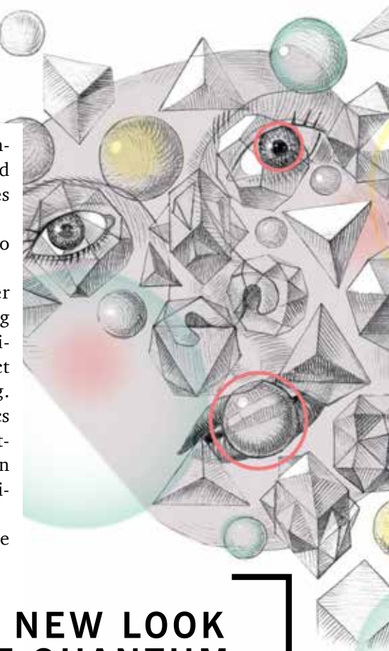
Helium is the second most abundant element (after hydrogen) in the universe, and also the most inert. It has no stable compounds under normal conditions. The authors of the study conducted a systematic search of stable helium compounds using the USPEX evolutionary algorithm. They predicted the Na_2He compound, which was successfully synthesized in a diamond anvil cell (DAC) experiment conducted at the Carnegie Institution for Science in Washington by Professor Alexander Goncharov and his colleagues. The compound appears at pressures of about 1.1 million times Earth's atmospheric pressure and is predicted to remain stable at least up to 10 million atmospheres. Na_2He is a special type of an ionic salt-like crystal called an electride. In these crystals, the role of the cation sublattice is assumed by sodium, while localized electron pairs assume the role of anion. Because electrons are strongly localized, Na_2He cannot conduct an electric current. Another compound, Na_2HeO, was found to be stable in the pressure range from 0.15 to 1.1 million atmospheres.

"Our study once again illustrates how little is known today about the influence of extreme conditions on chemistry, and the role of these phenomena inside planets has yet to be explored," says Professor Oganov.

THE RESULTS OF THIS STUDY HAVE BEEN PUBLISHED IN NATURE CHEMISTRY JOURNAL

ILLUSTRATION BY ALEXANDRA KUZNETSOVA

ILLUSTRATION BY ALEXANDRA KUZNETSOVA



A NEW LOOK AT QUANTUM COMPUTERS AND A.I.

– Jacob Biamonte –

Information is not an entirely virtual entity; it must be stored in a physical medium. Information processing devices like computers and smartphones are therefore governed by the laws of physics. Consequently, the physical limits of machine learning abilities are governed by the laws of physics.

As the best-known theory of physics is quantum theory, it must therefore be used to determine the absolute physical limits of a machine's ability to learn.

A quantum algorithm is a multi-step procedure performed on a quantum computer to solve a certain problem, such as searching a database. Quantum machine learning software makes use of quantum algorithms to process information in ways that classical computers cannot. This opens up entirely new possibilities and prospects. The effect quantum computers are able to achieve is called quantum enhanced machine learning.

Machine learning is widely used in biotechnology, pharmaceuticals, particle physics and many other fields. Thanks to the ability to adapt to new data, machine learning greatly exceeds the ability of people. Despite this, machine learning cannot cope with certain difficult tasks. Quantum enhancement is expected to help tackle tasks ranging from optimization to neural network learning.

In the new paper published in Nature, a group of scientists led by Skoltech Associate Professor Jacob Biamonte outlines the necessary steps to make quantum enhanced machine learning possible in practice.

Many researchers have thought that the primary applications of quantum computers would be the use of quantum computers to simulate chemical physics, which can be used in the pharmaceutical industry for drug discovery.

"Early on the team spent all night on Skype debating what our field of study even was. Ultimately we ended up writing three versions over eight months with nothing more than the title in common," said Jacob Biamonte.

THE RESULTS OF THIS STUDY HAVE BEEN PUBLISHED IN NATURE JOURNAL

At Skoltech's heart Labs

are its world-class laboratories, where brilliant minds and the most advanced equipment meet

CENTER FOR ELECTROCHEMICAL ENERGY STORAGE

Electrochemical Energy Storage Labs

The CEES performs cutting-edge research in several emerging fields focused on the generation of innovative products, including: the development of efficient technologies for solar energy conversion based on a conceptually new organic and perovskite solar cells; the design of innovative organic materials and large-scale redox flow systems for stationary bulk energy storage, e.g. to meet the needs of solar and wind power plants; the design of a new generation of metal-ion batteries (lithium, sodium, potassium, magnesium) with record-breaking capacities and long-term operation stability.
Skoltech PhD and MSc students are actively engaged in all of the lab's research projects.

CENTER FOR DESIGN, MANUFACTURING AND MATERIALS

Design, Manufacturing and Materials Labs

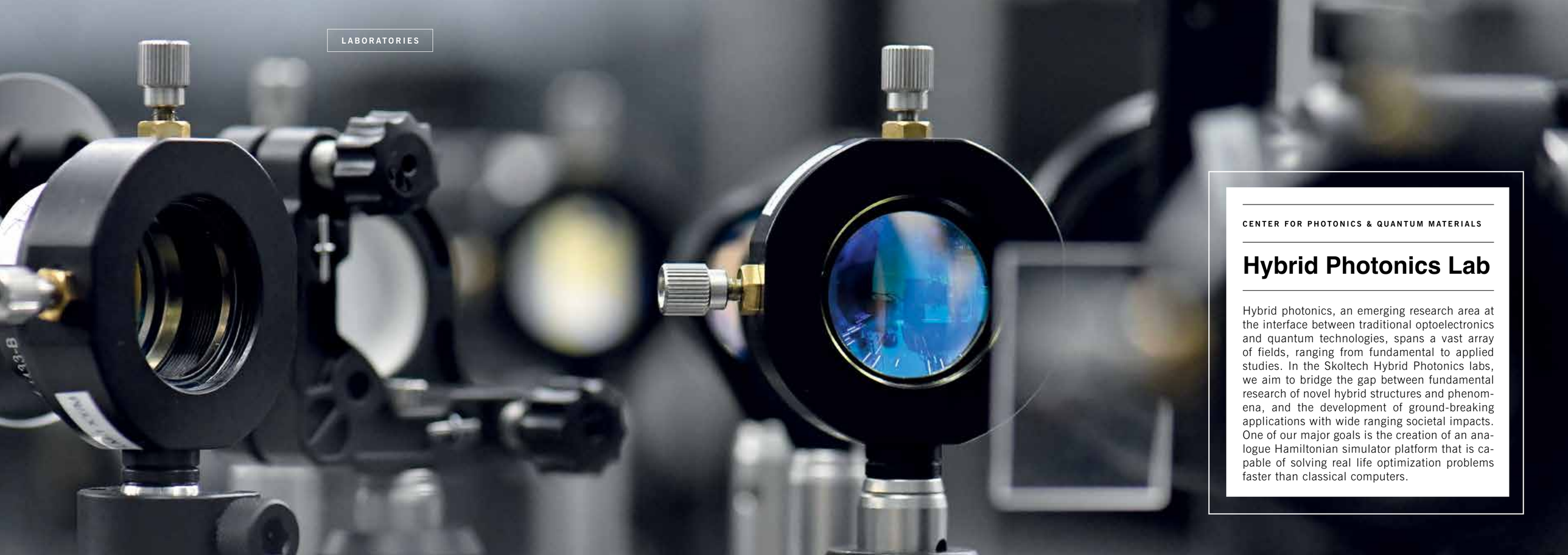
The CDMM conducts basic and applied research aimed at developing and implementing new design and manufacturing concepts, and creating advanced, lightweight and reliable materials and structures with enhanced lifecycles to meet the demands of various industries.

The Center's key research and education areas include: composite materials and structures; additive manufacturing and coating technologies; information technologies for advanced manufacturing; and micro- and nano-mechanics.

SPACE CENTER

Concurrent Engineering Design Lab

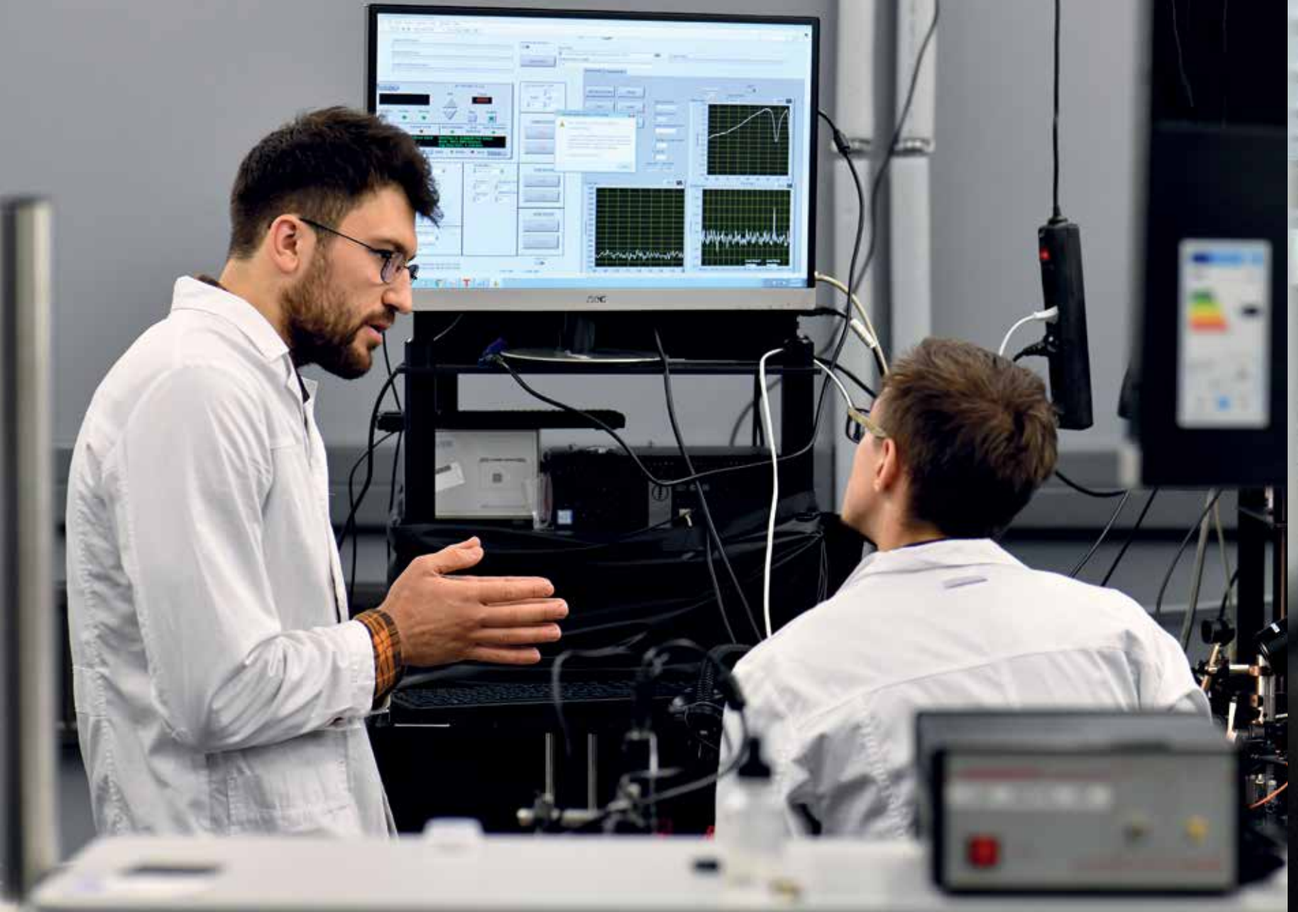
The Space Center lab aims for excellence in education, research and innovation. Students, faculty and researchers at the lab conduct studies on the newest methods of space exploration and remote sensing, including with the use of unmanned aerial vehicles. The lab's goal is to implement cutting-edge technological developments with the help of partners in industry.
Students in the program are actively involved in the creation of small satellites, from mission development to flight tests using CubeSat technology.



CENTER FOR PHOTONICS & QUANTUM MATERIALS

Hybrid Photonics Lab

Hybrid photonics, an emerging research area at the interface between traditional optoelectronics and quantum technologies, spans a vast array of fields, ranging from fundamental to applied studies. In the Skoltech Hybrid Photonics labs, we aim to bridge the gap between fundamental research of novel hybrid structures and phenomena, and the development of ground-breaking applications with wide ranging societal impacts. One of our major goals is the creation of an analogue Hamiltonian simulator platform that is capable of solving real life optimization problems faster than classical computers.



CENTER FOR HYDROCARBON RECOVERY

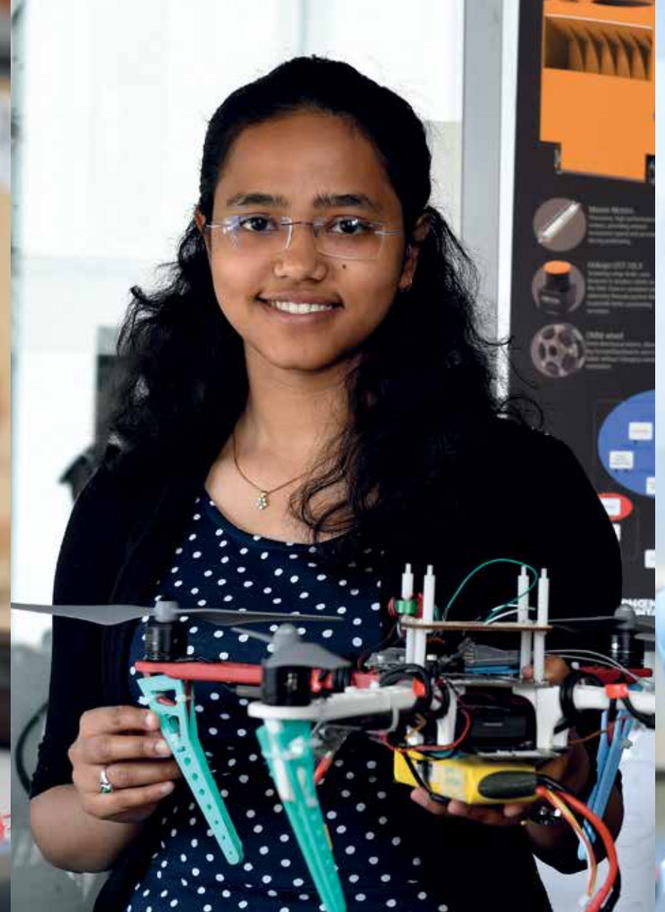
Hydrocarbon Recovery Lab

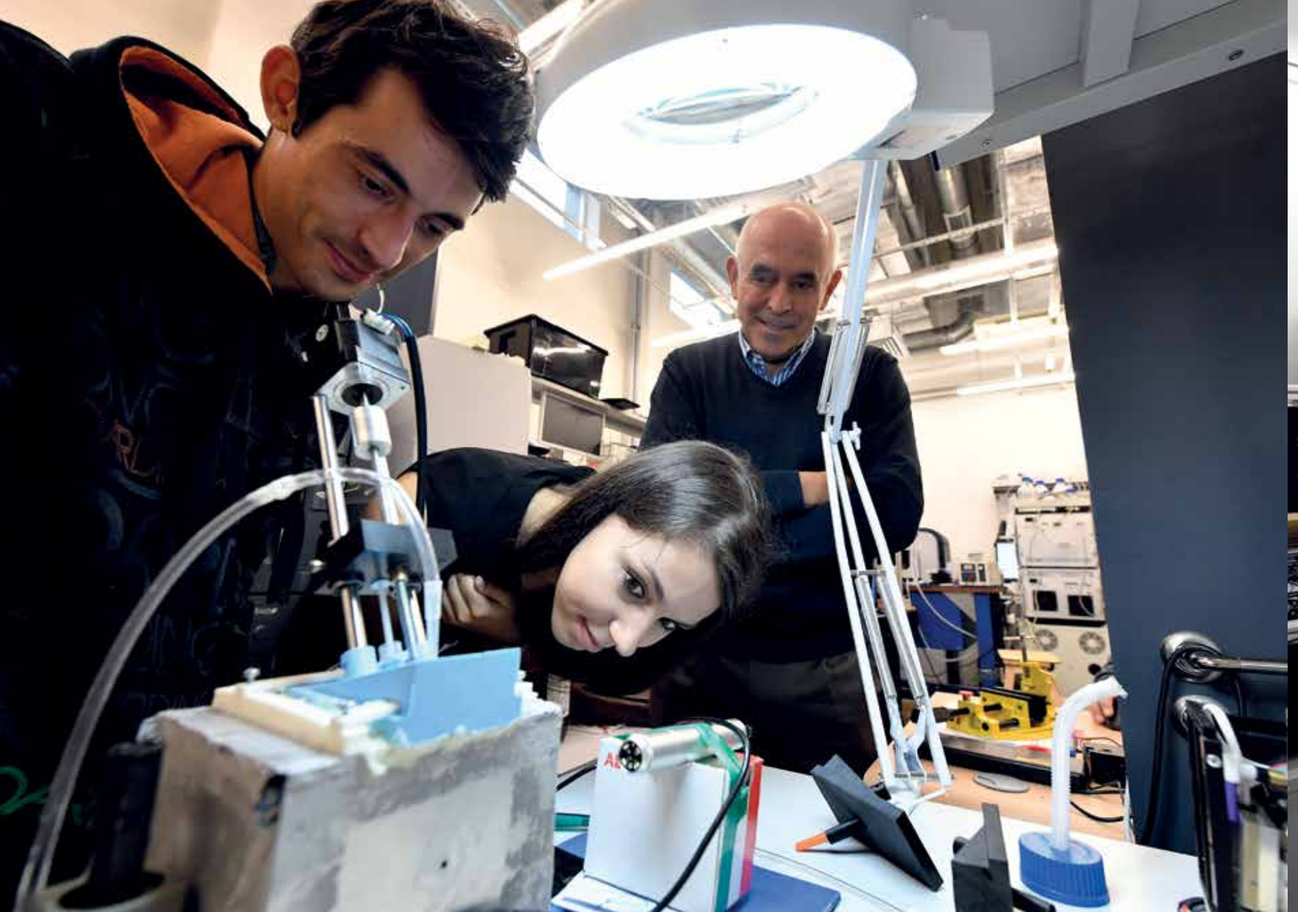
Skoltech unveiled its Center for Hydrocarbon Recovery's new state-of-the-art laboratory on 6 June 2017. The new lab is devoted to research and development of technologies for producing oil and gas that cannot be extracted using traditional methods – so-called hard to recover and unconventional resources, including brownfields, heavy oil, tight oil, carbonate and low permeable reservoirs and gas hydrates formations. Scientists will study the processes that occur in hydrocarbon reservoirs at depths up to several kilometers, and apply the results of their research to develop new solutions for the production of conventional and unconventional resources.

SPACE CENTER

Intelligent Space Robotics Lab

The Intelligent Space Robotics lab conducts research across a vast spectrum of robotics-related fields. Students and researchers associated with the lab have created warehouse automation solutions using both drones and mobile robots, launched an open self-driving car platform, created a technology for automated smartphone disassembly and constructed their own manipulators. They have also won numerous awards and honors, including the national Eurobot championship two years in a row.

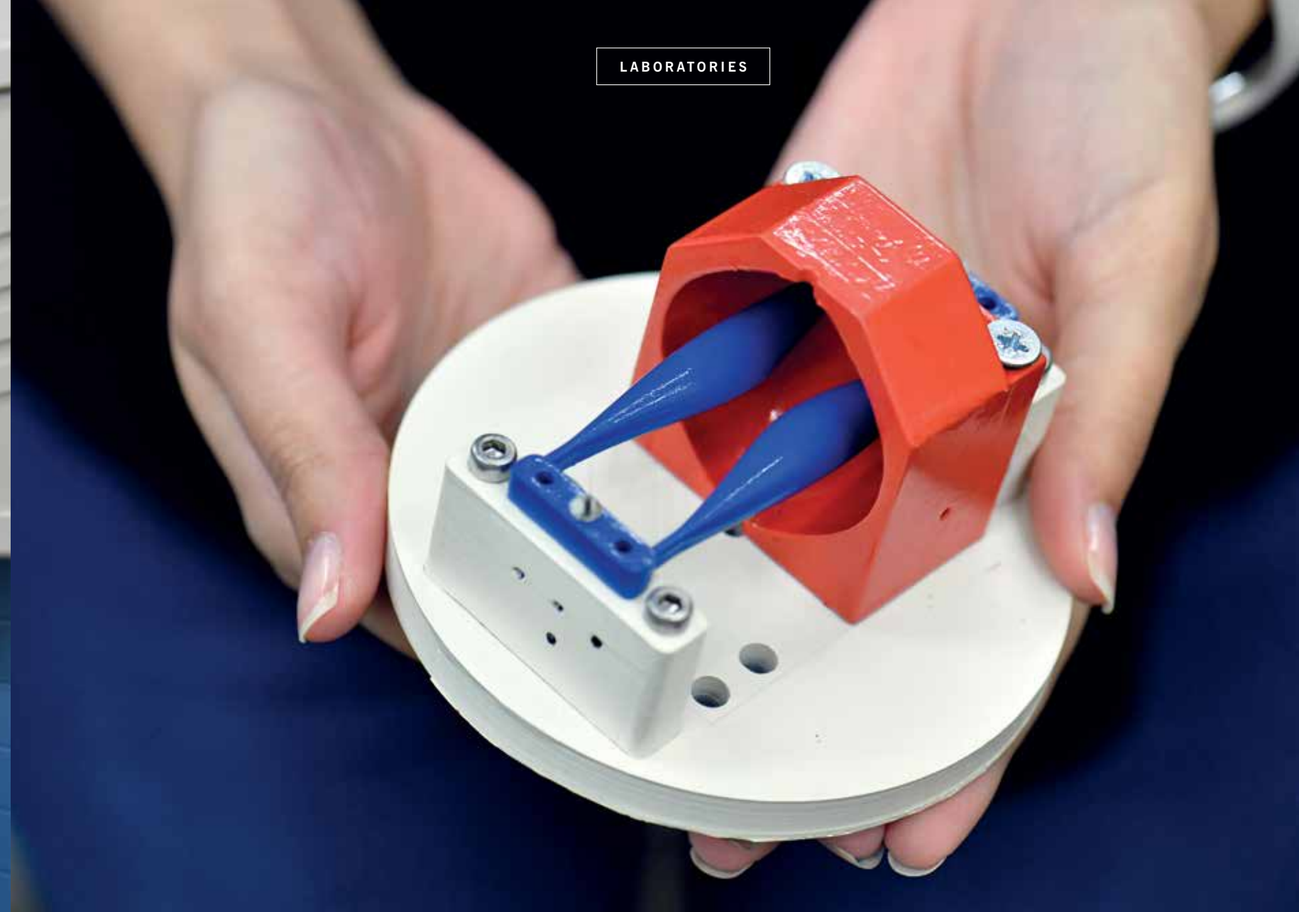


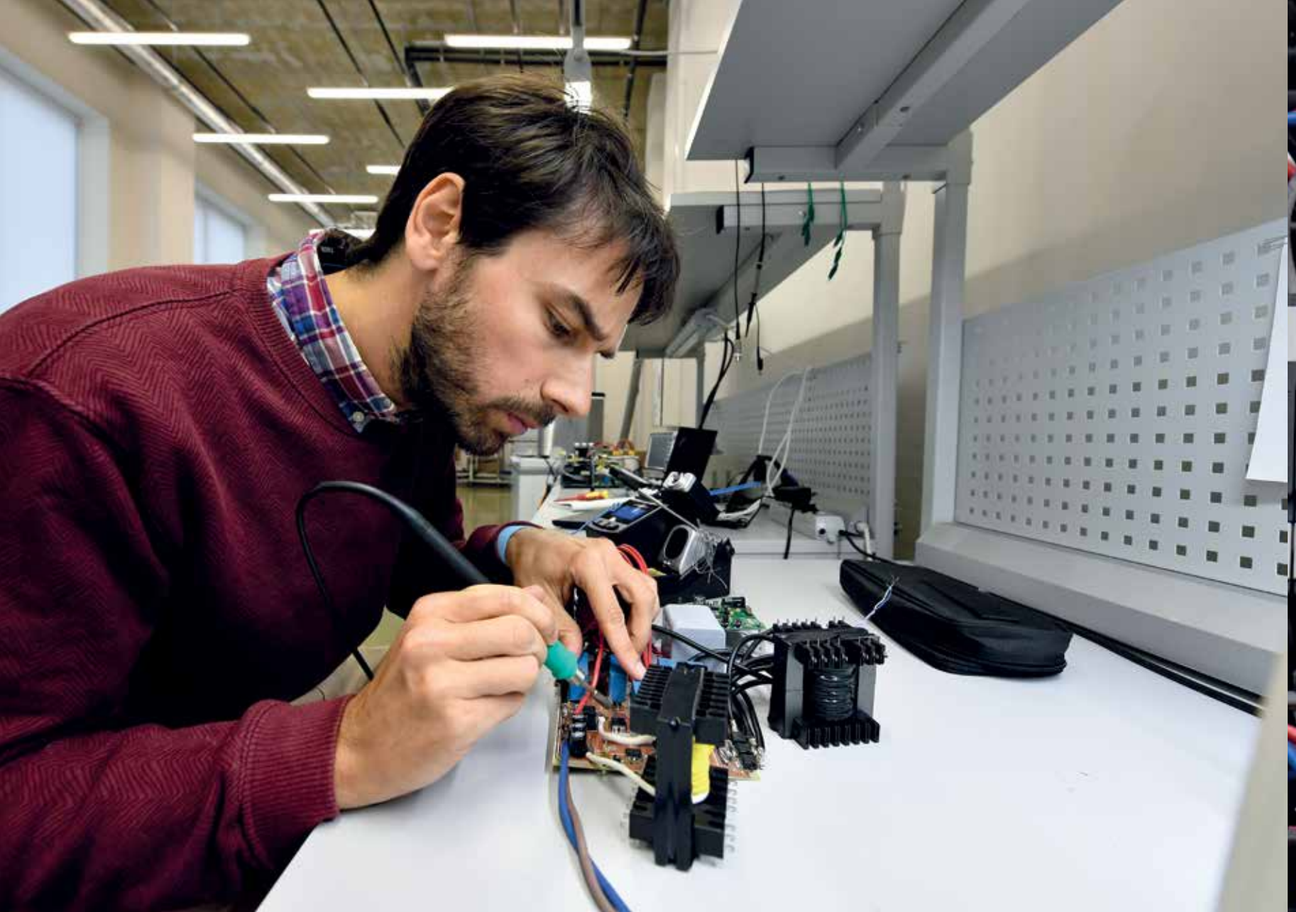


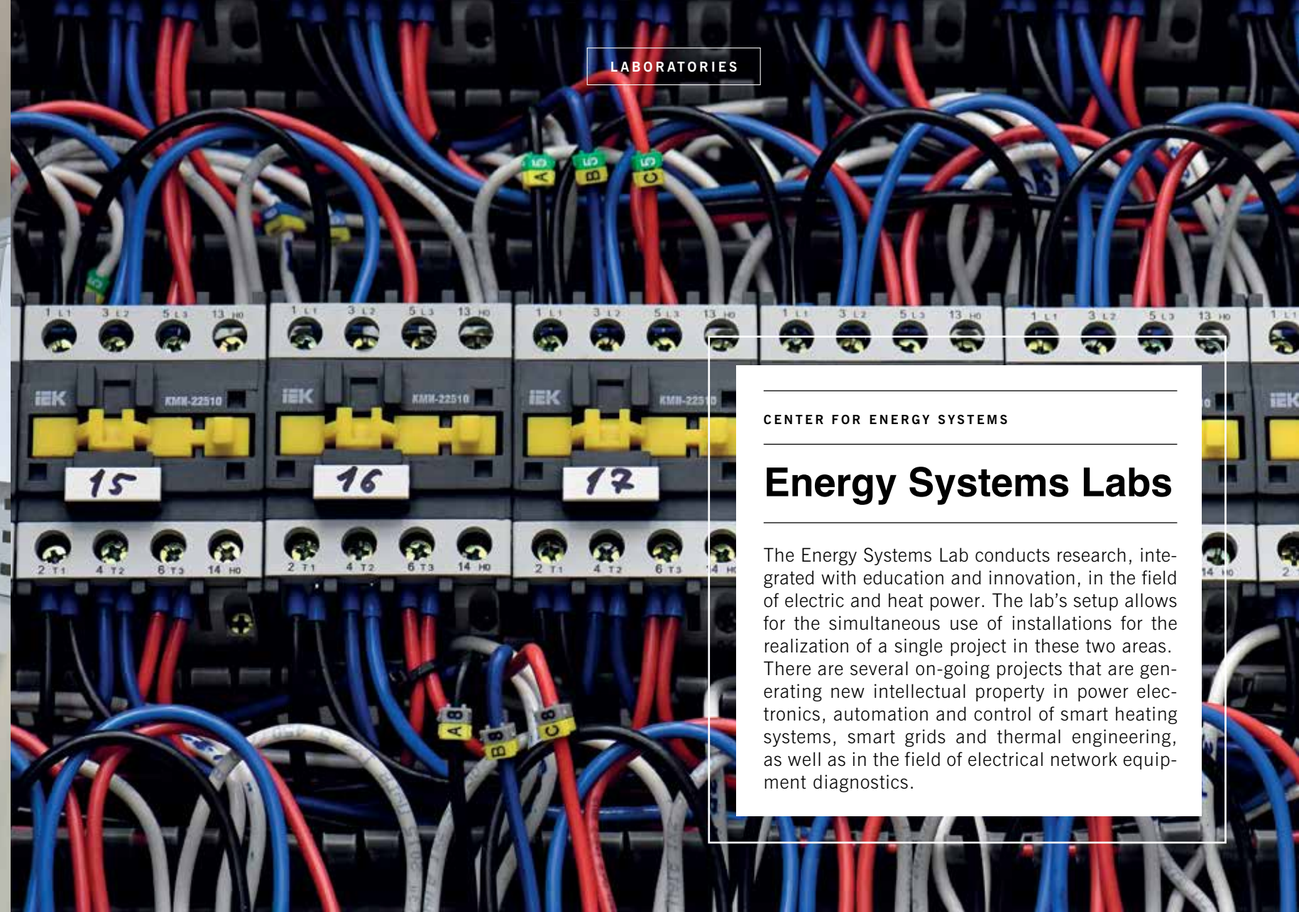
SPACE CENTER

Laboratory for Mass Spectrometry

This lab aims to create new types of mass spectrometers and to pioneer cutting edge mass spectrometry research methods. It also conducts research aimed at contributing to medical research via the development of technologies of analyzing complex chemical and biochemical mixtures. In particular, this pertains to research in the fields of neurosurgery, gynecology, and pediatrics, pulmonology, and oncology, and in agriculture in studies of plants and seeds with the aim of finding high performance crops and combating disease. The lab also serves as the site of the joint Skoltech-MIT Next Generation project aimed at creating a mass spectrometer for use in space exploration, as well as for everyday life.







CENTER FOR ENERGY SYSTEMS

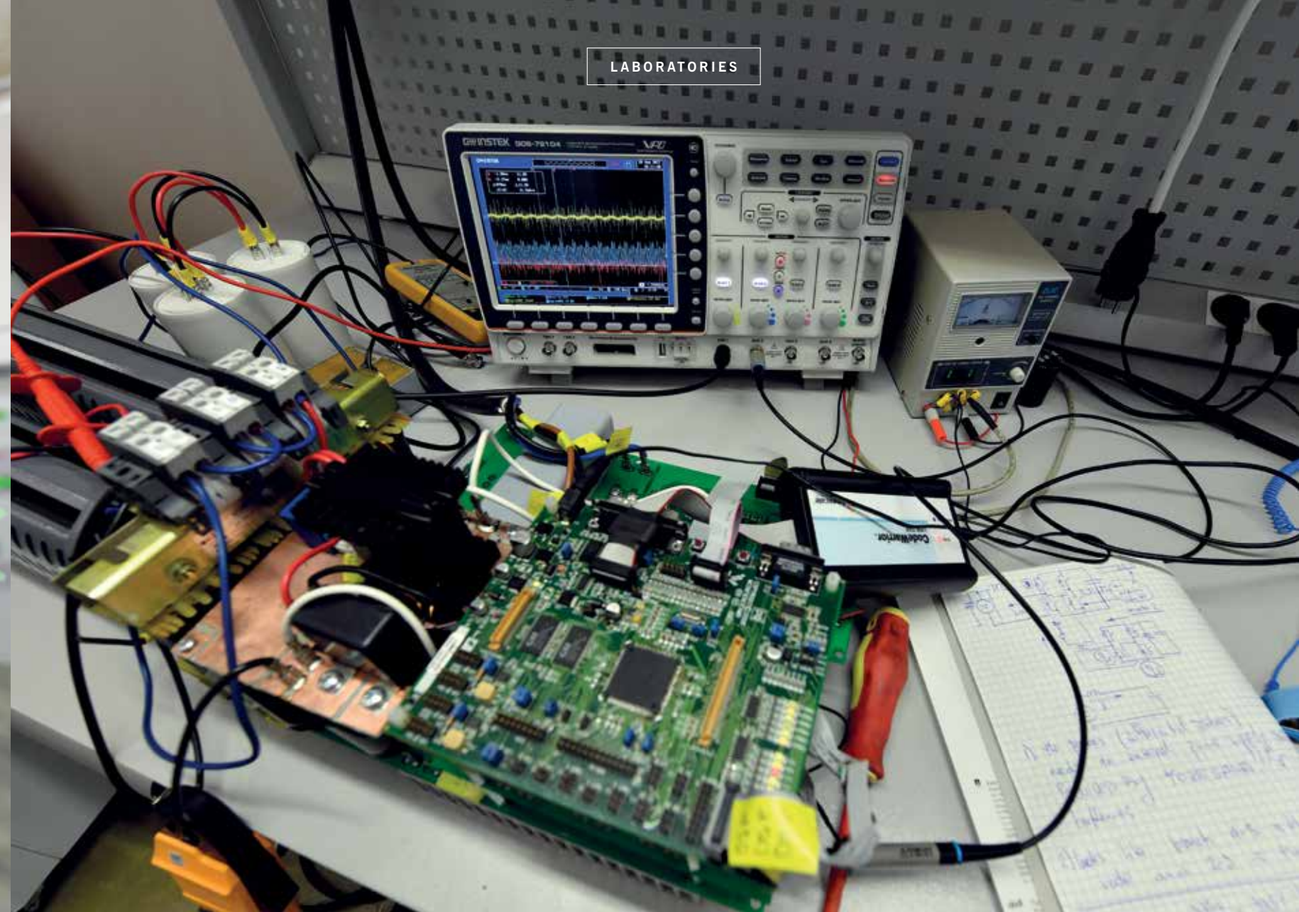
Energy Systems Labs

The Energy Systems Lab conducts research, integrated with education and innovation, in the field of electric and heat power. The lab's setup allows for the simultaneous use of installations for the realization of a single project in these two areas. There are several on-going projects that are generating new intellectual property in power electronics, automation and control of smart heating systems, smart grids and thermal engineering, as well as in the field of electrical network equipment diagnostics.

184

Center for Energy Systems Lab
Smart Grid

Установка «Интеллектуальная сеть» лаборатории Центра по энергетическим системам



CENTER FOR PHOTONICS & QUANTUM MATERIALS

Nanomaterials Lab

The Nanomaterials Laboratory conducts research in the field of synthesis of single-walled carbon nanotubes, two-dimensional nanomaterials and nanowires of metal oxides, as well as their applications in such fields as transparent and flexible electronics, photovoltaics, gas sensors, photonics, biotechnology, etc. The scientific group offers a unique environment for interdisciplinary research, has a reputation as a reliable partner in the field of high-tech research, and is among the best laboratories in the world.

#EXCELLENTEDUCATION
#MASTERSPROGRAM
#PHDPROGRAM
#STUDYABROAD
#STUDENTLIFE
#MASTERSKAYA
#UNIVERSITY24/7

excellent education

#2

Iskander Akhatov:

//One can design an entire engine and test it using its virtual digital prototype//

The Director of the Skoltech Center for Design, Manufacturing, and Materials and Head of the Advanced and Digital Engineering Technologies MSc program tells us about the fundamental objectives of materials science.

Materials science is a broad concept. If anything, it's probably not a science so much as the application of various sciences: mechanics, physics, chemistry, and mathematics. Our center is devoted to the study of the physical and mechanical properties of materials in large-scale engineering structures. There are two fundamental problems faced by the industry that are important in terms of the application of physics and mechanics to materials science, both being the subject of research of the Micro- and Nano-Mechanics laboratory in our center. The first is the problem of prediction of mechanical properties of composite materials. When a composite material is formed, a porous matrix of bundles of fibers is saturated with a resin, which is polymerized as it cools leaving a lot of voids, or pores in it. This porosity, ultimately, affects mechanical characteristics of the engineering structure. The physics of the formation of these pores has not been fully understood. Therefore, it remains unclear how to deal with them.

This fundamental problem can only be solved by interdisciplinary research that spans mechanics, physics, computational and applied mathematics. When engineering structures are made of composite materials, one needs to know their final mechanical characteristics. We can't build an air-

If you only rely on mechanical testing, you will test it, break it, make it, and test it again

plane wing or a part for a car if we don't know what loads they will be able to handle. Therefore, porosity is an important fundamental problem that needs to be addressed. It is important to understand where it comes from and find ways to eliminate or minimize its effect.

The second problem is observed in spraying or coating processes of additive manufacturing. Usually a spray gun is used to coat a solid object by spraying an aerosol and coating the surface. Small droplets, when hit a solid object, are not always arranged evenly on the surface and, when cooled, form an uneven, porous object. Again, the porosity has a significant impact on the protective properties of the film coating and its durability. To understand how to avoid heterogeneity, make the coating durable and imbue it with the necessary properties, one needs to understand the physics of the process of individual drops hitting the solid object.

THE APPLIED ASPECTS OF MATERIALS SCIENCE

Our center has three progressive laboratories. The first is a Composite Materials and Structures laboratory where we develop and study new manufacturing processes for creating composite materials and objects from them. For example, if you want to build a bridge, you can use cast iron profiles or composite materials. They can be made using a special method – pultrusion – and they will be stronger than steel.

Our second laboratory is devoted to the study of additive technologies. The majority of our work is linked to 3D printing using different materials. Polymers are the simplest of all as they are easily melted down and can be pulled. Metal is a more complex material because it requires a laser beam to melt it down. Ceramics are the next most difficult material. They are one of our most promising areas of focus.

Our third laboratory is the Information Technologies for Advanced Manufacturing lab. We study product lifecycle management (PLM). PLM involves virtually calculating the properties and predicting the behavior of a product before it is released. For example, you can design an entire engine and test it virtually. This approach drastically reduces the time spent on manufacturing new objects.

If you want to manufacture a car and only opt for mechanical testing, you will test it, break it, make it, and test it again. But with PLM technology, you can conduct initial tests on a computer and then go on to make a final sample. PLM is widely used in the aerospace industry, where experiments are extremely expensive. We are now trying to build a laboratory so that Skoltech can become a springboard for launching this technology into Russian industry.

Other applied laboratories closely cooperate with PLM: whatever data on the properties of materials we obtain is entered into the PLM database, which collects this information for use in subsequent designs. This is really a step into the future. This is what is happening all over the world.

In 2016, we put together our very first group of 17 students. In 2017, we only plan to accept about 20. After all, we are not tasked with making a large-scale course.

FARDAD AZARMI
PROFESSOR AT THE SKOLTECH CENTER FOR DESIGN, MANUFACTURING AND MATERIALS

The Advanced and Digital Engineering Technologies Master's program was established with a focus on the development and implementation of new simulation-driven design and manufacturing paradigms for the development of advanced materials, structures, and engineering systems with the enhanced lifecycle, mechanical and physical characteristics demanded in high-tech industries.

The Advanced and Digital Engineering Technologies Master's program
This program attracts students with fundamental knowledge in the fields of mathematics, physics, and engineering. The comprehensive curriculum includes courses in Simulation-driven (digital) Product Development, Product Life-Cycle Management (PLM), Advanced Manufacturing Processes, Composite and Nanocomposite Materials, Additive and Thermal Spray Technologies, Industrial Robotics, Mechanics, Micromechanics, and Physics of Advanced Manufacturing, Numerical and Optimization Methods in Engineering and Science, which provide an integrated scientific, technological and business perspectives of the high-tech sector. Throughout the program students also have a chance to conduct under the guidance of professors.

Ildar Gabitov:

//Biophotonics aims to study the building blocks of all living systems and extend human life//

Professor of the Master's program at Skoltech Center for Photonics and Quantum Materials Ildar Gabitov tells us about targeted drug delivery, and the future of Skoltech graduates.

Our center's area of research lies at the intersection of two key areas of science and technology – photonics and quantum materials. When we were putting together the MSc program, we combined courses on light-matter interaction with those on the key properties of quantum materials.

The basic knowledge delivered in the Photonics and Quantum Materials course includes light-matter interaction, and generating, detecting and controlling light. New materials are currently gaining particular importance in the quest for solutions to these problems. In classical optics, the main optical elements are lenses and mirrors made from materials with a high degree of uniformity. Modifying the surface of optical elements significantly affects their optical properties. This is seen, for example, in thin-film antireflective lens coatings. Modern technologies have taken great strides and make it possible to produce structured materials with unique optical properties. Elementary structures can be much smaller than the wavelength of light. In many cases, these materials' properties are determined by quantum effects.

Alongside basic research, our center works with problems with practical

application. These include compact light modulators, flexible displays, flexible optoelectronic elements, and efficient light sources. We also plan to include courses that provide MSc students with basic knowledge in the field of biophotonics.

BIOPHOTONICS

Biophotonics is a rapidly developing area of science that aims to study the building blocks of living systems and prolong and improve the quality of human life. One of the key areas of study within biophotonics is targeted drug delivery. Most medicines affect the entire body. Targeted delivery methods make it possible to ensure medication is directed to the necessary organ and its therapeutic properties are activated as needed.

Plasmon-enhanced therapy, which is designed to diagnose and treat tumors, is another promising area. With this approach, metallic nanoparticles enclosed in a layer of surfactants are delivered and selectively attached to the affected tissue. The metallic nanoparticle is heated to a high temperature using electromagnetic radiation, thus exciting the electrons. Localized heating can be used to both destroy tumor cells and effectively view affected tissues using ultrasonic diagnostics. Similar methods of plasmon resonance are used in high-sensitivity sensors that detect chemical and medical substances, and pathogenic agents. These are priority areas within biophotonics research.

INNOVATIVE SPECIALISTS

Highly-skilled specialists working in theory, computer modeling, experimental research and technology are all needed to further the advancement of photonics and quantum materials.

The subjects of study, methodologies and the tools needed for experimental research are becoming increasingly complex driven by the need for modern highly efficient functional devices. The increasing complexity of application-oriented problems pushes forward the development of new theoretical foundations. These advancements are impossible without computer modeling. Together, these factors create a considerable demand for specialists working in this field. They should deeply comprehend the physics of the processes observed in the experiment and master mathematical modeling methods.

What's more, technological methods and techniques are also becoming increasingly complex. For example, the subjects of modern research often have complex structures and are typically less than 100 nanometers in diameter. Creating these samples and working with them requires specialists with experience and skills in working at the molecular and atomic level, and the ability to construct objects from nanoscale components. In turn, this calls for the ability to work in controlled environments.

Working with the latest, cutting-edge experimental facilities, which with each new generation are increasingly complex, requires a knowledge base that not only encompasses engineering but also fundamental knowledge in the fields of physics, chemistry, biophysics and beyond. Specialists should have a strong grasp of all stages of the research process: the production techniques used to make research subjects, experimental analysis, and theoretical models.

THE FUTURE OF SKOLTECH GRADUATES

Our center at Skoltech boasts two first-class, well-equipped laboratories. Two further laboratories will open in early 2018 after we move to the new campus.

After graduating, Skoltech students have a wealth of choices, including: undertake further postgraduate study, work in industry or go into business. Postgraduate study can be pursued both at Skoltech and other educational institutions. Skoltech offers an industry-based summer internship designed to further students' skills and experience of working in industry. What's more, a program is being developed that will see students being trained, gaining work experience at IPG Photonics, and undertaking practical work at RTI Systems. We are looking to work with Russian Space Systems, state corporations, and large- and medium-sized companies. Furthermore, the Skoltech educational program will offer courses that prepare students to start their own businesses.

The Photonics and Quantum Materials Master's Program

This master's program aims to provide fundamental knowledge and experience with experimental research in the fields of modern electronics and optoelectronics. The program is run jointly with the Moscow Institute of Physics and Technology at the Institute of Spectroscopy of the Russian Academy of Sciences (RAS) and the Institute of Solid State Physics RAS.

PAVLOS LAGOUDAKIS
DIRECTOR OF THE HYBRID PHOTONICS LAB, SKOLTECH PROFESSSOR

The Advanced Photonics course will guide the students through a series of exercises that will demonstrate key experimental techniques, and illustrate basic principles of experimental laser science. The student will undertake a number of experiments during the 12-week course working on each experiment for 3 x 3 hour sessions in the lab, then analyzing their results and making sense of the underlying physics. In parallel with these activities, each student will write a short dissertation on one of a number of key topics in the field of laser physics. This course will be of particular interest to those contemplating a career in the area of optoelectronics, photonics or quantum engineering.

“Over the past few years much of what I’ve done is put out fires in science”

Mikhail Gelfand:

//High evolutionary biology is the science that attempts to explain how exactly things turned out like this//

The Director of Skoltech’s Biotechnology program talks about what’s in store at Skoltech for students entering molecular biology and genomics.

The first significant difference between our master’s degree program and those of other Russian universities is that it’s a master’s without a bachelor’s program. For that reason, we don’t have the typical situation in Russian universities where a master’s program is practically made up of in-house graduates. We recruit strong master’s students from other universities. We don’t have any administrative restrictions, so we can take on students who have completed specialized or master’s degrees at other universities but also want to enter our master’s program.

As for our second feature, I’ll put modesty aside for a moment and say that it’s the level of academia. There are strong biological faculties with world-class professors in several Russian universities, but if you look at the concentration, I’d say that Skoltech is the strongest.

The third is the very high level of freedom in choosing what is now known as an educational trajectory. We have few compulsory courses and quite a lot of elective courses. You can take courses in different Skoltech departments: if a student is interested in bioinformatics, they can take a course on data analysis in the corresponding school.

I'll put modesty aside for a moment and say that one of our features is the high level of academia

We have a compulsory summer industrial training program with biotechnological, pharmaceutical, agronomical and medicinal companies that are involved in molecular biology. Some of these internships are done abroad, for example, in Israel, at Israeli companies and Tel Aviv University, in industrial divisions as well. This training program is not a formality; students do indeed study to work in the industrial sector. Academic careers are structured like a pyramid: fewer and fewer people pass onto each ascending level. And that's normal – not everyone dreams of an academic career. In this case, coherent industrial training is very useful for those who are eyeing careers in companies.

Second-year Skoltech MSc students have the opportunity to do an internship at an international university for several months.

If a student's academic advisor has scientific contacts abroad – and most of us do – the student may very well work in a laboratory in the West. While this sort of opportunity may be commonplace for PhD students, Skoltech offers MSc students the chance to take advantage of such opportunities, and at no extra charge: everything is done with university funding.

I lead two courses at Skoltech. The first is called "Introduction to Bioinformatics." It's compulsory for everyone because it's impossible to work with modern molecular biology and genomics without using the methods of experimental data analisys.

My second course is "Comparative Genomics," which is elective and covers more complex evolutionary topics. From this year on, it will be a joint course between Skoltech and the computer science faculty of the Higher School of Economics (HSE); students from both universities can attend. We have two joint courses with HSE: for the third term there's Georgii Bazykin's course, "Evolutionary biology," and for the fourth, my course, which continues the topic. This is high evolutionary biology, the most interesting part of bioinformatics: it's science that attempts to explain how exactly things turned out like this. We expect that these experimental courses taught jointly with HSE will attract groups of both biologists and mathematicians. And when they begin to interact, it's very interesting to watch. The joint courses with HSE have an interesting background. For a while, the Yandex School of Data Analysis had a bioinformatics department, that I started. Then Yandex decided that they didn't need it, and it turned into an independent bioinformatics night school. It had no formal status, but we led students approximately at the level of the Skoltech master's program. The data analysis field in biology and medicine at HSE still largely follows that school's program. So, the bioinformatics school's initial intakes attracted people with mathematical and computer backgrounds, and biologists. However, the biologists weren't looking to switch professions and become bioinformaticians; they wanted to learn bioinformatics to improve their work in biology. They had the feeling it would come in handy. They organized seminars independently of the teachers, during which they explained to one another what they didn't understand: biologists told programmers about biochemistry, and the programmers told biologists about PYTHON and dynamic optimization. These people still talk, and one of them, Sergey Shmakov is about to get a PhD degree at Skoltech.

At Skoltech, that kind of close cooperation between IT and biologists has not yet been achieved, but I think that it will gradually appear here as well. Skoltech has a strong IT department and what's more, they have previous work experience with biologists, including joint scientific articles.

There's already a student in our program, Ekaterina Kondratyeva, whose scientific advisor is from the IT Center: Professor Alexander Bernstein. It's clear that these links will develop; all the necessary components are there.

The Biotechnology Master's Program

This two-year educational course includes courses in molecular and cellular biology, as well as bioinformatics courses and courses on mathematical modeling in biology. Exploring classic and modern approaches, students conduct research in the fields of biomedicine and biotechnology using methods of bioinformatics and computer biology. The Biotechnology Program invites not only applicants with bachelor's degrees in biology and chemistry but also those with degrees in physics, specialists in the field of IT and data analysis, and graduates from medical and agricultural universities. Biotech students collaborate with various relevant companies. Understanding how a biomedical business works helps students not only to choose a more successful career path, but also to become a more effective researcher.

Konstantin Severinov

//Biology needs sharp minds, computers and, after everything else, labs//

The Director of the Skoltech Center for Data-Intensive Biomedicine and Biotechnology talks about how to become an advanced biologist without test tubes and Petri dishes.

The Skoltech PhD program in the field of life sciences lasts four years. It is certified and accredited by all Russian state standards and is, essentially, a postgraduate program in the biological sciences and their realization in molecular biology, bioinformatics, and biotechnology.

We offer everything in standard Russian postgraduate courses, including a philosophy exam. It's not for me to say if that's good or bad. But, at the same time, our program is taught in English and we have quite a decent standard of material support for students – simply put, a stipend.

There's one factor that makes our program exceptional: we have the only biotechnology program in the whole world without a laboratory. On the one hand, it's not all that convenient, but on the other, there is a strong level of support and top-class professors, many of whom are world famous. This enables our graduate students to go on lengthy internships, from one to three years, in the best labs in the world at universities in the United States, Europe and Japan. In some instances, students do projects at Russian laboratories, as Russia also has very good laboratories. So, on the whole, this is a unique opportunity.

ON INTERNATIONAL INTEGRATION

With this arrangement and proper guidance — many of our professors

provide very competent guidance — students can quickly become important integral parts of the global scientific community. They have two scientific advisors: at Skoltech and at the laboratory where the joint project is carried out. This approach makes it possible for our graduates' work to become a fundamental part of scientific cooperation between two groups or even between two universities. That's a really good thing.

We have special funds that make it possible to send graduate students to scientific conferences. We make sure that our people only go to the most recognized, major world conferences, and that they speak at them. This is extremely valuable experience. In short, people who decide to enter our program will be in no less of a position than their peers at the best universities in the United States and Europe, in terms of both the learning environment and the level of the scientific tasks they solve.

Our graduate students are completely integrated into the international system precisely because many of them spend substantial periods of time abroad. Our students write their theses in English, and they defend them in English as well. But we insist that in addition to the Skoltech degree, the PhD, they also obtain the corresponding degree at Russian universities, having written their thesis in Russian. We don't have an academic council, but we do have a committee with at least two international specialists in the field of the thesis defense. This is the standard for all international defenses.

We strive to attract and incorporate everything that is rational in Western scientific practice in preparing graduate students in biology, without forgetting Russian characteristics, such as the course in philosophy and thesis defense in Russian. Also, our graduate students must work as teaching assistants for professors: that's how we've transformed the teaching practice requirements of the Russian Federal State Education Standard. This means, in our case, that every graduate student accompanies at least one of our professor's courses and assists them in lectures and seminars.

People who decide to enter our program will be in no less of a position than their peers at the best universities in the United States and Europe

We have fairly strict requirements regarding whom we allow to go on to thesis defense. We devised these requirements ourselves, and they are more serious than the requirements of a Russian postgraduate degree or review board. In order to finish in four years and obtain a Skoltech PhD, students must have no less than two scientific articles in scientific journals and feature as the first author of a minimum of one article.

Our program is young and very small, currently consisting of about 50 PhD students and 15 professors. Nevertheless, according to the Nature Publishing Group index, Skoltech occupies the third place in Russia when it comes to publications in life sciences journals. In this respect, we trail after such giants as the Russian Academy of Sciences and Moscow State University, which have hundreds or even thousands of experts conducting research in this area. Our PhD students are co-authors of most of those articles. So, it seems to me that we are doing well.

ON THE NEW LABORATORY

We should get a biology lab in the near future. I'm often asked how it's going to look. But you could just as easily ask a Catholic or Orthodox priest to describe heaven for you. Given that no one's been there and no one's come back, no one knows what it's like. We hope it'll be wonderful, and I'm prepared to believe that, but I don't have the imagination to picture how exactly it will look. I'm hoping it will be stunning.

Our program is largely focused on bioinformatics research, and bioinformatics doesn't really need laboratories; it needs computers and sharp minds. Due to infrastructure problems, Russian biologists are very strong in bioinformatics. So here we tap into the natural force of Russian science.

The Skoltech PhD program in Life Sciences

This program lasts four years. Students carry out research under the guidance of Skoltech professors from the Center for Systems Biology and Translational Medicine and can defend their theses in molecular biology, biotechnology and bioinformatics. Students have the opportunity to attend the lectures of leading Skoltech professors, selecting courses that are the most relevant to their scientific work. Apart from courses in the chosen specialization, there are also compulsory courses in scientific history and methodology, entrepreneurship, and pedagogy. Each student studies following an individual plan that is worked out together with their scientific advisor and approved by an individual committee, consisting of well-known scientists from Skoltech and other Russian and international universities.

Andriy Zhugaevich:

//The global focus of materials science has shifted to the nano scale//

An associate professor at the Skoltech Center for Electrochemical Energy Storage explains what exactly modern materials science is and talks about the program's star-studded teaching staff.

We launched our educational program in materials science in 2014. Though it was one of Skoltech's earliest programs, I would say that this year, 2017, is the first time it has stood on its own, independent of the institute's other programs. This year, we recruited around 20 students. The program's main distinction is its cutting-edge status. As a field of study, materials science is relatively widespread in the former Soviet space, but the form it's taught in has long become obsolete. Usually, if you ask the average person what materials science is, they'll tell you that it's science related to the sort of material tables, chairs, engineering structures or bridges are made of. But as a matter of fact, the global focus of materials science has shifted to the nano scale, and to relatively complex structural materials of all scales, from the atomic to the macroscopic.

Skoltech's Center for Design, Manufacturing and Materials (CDMM) works with higher scales, while our program focuses on the properties of materials at atomic scales. We study the modern materials that electronic devices for energy conversion and storage are made of, which are evidently lacking in Russia due to technological limita-

We prepare our graduates to begin work in research and development for any company that develops materials

tions. We export raw materials and ship these materials to Russia, but we would like to see them produced here.

We work with lecturers from three CREIs: the Center for Electrochemical Energy Storage (CEES), the Center for Photonics and Quantum Materials (CPQM) and the CDMM. Also, Professor Artem Oganov from the International Union of Crystallography has a large individual group. We have 10–12 lecturers in total. Each lecturer actively conducts work in fields related to materials science, and their activity is confirmed by a high Hirsch index. Each of our lecturer's average h-index is around 30. I don't think there are any other education programs in material science in the former Soviet Union taught by lecturers with such high figures in this respect.

Our center's electrochemical laboratories were launched at the end of 2016, so we have been able to recruit a record number of students. We also have experimental laboratories and processing power; students can carry out experiments, combining theory and practice. The laboratories have state-of-the-art equipment for materials research, including equipment that can be used to fully analyze and test rechargeable batteries and power sources, and produce laboratory prototypes of these devices.

Our program provides students with the fundamentals of materials science and hands-on experience. Materials science is a very broad field of study, which is why the specifics depend on the course. Students can study materials for energy conversion and storage, materials for optoelectronics, materials for photonics or structural materials (the CDMM deals more with this). We prepare our graduates to continue their higher education at any global university in a course related to materials science, or begin work in research and development for any company that develops materials or materials chemistry, including Mitsubishi, Samsung, and more.

Projects carried out by students in our program have included research of amorphous silicon-based solar panels, research of carbon nanotubes for super compositors, the development of cathodes for rechargeable batteries and predictions of small magnetic materials. There are diverse topics, and they are not merely abstract studies; they're linked to specific development projects carried out in our centers. Our instruction involves both theory and practice; it's difficult to separate the two in modern science.

The country is in great need of specialists in materials science. That's why we naturally wanted our first graduates to stay on at Skoltech. Most related studies all over the world are carried out not by famous scientists, but by students, postgrads and postdocs. That's the system we want to introduce in Russia. And we are extremely pleased that when we asked our best students to stay on at Skoltech, they agreed.

KEITH STEVENSON
DIRECTOR OF CENTER FOR ELECTROCHEMICAL ENERGY STORAGE AND CENTER FOR ENERGY SYSTEMS. ASSOCIATE PROVOST, DEAN OF RESEARCH

Our MSc and PhD Materials Science educational program is an interdisciplinary one that builds upon several core and elective courses taught by faculty members of the CREIs in Electrochemical Energy Storage, Photonics and Quantum Materials, and Design, Manufacturing and Materials. In addition to the specialized expertise, the program delivers a focused mix of both experimental and computational materials science electives that are unique for universities in Russia and beyond. Other elements of the program involve industry immersion and the entrepreneurship and innovation components.

MSc and PhD Program in Materials Science
Skoltech's program in Materials Science provides knowledge and skills in the development of new materials and devices for various applications, with a focus on those that are in high societal demand, such as renewable energy, consumer electronics and healthcare. The program includes both core courses that teach the basics of the subject and advanced courses taught by leading specialists in the field. The education is project-based, starting from the very first course, giving practical knowledge and allowing students to be engaged in state of the art research and development during the entire period of study. Our students can find jobs in research and development centers, innovation-intensive companies in such sectors as electronics, energy, the chemical industry, the automotive industry and other sectors that rely upon the development and use of advanced or complex materials.

Anton Ivanov:

//New commercial space programs are entering orbit//

The Acting Director of the Skoltech Space Center talks about how the changing information environment affects the learning process.

I really like the intensity of education at Skoltech compared to standard European universities, where courses are usually spread out in academic semesters. Intensive coursework with substantial student involvement makes it possible to focus more on the material: you just have to assign more tightly-packed material. Plus, at the beginning of the semester, there's an innovation workshop that rallies everyone and points students in the direction they're going to work towards in the following months and years.

Our main challenge is competing with modern technology. Nowadays, when students need to learn something, they just go on YouTube and watch a video. We used to buy books, read them, reflect about them… but now, if I need to do something in Photoshop, I find myself watching a video; it's quick and effective. In our field, an extensive series of Massive Open Online Courses [MOOCs] already exists on edX, Coursera, and several other platforms. My students say: "Anton, of course we understand there is a system, but we can still just look things up on Wikipedia." The Internet, the courses available, the huge amount of content – all of this is changing our lives. The lecture format also needs to change; at present, I go out and talk for two hours, with minimal interactive learning. But holding the attention of a modern lecture hall even for just 45 minutes is not that easy. Our main goal is to adapt courses to modern life and organize material in

such a way that it takes new forms of information consumption into account.

Skoltech can compare notes with École Polytechnique Fédérale de Lausanne; they have professional development courses for teachers. The structure of education will change soon; there will be no more large lectures. Of course, basic material will stay the same; Newton's law still stands. But we need a new form of presentation. How it is going to look? Will we have seminars or interactive learning? These are the biggest questions for me as the new director of an education program. The main thing is, we do have the resources to change that.

Given that MOOCs are in high demand, it would be a good idea to develop a number of similar Russian-language courses to reach out to Russian speakers. If people want to master certain subjects in Russian, they should have the opportunity to do so. At the moment, we have 653 students, but that number could reach 60,000 through online learning. The technology is already there: how to assign homework, how to offer feedback to students, and so on.

Engineering is one of the most difficult fields of space science. Here, you are not allowed any mistakes: after we launch a satellite, fixing it isn't an option. Our approach is based on a detailed elaboration of the project plan: we take into account the fact that the development cycle of the product or project is complex, that there's a testing cycle. We do our best to ensure that students are aware of the complexity of this process. When they say, "I'll do it in a week," we correct them and say that it won't take a week, but two months, minimum. Writing a code does take a week, but developing it, connecting it to other systems, developing interfaces, writing documentation, correcting errors – these things take time.

We want students to leave Skoltech with an understanding of their abilities, with an understanding of how much time the development of a complex engineering system takes. So that they use this systematic approach to build airplanes, helicopters and ships, namely, for work with any other complex system. Of course, we'll orient them towards businesses in the space industry and hope that there will be demand, but I think the graduates of our program would be useful in any field. There is a wonderful French word, *polytechnique*, polytechnic education, which involves applying your skills in different fields.

From the standpoint of building a scientific community, the world could learn something from Russian universities. Let's just say that we've worked a lot with Bauman Moscow State Technical University. It has a youth space center with an amazing atmosphere: students are excited to come after school to work on projects or just drink tea, go on field trips, set up a summer school. We are also going to work on creating a nice, warm atmosphere here, where students can feel at home.

Back in 2000, when I began working at the NASA Jet Propulsion Laboratory, I had a colleague. At the time, no one knew anything about 3D and he already had a display with glasses, and he showed us the flight of a satellite in 3D. I was stunned. In the decade and a half or so that has passed, that technology has gone mainstream. By the way, many engineers from his lab work at Disney now.

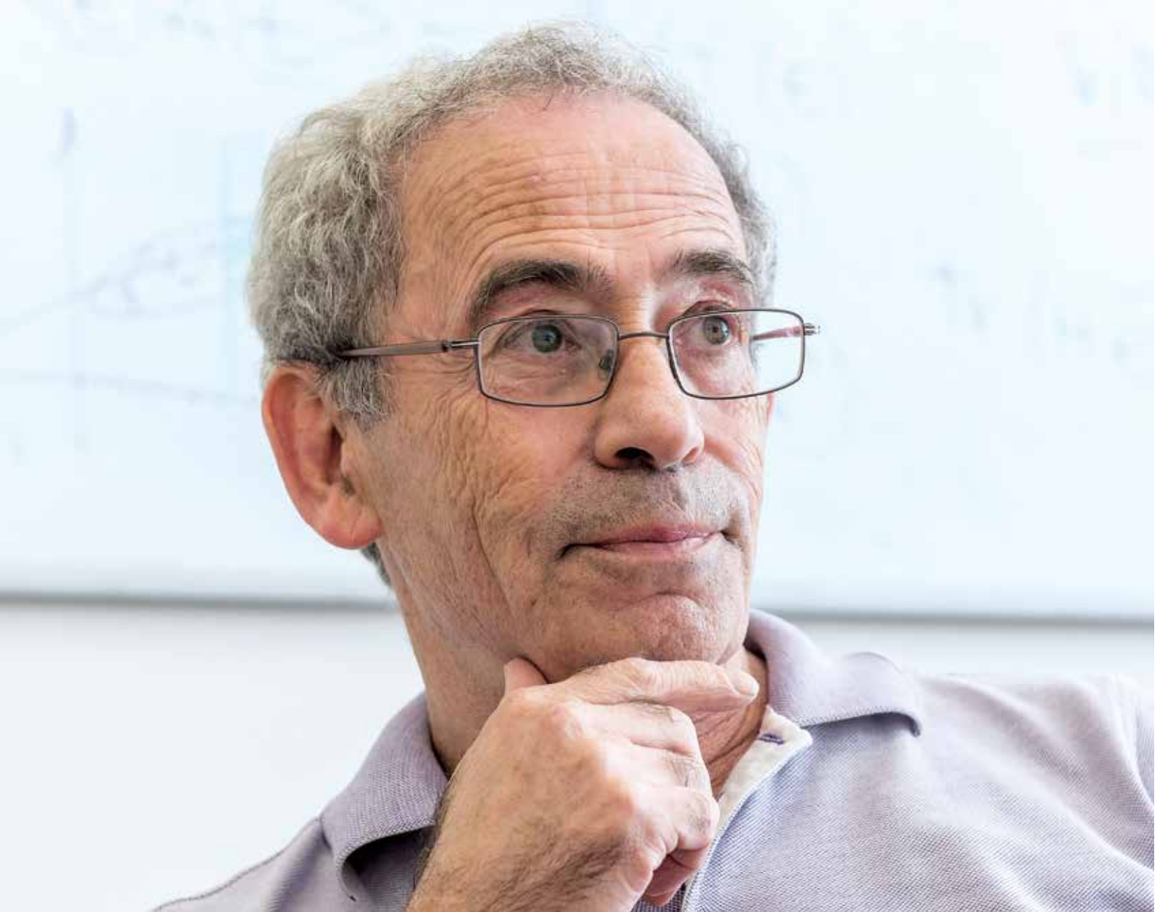
When my students start the course, I give them a list of must-see movies: *Apollo 13*, *Contact*, *Interstellar*, *Gravity* — the last one is good, but there are so many mistakes! I even gave students an assignment to make a list of everything that's wrong in *Gravity*. Science fiction is useful even for young scientists and entrepreneurs. Today, the structure of the space industry is rapidly changing, thanks to the advances of SpaceX and Elon Musk. New, commercial space programs are entering orbit. Skoltech has both the resources and the intellectual possibilities to develop and launch fantastic projects!

Space and Engineering Systems Master's Program

This program combines study of the general principles of complex engineering system construction with participation in satellite, drone and robotic systems-building projects. The main principles of education consist of a project-oriented approach and focus on interdisciplinary research at the nexus of engineering disciplines, including mechanics, electronics, mathematical modeling, and information technologies. Students in the program are actively involved in the creation of small satellites, from mission development to flight tests using CubeSat technology. Program graduates will possess fundamental knowledge in the field of system design and practical skills in the creation of complex systems. Upon graduation from Skoltech, they will be in great demand at the leading Russian and international industrial companies in the field of space technologies.

CLÉMENT FORTIN
DEAN OF FACULTY, SKOLTECH SPACE CENTER

We are at a turning point in higher education; the future belongs to institutions that will be able to blend well their learning modes. Skoltech is very well positioned for this as we have stood since the beginning on the principles of CDIO (Conceive-Develop-Implement-Operate), a worldwide initiative co-founded by our first president, Edward Crawley.
In the Space CREI, we are looking at developing complex systems in the most efficient way. And of course, the desire for close and deep space exploration will continue. These are phenomenal accomplishments for mankind, but we must never forget that complex systems can also be used to improve the lives of the men, women and children of the 21st century.



Igor Krichever:

//Mathematical physics classes demand twice the knowledge//

The director of the Skoltech Center for Advanced Studies and Head of the Mathematical and Theoretical Physics Master's program, tells us how to master both the language of physics and the language of mathematics.

Mathematical physics lies at the core of the MSc program run by the Skoltech Center for Advanced Studies. The modern understanding of what this term encompasses is very different from the original concept of mathematical physics.

MATHEMATICAL PHYSICS AS A FIELD OF SCIENCE

It is difficult to offer a brief and comprehensive definition of mathematical physics research. In fact, the propensity of the field to rapidly change and evolve makes it entirely impossible. Advancements in physics – particularly theoretical physics towards the end of the 20th century – required the use of unconventional areas of mathematics such as algebraic geometry, symplectic geometry, topology, and even category theory (one of possibly the most abstract branches of mathematics). Moreover, theoretical physics not only "employed" the latest mathematical theories – it introduced "physical intuition" and methods used in theoretical physics into many areas of pure mathematics.

This mutually beneficial cooperation led to rapid progress both in physics itself and in pure mathematics. Therefore, with some reservations, we can say that modern mathematical physics is a science that has emerged where physics and mathematics meet. This is where an interpenetrating and mutually fruitful synthesis of ideas occurs and new research methods of both physical and purely mathemati-

Bilingual people are usually raised in families where parents speak more than one language

cal theories are developed. Mathematical physics classes demand twice the knowledge and, what is perhaps even more difficult, fluency in two very different languages: those of mathematics and physics.

OUR EDUCATIONAL PROGRAM

It is well known that it is easier for children to pick up new languages and, most commonly, bilingual people are raised in families where parents speak different languages. Ten years ago, the Institute for Advanced Study at Princeton led an attempt to "teach mathematicians physics": they gathered a number of distinguished mathematicians who then attended lectures held by eminent physicists. They were then asked to solve problems. In my opinion, the greatest beneficiaries of this experiment were the graduate students and fresh new post-docs that also took part.

Our Mathematical Physics master's program is an attempt to create an environment where students simultaneously learn two languages from the very outset. As far as I know, this type of program isn't available abroad. In Russia, this type of program is offered by the Faculty of Mathematics of the Higher School of Economics (HSE). That said, the programs at Skoltech and HSE do not compete with each other. In fact, they complement each other. An agreement signed by Skoltech and the Higher School of Economics combines the programs and they are organized and run as a consolidated educational program.

PROSPECTS

A two-year master's program is too short to fully master the breadth of knowledge necessary to pursue mathematical physics and conduct comprehensive research. Therefore, our master's program forms the first stage of what would be understood as a PhD program in western universities, where the second stage involves postgraduate study. Not all students will want and manage to see the course through to the end. Therefore, Skoltech, with its multidisciplinary approach, is the ideal choice: offering graduates knowledge with clear, real application. Successful graduates of our master's program can be confident that they will obtain spots at our postgraduate school, but we also hope they will be sought after candidates at leading scientific centers abroad.

THE DISTINCTIVE FEATURES OF OUR PROGRAM

Our program is aimed first and foremost at giving researchers a grounding in mathematics and deep knowledge of mathematical physics. It also offers students the chance to pursue in-depth study of the fundamental models of modern theoretical physics. Students are expected to take part in research projects alongside eminent specialists, teachers, and foreign colleagues specially invited to participate. We are planning for a number of leading foreign scientists to fully participate in the educational process by supervising our students as well as holding series of lectures. The crux of our students' scientific career involves compulsory scientific seminars and mandatory attendance at summer and winter scientific schools.

The Mathematical and Theoretical Physics Master's Program

The key tenets of our Mathematical and Theoretical Physics educational program are compulsory scientific seminars (including student seminars) and a strong scientific community. Students study tailored, individual courses approved by their supervisors, who determine the range of selected courses depending on the specific area of the student's scientific study. We put emphasis on students' independent scientific study that encourages their rapid fundamental scientific (and thus career) growth. This has been proven by the extensive experience of our colleagues from the Institute for Theoretical and Experimental Physics, the Landau Institute for Theoretical Physics, the Independent University of Moscow, and the program's main partner — the Faculty of Mathematics at the Higher School of Economics. Our program produces students and graduate students with internationally recognized, top-level qualifications. The scientific world is their oyster: the doors of the world's leading mathematical physics centers are open to them.

MIKHAIL SKVORTSOV
ASSOCIATE PROFESSOR, DIRECTOR OF CENTER FOR PHOTONICS AND QUANTUM MATERIALS

Our consolidated Mathematical and Theoretical Physics educational program offers students the chance to solely study theoretical physics. Closely connected to experiments, theoretical physics involves identifying and employing mathematical models to explain the laws of observed physical phenomena. The aim behind the research undertaken by theoretical physicists is to reveal fundamental physical laws. When teaching theoretical physics, we aim to pursue in-depth studies of the fundamental properties of the condensed phase. This part of the program is run in conjunction with the Moscow Institute of Physics and Technology and the Landau Institute for Theoretical Physics.

Maxim Fedorov:

//Fundamental research in machine learning has set its sights on a new goal: multitasking//

The Head of the Computational Systems in Science and Technology and Data Sciences Master's programs, and Director of the Skoltech Center for Computational and Data-Intensive Science and Engineering Maxim Fedorov tells us about the current data science problems and next-generation universities.

Skoltech is a next-generation university. It is a new higher education model that combines innovation, science and education. It was originally founded as an innova-

Data Science Master's program
Our Data Science master's program is a two-year course combining both the study of the basic mathematical foundations of data analysis with new disciplines such as deep learning. The program's graduates will be able to develop automated methods for analyzing large data sets and apply them to find solutions to real practical problems. Our graduates will acquire knowledge of the basics and skills necessary in the application-oriented field, which will open up unique opportunities for them to use this knowledge to build scientific careers in machine learning and data analysis, start their own startup, or go on to be highly sought after as top specialists in leading IT, financial and telecommunications companies
Since new digital and data analysis technologies can now be found in almost all industries, Skoltech graduates are now finding themselves in high demand outside the conventional IT sphere in a wide range of sectors: Russian companies working in natural resource extraction and production actively seek out our Data Science graduates, for example.

tive university. Therefore, our center – a center of science, education and innovation – is also a new model. It is an attempt to face the challenges of the 21st century: the colossal stream of information that grows exponentially year upon year, the huge quantity of discoveries made at the intersection of various sciences, the rapid development of new digital technologies, etc. Our Centre is not a 'standard' applied mathematics or computer science department, but an interdisciplinary center of science, education and innovation. It is difficult for me to find its direct equivalents in other academic and research organisations. In some respects, it is an amalgam of the best we have gained from the classic Russian fundamental approach to natural sciences education and global experience in establishing innovative educational centers.

CURRENT DATA SCIENCE PROBLEMS

There are several principal areas within data science. One of them involves the ongoing search for new analytical and data processing methods and technologies. Key successes in this are linked to new machine learning technologies such as deep learning, a.k.a. deep structured learning or hierarchical learning. We already have a fairly wide range of tools that are successfully tailored to a number of specific tasks. For example: facial recognition technology. The issue of facial recognition, which until recently was considered difficult, has practically been solved. Now, computer programs have even begun to recognize faces better than humans especially in cases with large samples. What's more, they do not experience fatigue.

However, in general, they are programs that solve one task, albeit a very complex one. The same can be said about machines recently beating people at complex games such as Go and poker. It's important to understand that in each case the programs involved can only solve one task – winning a particular game. Fundamental research in machine learning has set its sights on a new goal: multitasking. So far, there is no universal program that can solve multiple, fundamentally different tasks like a human can. After all, humans play games, recognize faces, talk, etc. What's more, people can learn to solve new problems independently. This is one of the main challenges the science of artificial intelligence is currently tackling: creating programs that can multitask.

The search for new areas of application of the already available machine learning and data analysis technologies is another area gaining relevance. The analogy with electricity is a striking one. When it emerged and became accessible to the masses (i.e. a comprehensive infrastructure was created transmitting electricity far and wide), numerous inventions came about simply from the fact that any already-existing appliance could be made electric: mechanical meat grinders became electric, hand drills could be electric drills and so on. In some cases, there were peculiar failures due to technological shortcomings, but overall, electrification led to the creation of more effective tools.

The same changes are taking place in terms of applications in business. There are a lot of useful tools that use the latest advancements in data science, which can be tailored to suit a highly-specific task and can solve particular problems just as well as a person could – maybe even better. These applications are particularly effective at dealing with very large data sets that a person simply couldn't physically process. Methods facilitating the analysis of large and super-large data sets that quickly offer solutions in critical situations are a singular priority. For example, there have recently been very interesting developments in the real-time rapid analysis of large arrays of meteorological data with the aim of predicting hazardous meteorological phenomena (hurricanes, typhoons, floods, etc.) at a very early stage.

Machine learning applications in medicine for the early diagnosis of a range of fatal diseases are also undergoing rapid development. This is reducing the number of medical errors – as computers do not succumb to fatigue, stress and other human factors – and raising patients' quality of life.

Continuing on the biomedical theme, there is another promising area of application of note: using machine learning and supercomputer technologies to develop new medications. Various estimates suggest the number of different molecules that can be drug-like molecules may extend to an order of magnitude of 10^{23} to 10^{60}, ten orders of magnitude greater than the number of currently known molecules (10^{8}). Obviously, synthesizing all possible compounds and testing their properties is impossible even if we had billions of years to make it happen. This is where technologies at the intersection of supercomputer modeling and machine learning come to the rescue.

The idea is that huge numbers of previously unknown compounds are modeled on a supercomputer using programs that were previously instructed to find suitable candidates based on existing compounds. The virtual screening process identifies molecules likely to exhibit medicinal properties. This way, the effort required to

By now, computer programs have begun to recognize faces even better than humans – especially in cases involving large samples. What's more, they do not experience fatigue

We educate visionaries – those able to predict the course science and industry will take in the next 10-20-50 years and make justified decisions

discover new medications can be greatly reduced. It will even be possible to find new medications with improved properties: minimal side effects, extensive therapeutic properties, etc.

DATA ANALYSIS CENTERS WORLDWIDE

Supercomputing and data science are extremely popular: there are numerous groups engaged in their study worldwide. Institutions similar to ours include the Data Science Institute at Imperial College London, and the Edinburgh Parallel Computing Center. They both run very intensive educational programs in various areas, and master's and postgraduate programs that cover data analysis and supercomputing. The Jülich Supercomputing Centre in Germany combines supercomputing, Big Data, and data science. Postgraduate students from nearby universities are able to attend programs in these areas.

It goes without saying that MIT, Stanford, the University of California, Berkeley, and the research facilities at Google and Facebook play a crucial role worldwide. However, organizations dedicated exclusively to research lack a strong educational component. For example, the Max Planck Society in Germany is one of the world's best scientific organizations, with approximately 70 institutes. Some of them, such as the Institute of Informatics, are similar to our center in terms of structure and aims but they don't offer an educational track (you can't formally earn a PhD there for example). We have achieved a blend of educational and scientific components plus innovation. Similar approaches are currently being pursued in Singapore, South Korea and other countries.

Skoltech's model is also attractive in that it attempts to create leaders for the innovative technological sector who comprehend both the scientific and technical aspects, as well as being innovators with excellent leadership skills. The immense technological and cultural cornerstone that is Russian science is an undisputable advantage. We divide who we are standing alongside into two categories. On the one hand, we have long-standing

Machine learning applications in medicine for the early diagnosis of a range of fatal diseases are also undergoing rapid development. One of the applications is reducing the number of medical errors

Computational Systems in Science and Technology master's program

Our Computational Systems in Science and Technology master's program is a two-year course aimed at furthering students' knowledge and skills in developing and employing scientific computing algorithms for high-tech industrial applications. The curriculum includes the study of high-level engineering (high-performance computing, cutting-edge modeling software, etc.) with in-depth teaching of the fundamentals of computational science. The program's alumni enjoy a wide range of possibilities: participating in research projects, launching startups, or becoming sought-after specialists in the field of engineering design and modeling in aircraft construction, the oil and gas industry, telecommunications companies, and science-driven pharmacological or biotechnological companies.

establishments such as MIT, Stanford, UC Berkeley, Moscow State University, and the Moscow Institute of Physics and Technology, i.e. universities with a long and glorious history and established traditions. In terms of publications, fundamental developments, etc. we are their equals. On the other hand, we also compare ourselves to new establishments – new universities in Europe such as Jacobs University in Bremen, new universities in Southeast Asia, China, Singapore and the Arabian Peninsula such as the King Abdullah University of Science & Technology in Saudi Arabia. However, I'd like to reiterate that Skoltech's uniqueness lies in the fact that we are not going it alone: we are establishing a new university on a solid scientific foundation laid by our colleagues and ancestors.

SKOLTECH STUDENTS

We educate champions. Skoltech's aim is to educate the scientific and innovative elite. A successful Skoltech graduate possesses scientific and technological qualifications but has also been endowed with leadership, managerial and innovative skills. We educate visionaries — those able to predict the course science and industry will take in the next 10 to 20 to 50 years and make justified decisions on that basis, such as those related to which technologies should be invested in, which specialists are needed to find solutions to future technological problems, how to bring about a technological revamp in a certain field, etc.

By any standards we are a small university. Skoltech has no plans to become a largescale institute. It is our aim to train a select group of highly qualified specialists with a wide range of different skills. Basically, we educate department heads who may go on to become advisors to scientific and technological company heads. This is our main contingent and educational goal. We aim to educate future technological leaders for the leading economic sectors. It goes without saying that science is a top priority. The majority of our graduates stay on in science. Those who have already launched their scientific careers with us have already demonstrated excellent results.

ANDRZEJ CICHOCKI
SKOLTECH
PROFESSOR

CDISE's educational program strongly correlates with our cutting-edge research in the areas of artificial intelligence, machine learning (ML), and – especially, deep learning (DL). New techniques in the fields of AI and ML have enabled extraordinary progress in the application of tensor decomposition for dimensional reduction, especially when applied to the development of new practical Deep Neural Networks (DNN). This may lead to the development of new machines that will outperform humans in some difficult but still rather narrowly defined challenges, such as recognizing human faces and the early diagnosis of certain illnesses, like skin cancer or Alzheimer's disease. ML has dramatically improved in the past several years, but we are still quite far from reaching the level of human performance for broadly defined tasks. Often, machines still require the assistance of humans to complete specific tasks. We hope that after extensive coursework in ML and DL, our students will be equipped to develop a new generation of smart machines that will be useful for humanity, especially for a wide spectrum of biomedical applications.

Alexey Cheremisin:

//It’s normal for companies to select the best people and train them virtually from grade school//

The Associate Director for Experimental Research at the Skoltech Center for Hydrocarbon Recovery talks about the Petroleum Engineering program.

We created the Skoltech Center for Hydrocarbon Recovery in 2014. Our center’s mission is to train specialists and create world-class technology in the recovery of tight and unconventional hydrocarbon reserves, including new methods of oil recovery, heavy oil recovery, shale oil and arctic shelf hydrocarbons.

The Skoltech MSc program in petroleum engineering was developed by the leading Russian and international universities – global leaders in their research and academic fields. For example, a University of Calgary team under the direction of Professor Gordon Moore, who is the best in the world when it comes to thermal methods of enhanced oil recovery, developed block courses on modern methods in this field. Heriot-Watt University in Edinburgh created block courses on gas hydrates, methods of developing gas hydrate sediments and methods of combatting hydrate formation during hydrocarbon recovery and transportation. The leading Russian universities and scientific institutions were also involved: Bashkir State University, the Schmidt Institute of Physics of the Earth of the

Russian Academy of Sciences and the Trofimuk Institute of Petroleum Geology and Geophysics of the Siberian Branch of the Russian Academy of Sciences, among others. Our center's educational program absorbed the unparalleled experience of the leading groups and professors and institutes from Canada, the United Kingdom, the United States, continental Europe and Russia.

Our program also features the integration of scientific advances in various fields of knowledge. In fact, every student's course curriculum is formed individually, and they have the opportunity to obtain a vital set of skills, combining courses from our center and other Skoltech Centers for Research, Education and Innovation (CREIs).

We divided the program into two lines of study. One covers the exploration and development of tight and unconventional hydrocarbon reserves. Today, we need new specialists who are capable of conducting multidisciplinary studies and creating innovative technologies in the development of tight and unconventional reserves. The second line of study is modeling and data analysis in the oil and gas industry. This is a new field in the oil and gas industry, which is undergoing rapid development internationally. Specialist training is held jointly at the Skoltech Center for Computational and Data-Intensive Science and Engineering. Another feature of our program is that we don't have full-time professors. Professors come from all over the world to carry out research and are leaders in their fields. They teach courses and lead student research projects. Students have the opportunity to carry out part of their research in the world's most advanced laboratories under the academic mobility program. We are actively developing a student exchange program and double degree programs with international universities. For example, in 2016 we signed a student exchange agreement with IFP Énergies Nouvelles [IFPEN, formerly the French Institute of Petroleum]. English is the medium of instruction at Skoltech, and students are constantly immersed in an international environment. Our center's unique laboratory makes it possible for students to carry out research using the most cutting-edge equipment.

Most of our students' projects are carried out in cooperation with Russian oil and gas companies and service companies, as well as startups, Skolkovo Foundation residents, and other innovative centers in Russia.

In order to develop the program, we want to work with industry and attract leading specialists to lecture. This is imperative as students need to be ready to solve pressing industry problems. We are also engaged in active dialogue with Russian and international companies about so-called advanced training, when companies start preparing specialists several years in advance. Abroad, it's normal for companies to select the best people and train them in advance, virtually from grade school. Several companies in Russia do this, but not systematically.

Our students have a practical industrial training program, which involves work on a real-life project during summer break. Company specialists work alongside Skoltech professors to develop individual or group projects that students can complete in two months' time. Among the main requirements of our industrial training program is for students to complete a real-life project and defend the results before specialists and the industrial partner's executives.

In Russia in general, and in the oil and gas sector in particular, there are not enough small- and medium-sized businesses. One of Skoltech's tasks is to foster innovators capable of launching their own businesses or developing new areas in companies' R&D strategies.

Master of Science Program in Petroleum Engineering

The Skoltech master's degree program in the field of oil production is unique in that it prepares students using the latest research and technology, and their practical application in the oil and gas industry. The program also provides opportunities to develop vital skills in the fields of innovation, entrepreneurship, communication, and management. Students are given the opportunity to do internships in leading Russian oil and gas companies and at international universities. The program was developed in close cooperation with Russian oil and gas companies, Skoltech employees, and leading universities in Russia, continental Europe, the United States, Canada, and the United Kingdom to train graduates prepared for modern industry challenges. Students have the opportunity to carry out research in a world-class research laboratory using state-of-the-art equipment.

R. G. MOORE
PROFESSOR AT SKOLTECH AND UNIVERSITY OF CALGARY

Skoltech has assembled world-class EOR laboratory facilities which provide graduate students with opportunities to perform experiments on leading-edge equipment and to use this data as input to numerical simulation studies on a wide variety of recovery techniques. The Skoltech MSc program in Petroleum Engineering is unique in that it provides opportunities for the development of much-needed skills in innovation, entrepreneurship, communication, and leadership. It is complemented with an internship opportunity to gain work experience with an oil and gas company. The program is designed and delivered in direct collaboration with the Russian oil and gas industry as well as leading universities from Russia, Europe, the USA, Canada and the UK.

Michael Chertkov:

//I like our students. They're well rounded, highly educated and motivated to learn more//

The professor at Skoltech Center for Energy Systems tells how his students are planning the energy networks of the future.

You'd think Russia would have plenty of energy institutes that provide specialists for the energy industry. So, the question arises: why does Skoltech need this program? When we deal with energy at Skoltech, we're uniquely focused on research used in modern information technology. What's more, we don't limit ourselves to electricity; we also deal with heating, gas and energy networks as a whole.

Networks are a lot more than a particular facility or consumer. Draw all the power lines, gas and heating networks on a map of Russia and ask yourself, how to properly – that is, reliably and without interruption – manage these interdependent systems. Not only do these systems contain a million details; they are also subject to external influences and internal ambiguities. And with the introduction of new energy sources, storehouses and actively engaged consumers, who react to – for instance – prices and weather, interact with one another. In this context, expectations of uninterrupted management will only rise.

The aim of the Skoltech energy program is to foster a new generation of researchers who are prepared to respond to this complex challenge. Our students can generally be broken down into three categories based on their background. There are energy majors who come from the Moscow Power Engineering Institute, Bauman Moscow State Technical University, or the Gubkin Russian State University of Oil

and Gas, or who graduated from energy faculties in Novosibirsk, Irkutsk and Saint Petersburg. Our typical energy students are qualified engineers who, as yet, lack research know-how. The second category includes physics researchers who start out with a lack of expertise in energy systems. They tend to come from the Moscow Institute of Physics and Technology, Bauman Moscow State Technical University, Moscow and Novosibirsk State Universities, and Saint Petersburg Polytechnic University. Applied mathematicians trained in modern computer and computing technologies make up our third category of students.

Energy majors study programming, modeling and optimization at a far more profound level than they did as engineers. Physicists and applied mathematicians are taught engineering. As a result, all three types of students become well-rounded specialists, all the while retaining their own styles. Our research professors also, incidentally, come from different scientific backgrounds. For instance, I'm a physicist.

Network management, optimization, computer technologies, and machine learning combined with physics know-how – how electricity runs through wires, and gas and heating through pipes – all of these combined forms our unique specialization: smart networks. Nowhere in Russia does anyone teach this particular mix of subjects. This is a new specialization, even from a global perspective. The first course that I developed for Skoltech, Introduction to Electrical Networks, is aimed at mathematicians and physicists. Subsequently, I prepared a course in stochastic modeling and computing that combines topics from statistics, physics, computational science, and a mini course in graphic models. These are both general courses; students from across Skoltech attend them, not just energy majors.

As director of the energy program, I'm also in charge of planning new courses. In particular, I prepare a postgraduate course dedicated to the modeling, management, and planning of interdependent electrical, gas and heating systems, which is going to be absolutely unique – this is not yet taught anywhere else in the world.

All of our postgraduates take up practical industrial training and often continue research with our industrial partners in Novosibirsk, Moscow, St. Petersburg and Irkutsk. My graduate student Vladimir Frolov is a good example. His project is on planning the energy networks of the future about 20 years in advance. This is complex optimization, big computing, and smart algorithms. Vladimir is a physicist by training. He was accepted into the institute's first cohort, and during his five years here, he has emerged as an international leader in this line of research. He has published articles and continues to do so, and wrote a unique software package. He is invited to prestigious, specialized conferences. For instance, at the end of August he presented a specially selected paper at the IREP 2017 Symposium in Porto. The paper was very well received and prompted proposals for cooperation from our international industrial partners. That's just one example.

On the whole, I like what's going on at Skoltech. First and foremost, I like our students. They're well rounded, highly educated, and motivated to learn. It's exciting to be around them. I hope that in the next couple of years our students will lead public and private, applied and theoretical projects, along with teaching and carrying out research programs at Skoltech and at other Russian and global universities. Second, I like the multidisciplinary approach inherent to the Skoltech idea on the whole, and our Center for Energy Systems in particular. This has never happened in Russia; narrow specializations have always dominated. And there aren't all that many similar models worldwide: you can count small graduate schools focusing on the transition from fundamental to applied science on one hand.

JANUSZ BIALEK
SKOLTECH PROFESSOR, ASSOCIATE DIRECTOR OF THE CENTER FOR ENERGY SYSTEMS

Energy systems is an interdisciplinary field that combines knowledge of engineering (power, gas, heat/cooling networks and devices, control), mathematics (optimization, operation research), economics and many other areas. Consequently, the Skoltech educational program in energy systems draws from a number of disciplines to create a coherent program with two main flavors: one that is more mathematically oriented, and another that is more engineering oriented. We aim to educate well-rounded experts who understand both engineering and more formal mathematical aspects of designing and operating energy systems.

The Energy Systems Master's Program

This two-year course aims to ensure students' mastery of the disciplines and skills necessary for research activity in the field of planning and operational management of energy production, i.e. electrical, gas and heating, transmission and distribution systems, as well as the application of this expertise to knowledge-intensive industrial projects. The main concept of our program consists in combining modern theoretical and engineering disciplines, such as optimization, management, statistics, applied mathematics and physics, computational and information technologies, machine learning and data processing, with the applications of modern energy. The program aims to prepare specialists who will be scientific and technological leaders capable of developing and introducing new methods and technologies of power systems of the future.

Why did I choose Skoltech?

First-year students share their impressions

Konstantin Chukreyev

I want to go into science. Skoltech is the right place to be: here, you understand that a scientific career is possible. The professors are really motivational. Science is interesting! When you have the chance to do what you love – it's awesome. I'm interested in bioinformatics, data analysis, and machine learning. I really hope that I'll have my first successes in my two years here and can demonstrate my findings. Basically, I want to search for new algorithms, new methods and pursue data analysis in bioinformatics. This is all on-trend right now.

Anastasia Koloskova

I chose Skoltech's data science MSc program on the advice of my supervisor Maxim Panov and after hearing the feedback from current students. I then googled it and saw that the program offers great courses and the faculty is excellent. So I decided to apply. My parents were supportive of my choice.

Dmitry Fedoryaka

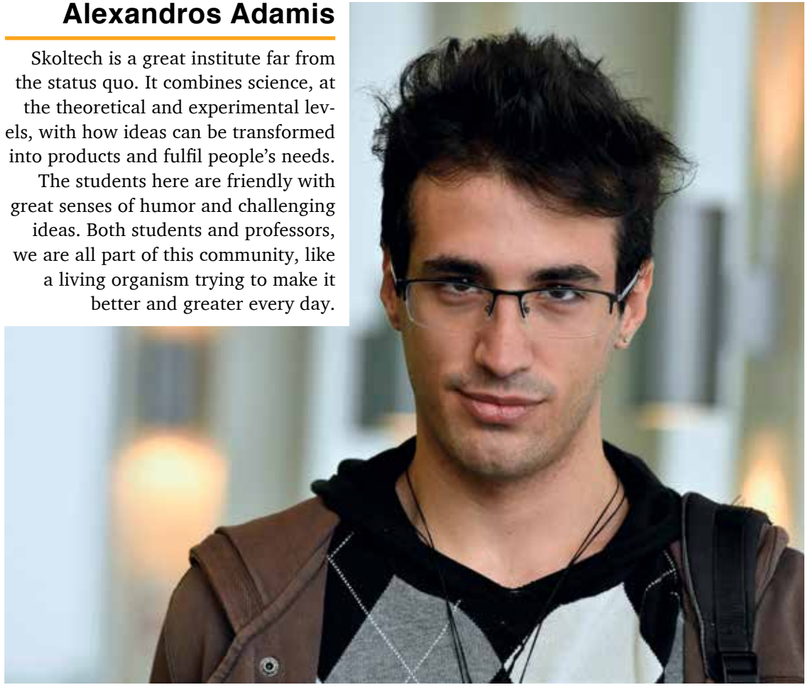
I really hope that the dream I've had since grade school will come true here: I always wanted to study artificial intelligence – deep neural networks, in particular. I know that Skoltech offers special courses on neural networks: I really want to work with professors like Victor Lempitsky and Evgeny Burnaev. At the interview I was amazed that they asked me straight up: Do you want to study deep neural networks? I knew then and there that I had to apply.

Artem Filatov

I decided to apply for the Master's degree in data science at Skoltech because it has the best professors in the field. I really want to attend Ivan Oseledets' course in numerical linear algebra and learn from Professor Vladimir Spokoiny. Skoltech offers excellent opportunities to study science, and write articles. The biggest plus is you are given a ton of scientific freedom.

Alexandros Adamis

Skoltech is a great institute far from the status quo. It combines science, at the theoretical and experimental levels, with how ideas can be transformed into products and fulfil people's needs. The students here are friendly with great senses of humor and challenging ideas. Both students and professors, we are all part of this community, like a living organism trying to make it better and greater every day.



Tinashe Prince Maviza

Skoltech has actually set the bar for me, as the environment has influenced me to view the world from a unique angle, which is, translating our scientific research and knowledge to help humanity, and this for sure completely resonates with my inner thoughts about the future. It's a rare asset to be in an atmosphere with great minds that allows one to connect and network with people who have the sole purpose of bringing change in our world.

Daria Shatko

At first, I wanted to apply to the Higher School of Economics but based on a friend's recommendation, I took interest in Skoltech, googled it and changed my mind. Firstly, I liked that all classes are in English. Secondly, when looking through Skoltech's master's programs, I realized that my interests are different from my graduate thesis – theory and equations. I've shifted from quantum mechanics towards materials: I'm particularly interested in this new area because of its far-reaching applications. I find the applied approach very appealing: when you find something interesting, get it into an experiment, then into the engineering stage, it's awesome! Photonics involves materials, complex theoretical topics, and has tons of prospects for new projects. Skoltech's master's program is flexible enough to allow me to explore my potential in both fundamental science and the application-oriented sphere.

A Model Kit

The Masterskaya workshop at Skoltech began in 2013 as 15 square meters made available for students to hack electronics and develop simple prototypes. When I was placed in charge of it, in comparison to Skoltech's other large research centers, it was barely even noticed. We worked hard to show our value to the Institute and received a steady increase of support from the President. Now we have grown into 700 square meters of advanced machines, and we serve all the Skoltech entrepreneur, student and professor prototyping activities. In the future we hope to grow into a full-fledged technology incubator, taking new ideas and developing them into products and companies.

BRENDAN SMITH
HEAD OF THE SKOLTECH MASTERSKAYA WORKSHOP

Space Tomatoes

The aim of my PhD project is to have a measurable impact on precision agriculture in Russia, particularly with respect to the development of a robust methodology for prediction dynamics of plant growth based on mathematical modeling and with the use of statistics. This topic is relevant in terms of fundamental research and possible commercial applications. More and more agriculture companies are seeking the latest technologies based on computational and data science in order to increase yields and improve the quality of products. Likewise, this research is important for the development and control of robust life support systems in space applications. The novelty of my work is that I will try to improve the accuracy and the time range of plant growth dynamic prediction in uncertain conditions, or when a small amount of data is available. I have conducted successful experiments related to the collection of huge amounts of data describing plant growth. My initial results were very promising. I'm currently planning my next generation of experiments. My PhD advisor is Skoltech Provost Rupert Gerzer.

DMITRY SHADRIN
PHD FELLOW, SKOLTECH SPACE CENTER

Dzmitry Tsetserukou:

//A country with a low population density and a huge territory must be fully automated//

Professor Dzmitry Tsetserukou, Director of Skoltech's Intelligent Space Robotics Laboratory, talks about the projects students are currently working on in his laboratory and what it takes to be one of them.

Which areas of research in the field of robotics do you consider the most important today, and which of them are being developed at Skoltech?

The most important area in Robotics has become business process automation and the transition to so-called Industry 4.0. The aim of this area is to improve production efficiency and reduce the number of human errors. Industry 4.0 encompasses several subdivisions. The first is mobile robots.

For instance, did you know that the number of robots at Amazon Robotics [formerly Kiva Systems, producer of mobile robots for order transportation at Amazon warehouses] has increased by 50% since 2015, from 30 to 45 thousand units? At the same time, warehouse operation efficiency has increased by 20%. Our laboratory works closely in this area with the Skolkovo company RoboCV.

A number of graduate students are currently working on the PickToGo system for large warehouses. Their objective is to automate a set of pallets with goods in warehouses. It's not a trivial task; it involves computer vision, manipulators on mobile platforms, the development of mobile robots, and other elements. The system must be fully autonomous.

By the way, Amazon's mobile robots are not an automated system; they fulfill tasks by moving along routes assigned in advance and navigating through magnetic markers.

There is also an area related to digital factories. This area involves the automation of the majority of business processes: robots in an automation system become more than merely machines that carry out operations. They must learn by themselves and adapt to situations in real time.

In the lab, we are pursuing a project in this field – in mobile phone management. It is being conducted under the Next Generation Grant Program for joint research projects between Skoltech and MIT.

These are two areas that I consider to be in the most high-demand as applied sciences.

Drones are also a very promising field. As Russian agriculture develops, there should be a growing market for them. The identification of plant growth indices, diseases, automated pesticide spraying – these tasks can be solved using unmanned aerial vehicles. Another potential use is the development of the Arctic and automation of ship navigation systems on the Northern Sea Route.

Is there interest in robots that interact directly with humans? Any advances in that direction?

Two new areas that we will launch in the near future are the Collaborative Robotics Lab and the Virtual Reality Lab. In the collaborative field, we will have the best robots – Universal Robotics, KUKA, Fanuc – all high quality and state-of-the-art.

The second laboratory – Virtual Reality and Tactile Interfaces – will be somewhat smaller but will feature all modern haptic platforms and a high-precision motion capture system.

Among other things, the Skoltech lab will work to create tactile interfaces that help people immerse themselves in virtual spaces. This will be useful, for instance, in the medical sphere. Doctors can carry out virtual rehearsal operations, in which they will feel the resistance of tissues, and the touch and texture of the relevant objects. Tactile interfaces are used for this purpose in virtual reality.

Do startups born at Skoltech receive some kind of support from the Skolkovo Foundation?

Certainly. In the field of robotics, we cooperate mainly with two Skolkovo clusters: aerospace and IT. Startups that emerge at Skolkovo receive, first and foremost, the foundation's expert support.

At the moment, two startups have passed the preliminary stage of preparation and are applying for foundation resident status. It makes sense for our startups to remain in the ecosystem.

Are there international students at your laboratory and, if so, where are they from and why did they choose Skoltech?

There are students from India, Serbia, Iran, Spain, and Costa Rica. They have very diverse origins. At present, the number of applications from international students is surpassing those of Russian students. At the moment, I'm planning to send two graduate students to the Massachusetts Institute of Technology (MIT) for practical training. Skoltech actually started working with MIT specifically in the field of scientific research, rather than just in education.

We are actively developing programs with the leading European universities: this year we're sending one of our PhD students to the German Aerospace Center [DLR] near Munich. One of the best robotics laboratories in the world is located there. The international academic mobility program for students is progressing well.

Which international universities does Skoltech collaborate with in the area of robotics research projects?

For digital factories – creating new robots and management systems for these robots, and computer vision systems – we collaborate with MIT. We're planning to work on stratosphere drones with DLR. That's a very exciting area. We also work with the Japanese University of Electro-Communications on tactile interfaces. We collaborate with Japanese partners on medical projects as well. I should also note that Skoltech robotics lectures are taught by internationally renowned professors. Five lectures of the Dynamic Management Systems course are taught by Professor Kamal Youcef-Toumi from MIT, who holds 30 patents and has written a book on creating direct-drive robots. Professor Hiroyuki Kojima, from the University of Electro-Communications in Tokyo, traveled from Japan to lecture here.

What professional goals do you personally set for yourself?

I came to Russia with a dream: to create a successful laboratory in Russia and train students capable of developing this area across the country, not just in Moscow. A country with a low population density but a huge territory must be fully automated.

Skoltech's student robotics team reSET has won first place at the Russian stage of the Eurobot competition two years in a row, and has received excellent results both years at the international finals in France

INTERVIEW

Vladimir Spokoiny:

//Entire areas of knowledge are starting to die out//

In 2017, the Higher School of Economics (HSE) and Skoltech launched a Statistical Learning Theory MSc program designed to prepare students for scientific research at the intersection of mathematics and computer science. The program's academic supervisor, Skoltech professor Vladimir Spokoiny, told us more about this exciting new program.

How did this program originate?

Two years ago, we launched a master's program at the HSE Faculty of Computer Science called Mathematical Methods of Optimization and Stochastics. The aim of that program was to provide data science specialists with the opportunity to gain an in-depth education in mathematical disciplines such as optimization, statistics, and stochastic analysis. This year, we launched a joint HSE and Skoltech project based on the program developed at the HSE. Our main goal is to offer students a full range of courses that encompass modern statistical learning theory. Two years from now, we expect the course to bear its first fruit: top-level specialists in one of the most sought-after areas of expertise.

Why do you think this area is in such high demand?

Machine learning theory and artificial intelligence are dynamic and rapidly developing areas of modern science. Finance and bioinformatics may have once been leading fields, but now attention has broadly shifted to artificial intelligence. It suddenly became clear that hundreds of thousands, perhaps even millions, of people are working in AI. However, they are focused on finding solutions to specific engineering problems. There are very few specialists that understand the mathematical essence of this area of science. Statistical learning theory courses are already on offer at various institutions including Berkeley, Stanford, universities in Paris and Berlin, and other

IN COOPERATION

To date, Skoltech has implemented MSc programs in network form with the Moscow Institute of Physics and Technology, the Higher School of Economics, the Kazan Federal University, the Far Eastern Federal University and the Baltic Federal University.

The institute has also organized joint educational programs, where students receive diplomas from both institutions upon graduation, from Novosibirsk State University and St. Petersburg State University of Aerospace Instrumentation.

In 2018, Skoltech plans to launch network-form MSc programs with the Southern Federal University and Surgut State University.

scientific centers. On the back of this, we decided to launch a similar program in Russia. We very much hope that gifted students from various Russian universities will show interest in joining our ranks.

What background and knowledge do students need to get accepted into the program?

The selection process is tough. We recruit students with degrees from higher education institutions. For example, the following programs are deemed a suitable background: those run by the HSE faculties of Computer Science or Mathematics, or by the Moscow Institute of Physics and Technology's faculty of Control and Applied Mathematics, or Lomonosov Moscow State University's faculties of Computational Mathematics and Cybernetics or Mechanics and Mathematics. We don't require anything super-specialized, but applicants must have a comprehensive grasp of calculus, linear algebra, functional analysis, probability theory, and statistics. If candidates don't have a command of basic conceptual thought, our program will not be suitable for them.

How many courses does the program have?

We put together a list of courses according to three gradations: compulsory, semi-compulsory, and optional courses, including those taught by guest lecturers. In total, the list has 28 courses broken down into these three categories. We require students to take a minimal number of courses, but they can take as many courses as they want. Instruction is structured in such a way that we first allow students to attend one or two introductory courses, which are quite immersive. Only later does it get really hardcore.

Is it all theory, or are there practical courses as well?

It's clear that there must be theoretical courses, but by no means should all courses be theoretical. In that respect, we have a wide range. There are highly theoretical courses, and there are completely practical ones. But theoretical courses are compulsory. This includes modern statistics, methods of computational linear algebra and optimization methods. Those are the fundamentals that every specialist working with modern machine learning theory and artificial intelligence needs to know.

Our concept holds that every student must immediately or reasonably quickly find a personal supervisor who will guide them through the entire master's program. We draw up a list of topics and proposals for students where we talk about what each professor is working on and what will be possible to join in on. Additionally, we organize seminars on various subjects. At the moment, we have three seminars, including optimal transport theory – the most mathematical one – or deep learning of neural networks, which is the most practical one. The aim of these activities is to engage students in active work.

Students have the opportunity to do internships at Western universities. We have partnerships with universities in Berlin, Paris and Grenoble, and internships are available at Cambridge, the Massachusetts Institute of Technology, Berkley and Stanford. We take all internships very seriously, and we don't send students if we find them ineffective. We expect productive cooperation with leading specialists in machine learning theory from around the world. A number of scientists have agreed in principle and are prepared to come and teach specialized courses in our program.

Which specific studies and research are open to master's students?

There are lots of them. One of the ones I'm working on at the moment is clustering. Multidimensional data clustering is a very interesting challenge. Imagine that you have data of any kind – medical records, videos, texts – anything. And they have to be broken down into groups of homogeneous objects called clusters. This task comes up in an enormous number of applications. There are thousands of algorithms, but so few theories that no

The coming technological revolution is entirely based on data science. In a number of fields, the computer has proven to be more effective than the human brain. It's very important that humans don't get lost in all this

one knows what a cluster is. Low-dimensional data can be visualized and broken down into clusters manually. But it's very difficult to propose a sound, stable method for true multi-dimensional data. That's what we're working on at the moment. A related subject is instruction in partially labelled data.

These are just a few mathematical problems, but there are also entirely practical projects that we have run and continue to run with different companies.

With whom exactly?

We recently did a traffic analysis project for the Chinese telecommunications company Huawei in order to optimize their telecommunication network architecture. We drew up another project on resource distribution optimization. We had projects with Sberbank, and now we're talking to Sbertech and looking forward to working with them. There are projects in Germany with Bosch and Opel. They're interested in deep neural networks, cluster analysis and a number of other, similar problems. But I can't disclose any details due to our confidentiality agreements.

On the whole, I would say that most of the scientific challenges that occur in the modern world require competency in all fields of applied mathematics. You have to be a specialist in statistics, in probability theory, in optimization theory, in computational methods and linear algebra. All are essential in their entirety and, if specialists don't have a certain body of knowledge, they'll have a tough time from the outset.

What are your views on the crossover of young people from science to business?

I assume this applies to a 1:5 ratio. If everything goes well, around 20% remain interested in science during the transition from a bachelor's to a master's program, and the same thing happens after a student obtains his or her master's degree. I'd say that we occupy the niche that students who want to stay in science come to. A process of elimination takes place beforehand; we warn students straightaway that we focus on training scientists. After that– we'll see how it goes.

In your opinion, what are the key approaches to the organization of the Skoltech master's program?

Skoltech is an innovative university that fosters students capable of making technological breakthroughs. But it is my opinion that a university is not a design office. Students have only two to three years during their master's programs to learn science, to immerse themselves in it. And then, if you have the expertise, you can develop further as a specialist.

In our program, we will plan and propose projects ourselves, and they must be knowledge-intensive. The results of the work should be published in scientific journals. Our version of a master's degree is a third to half of a dissertation. Those who go on to further study will do so with substantial material at the cutting-edge of science.

In terms of humanity at large, what's the meaning of your work?

We're working in the very area where humans are indispensable: in the area of understanding. Why this all works and where to advance from here. We don't just instruct common users, we foster creators. I believe that mathematicians will be more and more in demand; they'll always be in demand. Mathematicians build models, they understand what, how and why new ideas, methods and approaches happen and are generated. Without that, progress is impossible.

Two in One

Online educational programs provide students with the chance to use the resources of several educational or research organisations in the learning process, as well as to receive two diplomas (Skoltech and a partner university) after completing their program.

Students master one part of the educational program at Skoltech and another at a partner institution.

The advantages of these programs are:

1. The opportunity to use the resources of several organisations.

2. A unified educational program.

3. The opportunity to receive two diplomas after completion of the program (in cases of enrolment at both Skoltech and a partner university).

4. A single dissertation.

INTERVIEW

Anton Krotov:

//Students from Vladivostok now have the chance to study bioinformatics, functional genomics, and genetic engineering//

A Skoltech MSc student finds time not only to study bioinformatics and deepen the cooperation between Skoltech and the Far Eastern Federal University, but also to work with children at Sirius Educational Center and get involved in preparations for the re-opening of the renovated Polytechnic Museum.

Tell us about the university you studied at and how you got into Skoltech.

After graduating from the Far Eastern Federal University (FEFU), I looked into Moscow State University, the Moscow Institute of Physics and Technology and Skoltech. I studied chemistry, specializing in organic chemistry, and used to do laboratory research. After a while, I wanted to turn my hand to biology, but without getting involved in wet and dirty work. I realized I could try bioinformatics, i.e., working with data obtained from numerous experiments. Skoltech seemed to be an incredibly attractive environment where I could pursue side projects. In Vladivostok, my colleagues and I set up and ran educational and awareness-raising projects. For example, a science festival timed to coincide with the Illuminator Award. Our festival brought together the best practices of Vladivostok's pop-science projects at the FEFU, where we studied and worked. We invited young, inspirational speakers to attend. For example, an astronomer from the Sun Service Observatory spoke about the latest discoveries in astronomy and astrophysics. The creators of the Science on the Road: Primorye Quest made a scaled-down version of their project on our site based on the idea of a scientific quest for parents and

their children. Families could visit our university as microbiologists, archaeologists, and have a go at studying ethnography and the botany of the region all in one place: an excellent example of what is now called citizen science.

You worked at the Sirius Educational Center. Tell us about it.
In my opinion, Sirius is the best educational center for children. It has a great infrastructure, both in terms of technical set-up and the staff, and Sirius has a huge number of partner programs. Its projects are developed by excellent teachers from all over Russia, including Vladivostok. At Sirius, Laura Elidedt Rodriguez (my Mexican colleague from Skoltech) and I started working on a very interesting biology project. We grew a material similar in texture to artificial leather from a bacterial culture that can be used to make all kinds of household items – we made a lampshade. It's totally crazy! At first we just played around with the children but then decided to try out something more serious. We gave jewelry a try. Over the course of four lessons of about one and a half hours each, 12 children created the material and made earrings and badges from it. What's more, each child did everything themselves. It was genuine edutainment: we taught them in-depth microbiology lessons and instructed them on how to work with real microbiological boxes. A lot of the children had never studied microbiology before at all – some of them had a figure skating background, others – hockey. We intend to continue this project at Skoltech: we've built the studio, and now we're organizing the staff.

Which joint FEFU and Skoltech projects have you taken part in?
This year, Skoltech and FEFU launched a joint biotechnology MSc program. FEFU has a very impressive resource base, excellent laboratories, and outstanding biomedicine and natural science schools. However, the teaching staff lacks specialists from a number of important industries. Skoltech and FEFU's partnership means that students from Vladivostok now have the chance to study subjects their school doesn't offer: bioinformatics, functional genomics, and genetic engineering. They can also take courses that cover technological entrepreneurship, for example. FEFU students often pursue degrees linked with marine biology; in Moscow, this is a far rarer choice. Therefore, they can choose where they want to defend their dissertation and diploma theses: in Vladivostok or at Skoltech. In April, we announced a joint educational program run by Skoltech and FEFU. We organized a series of lectures specifically for this program in Vladivostok with the participation of my supervisor Dmitri Pervouchine and Skoltech Professor Mikhail Gelfand. They not only held serious scientific seminars attended by many young scientists and researchers from FEFU and other institutions but also gave popular lectures. For example, on why GMO is not a scary prospect.

What do you think the joint FEFU and Skoltech projects offer students?
The two universities together offer students a greater wealth of opportunities than they could separately. What's more, students have the chance to step outside their comfort zones; if you only study at one university, don't establish contact with the educational scientific environment, don't go to conferences or take part in internships, etc., your horizons are limited. The chance to attend courses at another university, study with great professors, gain experience, make friends and acquire contacts is amazing.

Do you think the program will be further developed?
Absolutely. Skoltech is really keen to forge partnerships with leading universities. It already has joint programs with Moscow State University, the Moscow Institute of Physics and Technology, the Tomsk Polytechnic University, and this year it embarked on a joint program with the Higher School of Economics. I think this list of universities will continue to grow because Skoltech wants to work with young, talented scientists.

Tell us about your scientific supervisor.
Professor Pervouchine is an outstanding bioinformatics specialist. In addition to Skoltech, he also has professorships at the Higher School of Economics and Moscow State University, has worked at the Center for Genomic Regulation in Barcelona, and collaborated with ENCODE (the global genome decoding project). He studies noncoding DNA sequences: a hot-button issue. There have been publications stating that 80% of them are actually functionally important. However, recent publications refute this fact. This is a very interesting and hotly-discussed topic.

You work with the Polytechnic Museum, don't you?
Skoltech has a project at the Polytechnic Museum run by a team of six students. We write pop science texts for the Polytechnic Museum and serve as scientific advisers to the Life section of an upcoming Polytech exposition, which is currently still under reconstruction. The section will explain what a cell is, what types of cells there are, how they differ, and how evolution occurs. We also advise the museum staff when they think up some kind of crazy idea for an exhibit – a three-meter DNA or protein molecule, for example. We listen to their creative ideas and try to steer them towards a more scientific approach.

What do you plan to do after you graduate?
I will probably teach or work on educational projects such as career guidance. I want to create a program that gives children the chance to try something out with their own hands in order to help them go on to decide what they are interested in.

SKOLTECH TEAM CONDUCTS CUTTING EDGE RESEARCH IN ANTARCTICA

Research takes Skoltech students not only to top universities and laboratories, but also to the edge of the world

For nearly a decade, Professor Konstantin Severinov, Director of the Skoltech Center for Data-Intensive Biomedicine and Biotechnology, has deployed researchers to the Southernmost reaches of the globe to collect snow.

Each year like clockwork, a carefully packaged shipment of melted, concentrated snow slowly makes its way from the alabaster shores of Antarctica to the concrete jungle of Moscow.

And with each new shipment of samples, Severinov's team gains a deeper understanding of the microbes that populate Antarctica and the lessons they carry for the rest of the world.

"It is both interesting and important to establish whether there are specific snow communities of microbes that live in Antarctica," Severinov said during a recent interview. For a microbiologist, the discovery of microbial communities that have evolved to withstand the harsh conditions of Antarctic winters could be the mother lode, carrying boundless potential for developments in fields ranging from genomics and industrial biotechnology to gene editing.

"It could well be there are no particularly adapted snow microbes, but rather microbes that get deposited on the surface of snow from the air," he added. "This is still interesting because then you can regard Antarctica as an enormous depository of microbes collected over hundreds of thousands of years. When the iceberg breaks down from the continent and goes to South America or Africa it may bring with it as fellow travelers the whole bunch of microbes which may be very, very old."

So even if there are no snow-adapted microbial communities, Severinov's findings in Antarctica could lead to invaluable discoveries regarding the global spread of microbes and viruses and their changes over the years.

In addition to studying the continent's microbial population, Severinov's group works with the Russian Antarctic Expedition [RAE or expedition]. Since 2012, the RAE, has attracted international headlines for drilling through Antarctica's frozen crust to reach Lake Vostok, a freshwater lake previously sealed off for millions of years. Professor Severinov's team serves as part of the expedition's biomonitoring group, assessing the anthropogenic impact on the continent's fragile environment.

What does Antarctica have to offer that the researchers couldn't find in another (more convenient) location?

"In many ways, Antarctica provides unique conditions for the investigation of the behavior of microorganisms in an

environment into which they were placed – that is, in an environment that they aren't native to," said Viktor Fedorchuk, a geologist interning at Severinov's center who travelled to Antarctica in late 2016.

Explaining that a portion of his research was devoted to the monitoring of microorganisms that humans introduce, he noted that Antarctica is globally unparalleled in terms of offering an environment that has never been home to permanent human populations or large communities of animals.

"There is practically no life in Antarctica," Fedorchuk said. "As such, if something is introduced there, it is very easy to register, even if we bring in these microorganisms in very small quantities."

What does Severinov's team do each year in Antarctica?

"Before looking at human-induced contamination, it is important to determine the background, that is, the natural level of microbial content and what characterizes the communities in the ice or the snow… where there has been no human influence yet," Severinov said.

He explained that to accomplish this, it is important to examine geographically remote locations, and to review the same points during different periods of time.

Once researchers collect snow samples from these locations, they ship their boons back to Russia via the RAE vessel to be analyzed. Once the samples arrive, a Moscow-based team of researchers working under Severinov uses state-of-the-art methods to analyze the DNA within the microbes found in the snow samples.

In 2016, for instance, his team found considerable diversity between bacteria collected at four different sites

in eastern Antarctica. Their analyses of these bacteria revealed thousands of unique CRISPR spacers – elements of prokaryotic DNA that enable bacteria to fend off viruses. None of these spacers matched those of similar bacteria located in the northern hemisphere. This team included Skoltech students along with researchers from the Russian Academy of Science, Moscow State University, St. Petersburg State University and St. Petersburg State Polytechnic University.

Despite his team's strong track record, Severinov decided to change course this year, noting the difficulty of circumnavigating Antarctica and re-visiting the same spots time and time again. This inspired the professor to assign a novel means of sample collection to Skoltech intern Fedorchuk.

"In Antarctica, snow only falls in the winter time, and in summer time – which is when people are there on expedition – it's mostly bright sky," Severinov explained. "So the snow that fell last year would then be covered by the snow that fell this year, and so on and so forth… So I told [Fedorchuk] to dig. He was digging holes – going down by some 2-3 meters with his shovel, and as he was doing that, because he's a geologist by training, he easily identified layers of snow and ice from different years, and then he was collecting samples from different layers, travelling

In Antarctica, snow only falls in the winter time, and in summer time it's mostly bright sky

back in time by up to about 20 years while being in the same place."

Fedorchuk noted that the novelty of the technique came with a steep learning curve. "The most challenging part of the expedition probably was working on a job that I had never done, in an environment in which I had never been. And the main difficulty was that no one had done [this type of work] before me. I needed to develop a robust technique from scratch and make sure that I did not contaminate samples such that only resident microbes were present" the geologist said. He then added that he had to tweak the process in progress.

What's it like to travel to Antarctica?

When Fedorchuk was asked to travel to Antarctica, the offer caught him totally off guard. A friend of his – a biologist – was supposed to go on the expedition, but in

the 11th hour, had to back out. The expedition urgently needed a replacement, and Fedorchuk was recommended. When he first learned about the offer, he said that the paperwork and preparation seemed daunting.

"Then I realized that this is the sort of opportunity that comes once in a lifetime and you have to take hold of it," he said. "I realized that I couldn't afford not to get involved in this adventure."

Some expedition members boarded the RAE vessel – the "Academic Fedorov" – in St. Petersburg, while others flew down to Cape Town to board the ship once it arrived. Fedorchuk was in the latter camp, noting that the voyage from Russia to South Africa would take

a month, and because he was invited to join the expedition on such short notice, he needed all the time he could get to prepare.

The sea voyage from Cape Town to the coast where he collected his samples took just over two weeks, with several stops at peripheral stations along the way, Fedorchuk said.

When asked about life on the Academic Fedorov, he explained: "Well on the ship, all life depends on the meal schedule. Between meals, some expedition members had scientific programs and others didn't. In the latter case, you could sleep, read, watch movies, play table tennis, work out, etc."

Though he said that the RAE issues all expedition members with a set of gear in order to stay warm, he added that summers in Antarctica are surprisingly mild, noting that the daytime temperatures where he was working typically hovered above zero degrees Celsius. He noted that at the time, back in Moscow – whose winter coincides with Antarctica's summer – temperatures were sinking to nearly -30; Antarctica was practically toasty by comparison.

The samples Fedorchuk gathered are now on their way back to Moscow on the RAE vessel.

"Once they're here in June, we will be analyzing them by determining DNA sequences of microbial communities present in the samples collected by Victor and then we will go through an arduous process of bioinformatics analysis of the data to identify differences and commonalities between samples from different years," Severinov said.

In the absence of conclusive results, asked about his most thrilling takeaway from the expedition, Fedorchuk said: "My personal experience, of course. Because much of what I did there, I had never done before in my life."

Universities. Countries. Continents.

In only the past year, Skoltech postgraduate students made 86 visits to international research centers and laboratories. The United States attracted the largest number of internships, with 28 trips to the Massachusetts Institute of Technology, the University of Southern California, Boston University, Harvard University, and the National Institutes of Health. Skoltech students also spent time at universities in Germany, France, the United Kingdom, Switzerland, Italy, China, Canada, Chile and Israel, among other destinations. The average trip lasted between two and six months. From September 2016 to September 2017, Skoltech students participated in 122 international scientific conferences and symposia in Europe, the United States, and countries in the Asia-Pacific region.

Pekka Viljakainen:

//The only way we can keep the best people in the Skolkovo ecosystem is by having the best ecosystem//

The Senior Advisor to the President of the Skolkovo Foundation and founder of the Startup Village project talks about the Skolkovo ecosystem, what the startup mindset is and what a modern team has to look like.

What are your expectations of Skoltech graduates?

My number one expectation is that these people must have an international mindset. Of course Skoltech is about science; of course a technological education is about understanding technology and the future of it, but still, my expectation is that they are ready and willing to be involved in global interactions, because the world of technology is global.

You see, there are a lot of people who think that these global capabilities boil down to being able to speak a foreign language, but that's not the case. I'm from Finland, and 99% of Finns speak English. But perhaps 5% of Finns are able to do international business. So this is not about the language; it's about how to build trust between foreigners, how to build trust with different cultures; are you curious enough to understand what others are doing, or do you just want to rely on what you know about your Helsinki or your Moscow or your Novosibirsk?

My second expectation is you should understand basic logic about how to make a business. A great product or innovation alone is not enough; sales knowledge alone is not enough. You must have both. You also have to have a basic understanding of the timeline of the life cycle of the business. That's why I'm also heavily supportive of the Skolkovo edu-

cational hub with Skoltech and the Moscow School of Management Skolkovo, so that the tech people of the world have a broader scope of knowledge, extending beyond technological excellence.

My third expectation is related to leadership. In Russia and in many places in the world, there's this idea of one strong leader – one great hero. For example, when people talk about Sberbank, everyone thinks of Herman Gref. But we are talking about an organization with tens of thousands of employees. If you take Apple, for example, Steve Jobs was a micromanager for sure, but the success of Apple is the product of thousands of brilliant technological minds working together. I think this understanding must be embedded into the minds of Skoltech students.

What opportunities do the best graduates with the most promising startups have when it comes to getting their companies off the ground within the Skolkovo ecosystem?

The only way we can keep the best people in the Skolkovo ecosystem is by having the best ecosystem. The idea that we can buy people by giving them the most money is not sustainable. This Skolkovo ecosystem needs to be good for living, housing, transportation, train and subway connections, parking, restaurants, good food… we have to be competitive.

Right now, we're not at the beginning, we're not complete; we're somewhere in the middle. We have kids attending grade school in the Skolkovo Gymnasium, we have people living in the flats at Skolkovo, we have swimming pools up and running, we have parking places and roads — and this wasn't the case five years ago.

The beauty of the startup community and the beauty of the ecosystem is that it's 100% transparent. It is what you see, what you feel. It's not just what Mr. [Skolkovo Foundation President Victor] Vekselberg says, or what Pekka says, or Prime Minister [Dmitry] Medvedev says – it's very concrete. It's physical. That's both the bad side and the good side; because every problem is very visible.

But also all the good things are very visible, and that's why I think we will have such an ecosystem that will attract people to stay here. And luckily, we now have evidence of this. Three years ago, selling an open field saying here there will be a school when there was only dirt – that was difficult.

How is Skoltech similar and different from the world's best tech schools?

The ecosystem is all about people; the people are all the same. Whether you have a Chinese girl or an American boy, the same age – they are pretty much the same. We all want to have food and a safe place for our children. So basically, this generation – our potential audience for Skoltech – is more united, than the one from 20 years ago.

When it comes to Skoltech or to the Skolkovo ecosystem, it's clear that there are a lot of scientific people in this ecosystem. If I walk around at a business school event at Stanford or in Helsinki or Seoul, I would see a lot of people who are talking about the business of sales and marketing. Here you see more technological people. I think this is the main difference and that's why – once again – the hub connects Skoltech with surrounding business schools. This is something that we have to work on.

Other than that, I think we are extremely competitive in the global arena.

What are your favorite Skoltech student startups?

There is a number of interesting projects. But specifically to your question, if I would have chosen by now any particular company I would have already invested into it. And this you would know for sure!

What is typical of a successful startup?

The leader and the founders are not afraid of anything. When they wake up in the morning, when they open their eyes, their first thought is not: Who will cheat me? Who will steal from me? This is a very different mentality. Having no fear is about not being afraid of people. You have to have the guts to have smarter people work for you.

If you are able to go to the global market, you have to make your company international in the very early phase. And of course if you're a small startup, you don't have the money to make big offices or branch offices in the United States or Europe, but a good start is a team with international people.

If you have a colleague from a university exchange from Britain or Helsinki or Boston, invite them to be part of your business. You have to learn how to lead your team. You will have a virtual team where messages are written in English and your employees are not in shouting distance. It's important to work in such an environment where you are not so close, but still you're mentally close. I have worked like this for 20 years. With my colleagues, we have Telegram chats every day, video meetings when needed. I don't even think about what country I wake up in. I might be in Paris and have to talk to guys in Miami and Moscow and Stockholm. And this is totally normal.

With an international team, your likelihood of success is much higher than if you are just five engineers sitting in Moscow, speaking Russian and sharing a Russian mentality.

What industries are the most start-up-friendly today?

In Russia, we could have much more consumer-driven products, i.e. retail, gaming, and entertainment, as opposed to business-to-business startups. Another quickly growing area is the internet of things. There is much left to be invented, such as increasing manufacturing capabilities.

How do you think Skoltech will change once we move into the new campus?

I would say that you will move to one of the finest campus buildings in the world. It's like the Enterprise starship from Star Trek.

Still, I want for Skoltech to be able to keep the feeling of a small university. The university should be about people, not about the hierarchy. Other universities will also probably visit the new campus, which will help Skoltech retain its international nature.

INTERVIEW

Nina Mazyavkina:

//I made up my mind—new town, new college, new start—just go for it//

The president of the Skoltech Student Council talks about how the institute's young scientists and entrepreneurs spend their downtime, and the values forming within Skoltech's walls.

Nina, would you mind telling us why you chose Skoltech?

I did my bachelor's degree in Rostov-on-Don and studied in the faculty of mechanics and mathematics at the Southern Federal University (SFU). I heard about Skoltech from my dad; he's very proactive. He was attending the annual Skolkovo StartUp Tour when he first heard about Skoltech. I looked at the website and really liked what I saw. At that point, I didn't know that Russia had such top-flight educational institutions. I was thrilled, and for a year I only had one thing on my mind: "Skoltech." I got in the first time, which I was really happy about. Now I'm a second year MSc student studying IT & Data Science.

Which projects are you pursuing at Skoltech?

I'm not a typical IT student because my scientific advisor is from the Space Center: Dzmitry Tsetserukou. At the moment, we're developing a virtual reality simulator that can be used to train nurses. Right now, I'm attempting to create a reinforcement-learning model for this simulator, meaning I'm trying to use my IT knowledge at a practical level.

How did you become president of the Student Council?

There are two levels in the Student Council: one is more representational: foreign students, MSc students and PhD students. The second rung of the Student Council hierarchy includes the president, the vice president, and

the secretary. In order to move to the second rung, you have to work for a year in the Student Council. Last year, I became a member of the Student Council and focused on club activities. At the end of last year, we had an internal vote and I was elected president. Honestly, I don't know why I was chosen in particular. I guess people see that I'm genuinely interested in Skoltech, that I care about the students, and that I really want Skoltech to become a truly fantastic university. The potential's there; we just have to take advantage of it.

Have you always been a leader?

When I lived in Rostov, I had a pretty passive attitude to life for my first three years of study. But when I got into Skoltech, I suddenly realized that I wouldn't be a student forever, and that maybe I wouldn't ever have the chance to lead an active student life again. I made up my mind: new town, new institute, new start; just go for it. I had a good example to go by: my best friend in Rostov is a very proactive girl, and

is president of the Academic Council at SFU. And I decided that if she could do that, why couldn't I? When I got in, I immediately came up with the idea of organizing a club festival. At the time, Skoltech didn't have a very active club scene. There was a good discussion club with an amazing president, a girl from Korea. But beyond that, the club scene wasn't particularly well developed, and I wanted to give it a kick-start. We organized the club festival with the aim of telling the Skoltech community about the existing clubs and inspiring them to create new ones. Everything turned out great, everyone had a wonderful time, and since then, several clubs have been created.

Our conversation is punctured by the bounce of a tennis ball, and on the doors I see a poster for a yoga club. It's clear a lot of things are going on. What are some other kinds of clubs?

There's a certain pattern: at the beginning of the year, most people, especially first year students, are full of

energy and ready to set up clubs. First year students send us a load of proposals, from Japanese language clubs to data science clubs. There are always a lot of initiatives. But after classes start and people realize that there's a big workload, the frenzy often disappears. Right now, we're continuing a tradition: last year people went to the gym at the Moscow School of Management to play volleyball, soccer, there was yoga; last year there was pretty much everything. We're planning to host another club festival soon to foster exciting new ideas.

So Skoltech gives every student the opportunity to share their ideas and get in touch with like-minded people?
Yes, and I really encourage that. When I met this year's incoming students on the first day of the new term, I tried to explain to them why this is important. I always cite as an example the Massachusetts Institute of Technology, where there are more than thirty clubs and they're booming. Many students came here from other cities and countries. Clubs are a fantastic way to meet people and make friends. No one knows where we'll be in 5-10 years. You might just walk into a German language club and meet the future president of Yandex or some other corporation. And, of course, it's an excellent opportunity to kick back and build a student community.

Do Skoltech students have any distinctive features?
Yeah, I'd say we're already a brand. I think that, firstly, students who know exactly what they want to do are confident; they've got plans. They have solid critical thinking skills and they're always ready to get into a healthy debate. Another really important thing: people here aren't into showing off. They're really open and also just very interesting people. Everyone's doing something outside of study: playing musical instruments, drawing, sports… Last year we held a Skoltech talent show for both students and staff members. It was incredible. There were dances, gymnastics, people played musical instruments and performed their own songs.

How is student week organized?
We have a University 24/7 concept; the university is open around the clock. And I can see that students love being here. Students don't just come to attend classes, but to meet up with their friends, soak up the Skoltech atmosphere, just be here. They spend all day and even evening here. I have a friend who loves to work nights. He's been known to spend up to three days at a stretch here. There's an atmosphere at Skoltech that stimulates creative thinking and immersion. No one considers Saturday to be a day off; only on Sundays are there fewer people here. Students often prefer to come here rather than stay at home.

How are relations with the university administration?
At the beginning of August, we met with Skoltech President Alexander Kuleshov. We shared our plans and ideas, and he gave us suggestions. We told him how we envision the Student Council. I don't want students to be shy about expressing their opinions about the university. If students come to me with proposals to improve their workspace, for instance, I'll advocate for them and promote them as I would my own ideas. I think that students make the university. Without students, there would be no university, which is why it's important to give them a chance to speak up.

How does the Skoltech atmosphere manifest itself? Do you guys have any unwritten rules that you follow?
Every new group of students brings something of its own. Of course, we have our little particularities and traditions: for example, in Room 404 all computers are always occupied. It's

FIRST DAY
The President of Skoltech Alexander Kuleshov and Associate Provost, Dean of Education Anna Derevnina opening the new academic year 2017–2018

Everyone's doing something outside of study: playing musical instruments, drawing, sports

customary to arrive and agree in advance to use someone's computer. IT students often need to calculate things, and there are powerful computers there.

What's new this year and what would you like to say to applicants?

My task this year is to inspire students to get into extracurricular activities so that they realize how exciting and cool they are. Plus, I want students to get involved in life at Skoltech. There are people on the third floor who write various rules for students, think up things, but students aren't particularly involved. As a representative of the student community, I'm often asked: what do students want? I can guess, but it's important to hear real concerns. I want to organize regular meetings so that those who have already been here for a year or two can share their insights and experiences with the entering class. Second year students aren't at Skoltech as often as students in their first year, so there aren't all that many opportunities for interactions like this.

What are your personal plans for the future?

I always dreamed of developing computer games. I'm still holding onto this dream, but after having taken Data Science courses, that field struck my interest. Therefore, at the moment, I am trying to combine these two areas in my scientific work.

Ido Nativ, Community Communications Manager

The Student Life Office is committed to the support and development of our student body as a community by itself, and as part of the whole Skoltech and Skolkovo community. We aspire to create together with the students an atmosphere of creativity, curiosity, ingenuity and self-efficacy.

In practice, the Student Life Team takes care of all extracurricular activities, including social activities, sport activities, clubs and other services. To do so, the Student Life Office works closely with the Student Council, and the two bodies complement each other in their work for the students.

We are working together with our alumni on creating a long-lasting network of cooperation within the Skoltech-alumni-Skolkovo trifecta.

Another important role of the office is to support international students with their unique needs. We help them get their bearings in Moscow and in Skolkovo, we introduce them to the Russian culture, and we take care of the bureaucratic aspects of being a foreign student.

INTERVIEW

Denis Stolyarov:

//We support any productive student initiative and provide resources//

Head of student recruitment and selection at Skoltech Denis Stolyarov talks about recruitment and student life at the institute.

Let's imagine that I'm a student seeking a science, tech or engineering education. Why would I choose Skoltech?

It's simple. First, it's about the quality of education. It's important to us that students who enter our master's program won't merely spend two years sitting at their desks. Rather, they will lay a foundation for a brilliant career in science or tech. The only thing that can guarantee a successful start is a high-quality, world-class education.

Skoltech is part of a group of institutes carrying out cutting-edge research. Our students work with professors who are published in the leading global scientific journals and all of our lecturers have work experience in the world's top universities.

SKOLTECH is a private higher learning institution. The university has a state license to carry out educational activity and government accreditation of educational programs. There are no state-funded places, but Skoltech finances the studies of everyone who passes the entry exams and provides them with stipends. Graduates receive two diplomas: a State Diploma of Education and Master's Qualification and a Skoltech Master of Science degree with a European diploma supplement.

One of our objectives is for students to develop their ideas and projects and become employers themselves, creating job opportunities in high-tech sectors of the economy

Second, I would point to the uniquely-equipped Skoltech laboratories. They're available to all our students for research. At other universities, students are often not even allowed near important laboratory equipment.

My third point has to do with R&D internships. Our students are required to do two-month internships in specialized departments of companies, where they are completely immersed in the process of technological research and development. Among our partners are high-tech industry representatives like Yandex, Sberbank, Boeing, Rostec, Lukoil and other Russian and international companies.

How do you develop entrepreneurial skills and motivate students to create their own projects? Or do you recruit motivated students from the outset?

As for entrepreneurial skills, we strongly emphasize their importance. In the Skoltech education process, there is an Entrepreneurship and Innovation module. These disciplines are taught to all students, regardless of their programs. One of the module's most interesting courses is the Innovation Workshop; it's based on an accelerator model.

In this course, students must put together a team, come up with an idea and, by the end of the term, turn the idea into a product or technology. They then do a presentation for our professors and guest experts, who may be from, say, venture capital funds. We also offer students support with establishing startups. For example, we teach patent law and other legal support issues related to business activities.

Real companies often emerge from these training projects, which the founders continue to develop. If a student is successful in this, they can gain access to the Skolkovo Foundation's capabilities. When a company like that becomes a Skolkovo resident – and we have precedents for this – it gets access to all the relevant infrastructure.

One of our objectives is for students to develop their ideas and projects and become employers themselves, creating job opportunities in high-tech sectors of the economy.

Skoltech has academic mobility programs. How do they work?
We have several key international academic partners. First on the list is, undoubtedly, the Massachusetts Institute of Technology (MIT). You could call MIT our older brother, as Skoltech was founded through close cooperation with the legendary university. Currently, many of our students at all stages of study are working on joint programs and projects with their colleagues in Cambridge.

That said, if we take a look at the bigger picture, our students have the opportunity to go to any university in the world via the academic mobility program. For example, say you're studying Photonics and Quantum Materials and, for your MSc dissertation, you need to carry out research in the famous Los Alamos National Laboratory (New Mexico, United States). If your academic advisor gives their approval, Skoltech will get you there, all expenses paid: tickets, accommodations, insurance, etc. As a rule, the host party is all for it. Talented students arrive at no additional cost, ready to carry out joint research projects.

Skoltech also offers a number of online educational programs that allow combined instruction at several universities. How does that work?
Skoltech has numerous online programs with partner universities. Included among these partners are the Moscow Institute of Physics and Technology (MIPT), the Higher School of Economics and several federal universities, including the Immanuel Kant Baltic Federal University, the Far Eastern Federal University and Kazan Federal University.

The implementation of the online education program assumes that if two students have entered Skoltech and, for instance, MIPT in the same subject area, they can study in two different places but in one program. It's just that different modules are studied at different institutions. Some of the courses are at Skoltech, while others are at our partner universities. Upon completion, the student writes one dissertation and, if they defend it successfully, receives diplomas from two organizations.

At Skoltech, students choose their own courses. The same practice is widespread at Western universities. How does that work?
Yes, the structure of our education program is based on the Western model. Students must accumulate 120 credits [ECTS credits, the European Credit Transfer System] in two years of full-time study at the master's level. The education program is made up of several modules. The first is Compulsory Courses. These are the courses that form the core of every program.

There's the Entrepreneurship and Innovation module that I've already discussed. The rest is based on the chosen professional trajectory of each student.

In the Elective Courses and Projects module, students can take courses from Skoltech's entire course catalogue. For example, a student in the Biotechnology program can take a course from the Data Science program. And vice-versa. The whole logic and structure of Skoltech education is based on a multidisciplinary approach.

Nowadays, all the most innovative ideas are born at the nexus of several different spheres, and the possibility of acquiring knowledge from different scientific fields allows students to do remarkable things.

Would this not lead to a situation where students acquire a lot of superficial knowledge at the cost of profound learning in a single area?
No. If students take on a course, they must study and successfully complete it. And we naturally advise our students to always turn to their academic advisors for help and guidance. They are mentors for our students and help them make informed choices.

Skoltech students have a lot of personal projects. Is this thanks to Skoltech, or does the university initially recruit only those students who are motivated and driven to achieve?
I think it's a combination of factors. I'll repeat that, on the one hand, we recruit motivated people. On the other, the opportunities Skoltech provides contribute significantly to the development of their own projects, ideas and initiatives.

Skoltech's official stance is to contribute as much as possible to the development of additional activity not directly related to the education program, but nonetheless concerning students' professional activities. For instance, our robotics team's participation in the Eurobot competitions is organized and financed by Skoltech.

How do international applicants find out about the university? And how do you recruit them?
Currently, international students comprise about 20% of the Skoltech student body. We have a lot of professors who

An important point we look into during the interview is motivation. Students tell us why they want to enroll in our MSc programs. We want to see people who clearly envision their future professional or academic path

Skoltech's official stance is to contribute as much as possible to the development of additional activity not directly related to the education program, but nonetheless concerning students' professional activities.

do not speak Russian, and just as many students. This doesn't bother anyone, as our official language of communication is English. As soon as students cross the threshold of Skoltech, we expect them to communicate in English. That's why language is one of the important criteria in the selection process.

As for the recruitment of international students: we are actively developing international networking in the academic sphere, and our international students recommend Skoltech to their friends.

Would you mind speaking about the admissions process in general?

The application process is as follows. On the apply.skoltech.ru site, you have to fill out a form that has several important features. First, references. Reference letters must be attached, and we advise that one of them be from the applicant's current academic advisor in their bachelor's program. It's worth looking into any case where a current advisor is unwilling to vouch for his or her student.

It's important to convey all of your achievements on the form, particularly when it comes to publications and participation in academic competitions. We then shortlist all appealing candidates, and invite all shortlisted applicants to participate in a two-day admissions process. During this process, applicants take exams in various areas. All applicants take a mathematics exam, and the other exams are course-dependent. After that, each applicant conducts an interview with professors. These tend to take about 20-30 minutes. During interviews, candidates must present themselves and talk about their research and their academic and professional achievements. On the second day, we hold an English proficiency exam.

An important point we look into during the interview is motivation. Students tell us why they want to enroll in our MSc programs. We want to see people who clearly envision their future professional or academic path, can tell us about their interests in a scientific field and can explain why exactly Skoltech can help them pursue their dreams.

Setting academia aside for a moment, what can Skoltech students do in their free time?

Skoltech has a lot of clubs and societies based on shared interests, including sports, dance, discussion, music, language and, of course, tech.

We support any productive student initiative and provide resources. We believe that effective study requires a comfortable environment. Extracurricular activities are a very important component of that comfort.

AT A GLANCE

- In the 2017 application campaign, the Skoltech Master's programme received, on average, 15 applicants per place, though in several courses there were as many as 30.
- In 2018, Skoltech will move to a new campus currently under construction at the Skolkovo Innovation Center.
- By 2020, 1,200 postgraduate students will study at Skoltech.
- The standard stipend of the Skoltech Master's programme is 40,000 rubles. That number can increase to 50,000 rubles during the first year of study and 55,000 during the second. Stipend level depends on academic success.
- All students of military age are provided with an official military service deferment.

WELCOME!

In the 2017-2018 academic year, 251 graduate students swelled the ranks of the Skoltech student body, including 4 visiting students and 47 international students from Mexico, Brazil, Greece, and India, among others (24 countries in total). According to the results of the latest competitive recruitment process, the Data Science, Biotechnology, Space and Engineering Systems, and Materials Science Master's degree programs are in high demand among international students.

#CHANGINGTHEWORLD
#PHOTONICS
#ROBOTICS
#QUANTUMMATERIALS
#ENERGYSYSTEMS
#DNAEDITING
#SPACEWEATHER

changing the world

#3

Biologist and Skoltech PhD candidate Sergey Shmakov shares some insights about his scientific journey, genome editing technology, his hopes for the future and how he strikes a good work-life balance.

Genome editing is one of the most promising areas of modern biology. In the 20th century, it was used in pharmacology, to produce human insulin, for instance. Nowadays, thanks to discoveries in bioinformatics and advances in molecular biology, the potential of genome editing has revealed itself to be nearly limitless: from developing hypoallergenic fruit and vegetables that are resistant to pests and can be preserved several times longer, to human genetic modifications aimed at treating both hereditary and acquired diseases.

Sergey Shmakov

//Working with human embryos poses a lot of ethical questions//

How did your early education influence your career?
I attended a typical secondary school in Voskresensk [near Moscow]. I was influenced by my parents and, of course, my grandmother. She was a math teacher, and that left a strong imprint on me. In school, I was really into computer and information sciences. But our school had an in-depth biology class. Its key distinction was the teachers, who were known for being excellent educators, so I opted for that path. Upon nearing graduation, I applied to Bauman Moscow State Technical University.

What course did you choose at the university?
When the time came to choose a department and a course, I applied to Information Security but enrolled in Software and Information Technologies.

How did you move from Computer Science to Biology in university?
We had a modelling course, and a friend and I began brainstorming how to model live cells. You could say that was the start of my path toward bioinformatics. Then I took coursework that involved modeling a multilevel security system. While completing this course, I was inspired by books and lectures on the structure of human and animal central nervous systems. I wrote a dissertation entitled “Fuzzy Logic Controllers for Financial Market Objectives.” Essentially, I wrote an expert program that made decisions based on known input data. After graduating from university, I accepted a job at Microsoft Russia, where I worked for six years, until 2014.

How did you decide to return to science?
I couldn’t let go of the ideas and pursuits I had developed at university. In 2012, I entered the Yandex School of Data Analysis in Bioinformatics. At that time, Professor Mikhail Gelfand was in charge. The lecture course was taught by Professor Konstantin Severinov, who is now my academic advisor. His subjects interested literally everyone, and during the summer holidays we agreed to try working on a project together.

When did you enter Skoltech?
When I finished bioinformatics school, I was grappling with what to do next. I felt that the only way to continue building my career at Microsoft would have been to move to Denmark or the United States, where the company’s largest offices are located. On the other hand, bioinformatics offered fundamental challenges and the opportunity to work with extremely interesting people. In the end, I chose bioinformatics when Professor Severinov suggested I enroll in the Skoltech postgraduate program.

And that was followed by a joint project with Eugene Koonin, an expert in computational evolutionary biology at the National Center for Biotechnology Information in the United States, for which you received the National Institutes of Health [NIH] Director’s Award. What was that project about?

We created a pipeline [a chain of transformation processes based on input data] to analyze databases in order to search for new CRISPR/Cas systems. Our pipeline analyzed data in the database after we gave it examples that interested us. The algorithm ranks proteins that are located next to the right area according to certain criteria, and then we review the result and select the data that interests us. When we were writing the algorithm, we started from paradigms of gene collocation that have a common function. If there is a CRISPR/Cas cassette with a set of spacers separated by repeats, then there must be CRISPR/Cas genes nearby. First we took Cas1 protein. In the future, the CRISPR/Cas system will use these resources to recognize foreign DNA and destroy viruses. In all, this process helped us discover four new CRISPR/Cas systems.

Why did you take Cas1 protein specifically?
Because it's the most conservative protein of the entire system. It's part of the adaptation module of spacer integration into a cassette, which helps bacteria to eventually become resistant to a virus that has the same DNA sequence as the one written in the spacer. The subjects of our search were nuclei that cut DNA viruses. This is very important and useful from the perspective of improving potential genome editing.

Is your program available to other researchers? Does it have any counterparts?
It's not a full-fledged program; it doesn't have an interface, only data transformation algorithms. The pipeline is written for direct work with databases and is not intended for remote work, such as by using a web interface.

There are no available programs with that functionality because we wrote algorithms to search for the specific traits of CRISPR/Cas systems in all available genomes and metagenomes available at the NIH.

What did you discover?
During the implementation of the first study, we discovered four new types of CRISPR systems: types 5a, 5b, 5c and 6, with corresponding proteins Cpf1, C2c1, C2c3 and C2c2. I recall that we started our search with Cas1 protein and published our work in 2015. In the second study, we changed the data set and took located CRISPR cassettes from the point where we'd started our search in the database.

We launched a pipeline with cassette data and found several more system types. We discussed the fairly interesting data we'd acquired at a conference last summer, while the paper came out just recently in January of this year in Nature Reviews. Publishing a paper is a fairly lengthy process due to stringent editorial requirements.

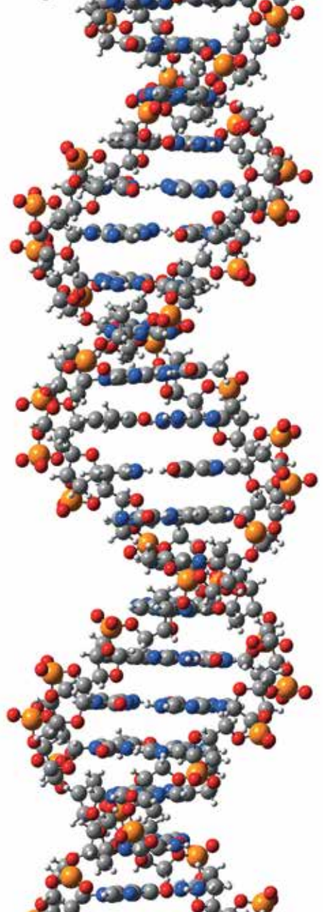
How much has yet to be discovered in this field? Do you think it's likely that there will be unexpected developments and entirely new proteins?
On the one hand, the list of open proteins and system types is constantly expanding. First we described four, then we published the next study, where we described several more types. Another group of researchers found several more. I think that's how this work will continue.

But I agree with my colleagues who say that the main players in the CRISPR systems have already been discovered and that the addition of new proteins won't radically change the big picture. The recently-added types 4, 5 and 6 have a prevalence of around 1.5%, if we consider all bacteria and archaea.

Interesting. Switching gears now: how difficult was it to enroll in Skoltech?
The competition was fairly high. There were exams for various courses and a tough English test.

Was it difficult to combine your studies with your work at Microsoft?
Studying at Skoltech is intensive. I found that I needed to dedicate nearly all my time to my studies, and ultimately I had to quit my job.

Did you live on your stipend alone?
The Skoltech stipend is quite generous – it was only slightly lower than the salary I was earning at Microsoft. I have to say that a high stipend is an incredible advantage, as you don't get distracted from your studies by frequent financial issues. On the other hand, it can also relax you: why go somewhere else if they pay you well here?



Tell us a little about the study itself.
My program is made up of modules and different specialized courses. For instance, Professor Pyotr Sergiev from Moscow State University taught a course on molecular biology, and there were courses on stem cells and other lines of study as well.

Did all students have similar areas of study?
No, not always. We were given time to decide on an area of study and later work. There were a lot of meetings and discussions with lecturers and professors from Russia and abroad. One of Skoltech's strong points is its inclusiveness. Soon we'll have our own laboratory for research in the field of biotechnology. That will be really nice: before we had to send graduate students to other laboratories in Russia and abroad.

There were a lot of meetings and discussions with lecturers and professors from Russia and abroad. One of Skoltech's strong points is its inclusiveness

What was it like to work with one of the most well-known Russian scientists, Konstantin Severinov?
That's an interesting question. When I began study in the bioinformatics school, I didn't know anything about Konstantin. Now I can say that working with him is very interesting. He's an open person and not limited to his area of expertise.

I can tell you that scientists I've had the privilege of working with have been established and well-known in their fields of study. As supervisors, they want results. On Friday of every week I draw up mini reports of what has been done in the past week and what is planned for the next. When I began work with Eugene, it started to take me about an hour to draw up those reports, because he asked me to describe everything in greater detail.

Were you nervous before your first publication? Were there any doubts or suspicions about the data?
During the publication process, we already knew we'd found a working CRISPR/Cas system. Before publication we had started working with experimental laboratories that received our data about the candidates. The moment the paper was released, we already knew that our discovery indeed existed, worked and was a subject of interest for other scientists. That's why there weren't any doubts as to the validity of the data. Of course I had some anxiety about the following paper as well, but it wasn't too bad; when there's a lot of work to be done, there's no time to waste on nerves.

How did you feel when you learned you had won the NIH Director's Award?
When the letter arrived announcing I had won, I didn't think too much of it. I figured it was just another nod of approval. But later, when information about the award began to spread around the NIH and beyond, people I didn't know, whom I'd only met in the corridors, began to congratulate me. The award is quite prestigious and demonstrates the importance of the study. The ceremony took place at the NIH, in the main hall. Though the award has no monetary benefits – no prize money or other rewards– it was a big boost of confidence and strong motivation to keep moving forward with my work.

Who else won the award with you?
It was given to the entire team: Koonin, Kira Makarova, Yury Vulf and I. They gave us a large framed document stating that we had done some excellent work.

What changed after the awards ceremony?
Essentially, nothing, but that award motivated us to keep working and gave us a public response. We've gotten noticed, and that's good for receiving grants and money for further research in the laboratory.

You work a lot in the United States, in Koonin's laboratory. Is this necessary for your research?
When Eugene and I began working together, he set the condition that I had to work for at least three years. We had something like a contract, which is why in February 2018 I'll continue to work at his laboratory. I don't have to go there to monitor things, it's just far easier to collaborate in person. The problem is that we have too great of a time difference. When it's daytime in Russia, it's still night there. And vice-versa. Sending e-mails isn't convenient, because you have to wait a day to get a response. There, all you have to do is knock on the next door.

Meanwhile, you're continuing study at Skoltech?
Yes, right now I'm getting ready to defend my PhD dissertation which, unfortunately, has limited my work opportunities. But after that we have several more projects that I'd like to complete.

What do you think the future holds for your research?
CRISPR/Cas systems can be utilized in several fields. First of all, there's gene therapy. There are no fundamental problems, as it doesn't change the structure of the entire genome, but treats separate cells in the adult body. For instance, there already are methods of gene therapy at the primary stage of clinical trials for oncological diseases.

Another field is embryo editing, not necessarily for humans; you can also edit animal genomes. For instance, to create cows with milk that contains essential nutrients.

A lot of ethical problems arise when working with human embryos, because any modification can give advantages relative to normal people.

If genome editing methods are abused, this will negatively affect population diversity. For instance, if everyone makes their children blue-eyed and blond-haired along with other preset parameters, for example, metabolism or body proportions, that can lead to human populations becoming vulnerable to pathogens that exploit the uniformity of the species.

Something similar occurred during the uncontrolled spread of antibiotics, which were taken in the 1950s and 1960s for practically everything. In the end, we accelerated the evolution of pathogenic bacteria with resistance to antibiotics.

It's important to understand that a CRISPR/Cas system is a tool, and how it will be used is a decision that everyone will have to make.

The assistant professor of the Skoltech Space Center shares her thoughts on the importance of space weather and the Sun for our daily lives.

Tatiana Podladchikova:

//We have to take space weather forecasts into account in our daily plans//

When you want to understand something at the beginning of a journey, you don't know what's driving you. Standing by a river, we can watch the water endlessly, look forever at the flames while sitting by a fire, and gaze ceaselessly at the sky while lying on the ground on a starry night. My journey began with the Sun.

The idea of a link between humans and the external environment arose in ancient myths and beliefs. A scientific study of these solar-terrestrial links was established by the renowned Russian scientist Alexander Chizhevsky. He said that Earth is always in the embrace of the sun. And the mood of the Sun is transmitted to Earth through these embraces.

Dynamic events on the Sun influence both humans and the operation of technological systems. Space exploration, which has been undertaken relatively recently, has led to the emergence of a scientific field that studies space or solar weather. Today, space weather forecasting is used in many areas of human activity in space and on Earth. Due to heightened solar activity, satellite television antennas and other equipment is temporarily turned off, warnings are issued about the faulty operation of navigational devices, flight trajectories are changed, and all satellite maneuvers are halted.

Solar wind is constantly leaking from the solar corona, the Sun's atmosphere, in the form of charged particles that blow over Earth and the other planets of our solar system. Solar wind carries the Sun's energy, and stretches and carries the solar magnetic field into outer space. As a result, the entire solar system is full of solar wind and the solar magnetic field. Because the Sun revolves, the magnetic field in interplanetary space assumes the form of wavy spiral folds, like the multi-layered skirt of a ballerina. Earth and every planet in the solar system inhabit these folds. Thus, we live in the Sun's atmosphere, part of an inextricable link between space and humanity.

On 23 November 2015, at the 12th European Space Weather Week in Belgium, I had the great honor of receiving the International Alexander Chizhevsky Medal for Space Weather and Space Climate, which is awarded for "major contributions to space weather research of those who were unafraid of risk and followed uncharted paths in order to succeed." I was lucky enough to work together with like-minded people who shared their profound knowledge with me. Together, we found the necessary tools to create new space weather services, forecast solar activity and geomagnetic storms, and also create an effective model of the recovery of the dynamics of Earth's radiation belts.

We already have to take space weather forecasts into account in our daily plans. In 1859, a powerful geomagnetic storm disabled the entire telegraph system in North America and Europe, and certain devices that were disconnected from communication lines continued to be charged directly from the atmosphere. In 1988, a geomagnetic storm triggered a massive power failure in Canada, leaving six million people without heating, power and radio for nearly a day. On 4 November 2015, a solar flare led to the interruption of air traffic over Sweden due to the disruption of the radio and radar systems operations. Recently, on 6 September 2017, a powerful solar flare compelled ISS crew members to relocate to an onboard shelter. Cases of the disruption of rail network signaling systems are well known, i.e. cases when the railway signal spontaneously changes color from green to red. Knowledge of space weather and its influence on humans and technology will make it possible to understand when humans are safe in space and on Earth. I hope you're all enjoying the nice space weather!

A second-generation geologist, senior research fellow and one of Skoltech's emerging stars, Leyla Ismailova is about to play a very important scientific role in a cooperation with Gazprom Neft

Leyla Ismailova:

//Be interested in what's going on around you and be proactive when it comes to taking new initiatives//

The daughter of a field geologist, Leyla Ismailova seems to have been born with an innate passion for science and a unidirectional work ethic. By 16, she had chosen to follow in her father's footsteps and enrolled in one of Russia's leading university programs in Geology. A decade later, while many of her peers were still grappling with what to do with their lives, she has already earned her PhD from a prestigious university in Germany and landed a coveted research position with Skoltech's state-of-the-art Hydrocarbon Recovery Center. In the interim, she published a host of articles in such prestigious international journals as Science Advances, Nature Communications, Nature Scientific Reports and American Mineralogist.

Ismailova has achieved feats in her young career that to many would seem unfathomable.

"I'm still deciding whether I want to pursue a career in academia or in industry," she said. "This is one reason I was attracted to Skoltech, because it bridges the gap between the two."

The project Ismailova is currently engaged in is a prime example of the fusion between these two spheres. In June, Skoltech President Alexander Kuleshov and Vadim Yakovlev, First Deputy CEO of Russian oil giant Gazprom Neft, signed a cooperation agreement aimed at formalizing a long-term partnership between the Institute and the company. The planned cooperation will use machine learning in the context of big data to help resolve areas of uncertainty that industry professionals have long struggled with, and to help oil companies make more optimal decisions, according to Skoltech Assistant Professor Dmitry Koroteev, an author of the agreement. Ismailova will play a key role in this project, maintaining responsibility for measuring, analyzing and testing the physical and chemical properties of rocks and minerals using various lab techniques.

She developed the relevant skillset while earning her MSc at Lomonosov Moscow State University (MSU) – during which she focused on diamond formation – as well as during her PhD program at the University of Bayreuth in Germany, where she studied the effect of various elements on the physical and chemical properties of the Earth's mantle.

"From a scientific point of view, what I'm most proud of in my career thus far is a project that I did during my PhD study," she said. "We found a stable mineral in the Earth's mantle and also showed how iron and iron oxidation states can change the physical properties of mantle." The resulting paper can be found here.

In a subsequent study, Ismailova and her team made a groundbreaking discovery regarding the process of diamond formation near our planet's core.

To conduct these studies, Ismailova and her team simulated the conditions present deep in the Earth's mantle. Such simulations are necessary because they're looking for information pertaining to depths of 2,500 kilometers, while the longest drill on earth can only reach depths of some 12 kilometers.

Ismailova attributes much of her professional success to the fact that she had the foresight as a teenager to choose an academic path that she loved. "I'm proud that I'm still following that path that I chose for myself when I was at university," she said, explaining that many of her university friends realized during their studies that Geology wasn't the right fit for them, and ultimately opted instead to pursue fields as diverse as fashion and consulting.

Beyond choosing a field they love and finding mentors who believe in them, Ismailova has some simple, sage advice for aspiring scientists: "Be interested in what's going on around you and be proactive when it comes to taking new initiatives."

A computer science specialist, Skoltech research fellow Mikhail Belyaev told us about his path to science, explained his work process with research data and explained how people can manage various devices using the power of thought.

Data analysis and machine learning expand far beyond smile recognition in smartphones and individually targeted product displays. Big data helps companies save time and money on the development of high-tech products, defeat incurable diseases and help paralyzed people interact with the world.

Mikhail Belyaev:

//For us, all challenges are mathematical//

Mikhail, would you mind telling us what school you went to? Did it specialize in mathematics?
Not at all. I graduated from a typical school with a general education program in Ryazan, but I studied in a physics and mathematics class. Then I enrolled in a physics and technology institute in the radio-frequency engineering and cybernetics department and studied data analysis and machine learning. I began participating in industrial projects when I was still a student. I was able to design and integrate machine learning algorithms for several large engineering companies.

What projects have you worked on?
One of the tasks we have worked on involved a Formula 1 car. The heaviest part of the car is the safety capsule, where the driver sits, around which a chassis is built. These formulas are based neither on aerodynamics nor on the knowledge of physical processes, but rather on the data that we gather from our experiments. We have created a model that works for different sets of parameters and can tell the strength of the capsule according to different data. We now have a machine that can quickly give answers for different combinations of parameters. We can input different parameters or use special optimization algorithms to find the best option. As a result, we have managed to reduce the weight of the capsule by 10%, without sacrificing its strength and security.

After graduating from the Moscow Institute of Physics and Technology, you continued your scientific work and became an employee at the Institution for Information Transmission Problems of the Russian Academy of Sciences and the Datadvance company, a spinoff of the Institute, where, among other things, you led a project to build a model for a cooling system for nuclear power plants. Would you say that machine learning could prevent a catastrophe like Chernobyl?
We had a more modest task. We made a prognostic model of how cooling systems at nuclear power plants become clogged. A water cooling system is usually used at power plants. It consists of

The current level of information technology makes it possible to gather an extensive database of patients who suffer from a particular disease, and then apply advanced methods of data analysis

A headset reads the patient's neurophysical indices and transforms his thoughts into text typed on a keyboard. An immobilized person can type a text without any physical effort

a huge number of pipes through which water flows and cools the steam used to rotate the turbines. Over time, this system begins to clog. Our client wanted to know if it was possible to analyze the extent of the clogging using electromagnetic measurements outside of the pipes. We created a model which reliably describes the degree of clogging within the system, using these measurements. All of our experience and developments, which we used in projects with Formula 1, Airbus and other clients, formed the basis of the algorithmic core of the pSeven program, which helps engineers without experience in data analysis improve the technical characteristics of products during the design phase.

How much time does a project like that usually take?

Depending on the complexity of the project, it typically takes about one or two months. A lot of this time is spent not on solving the problem but rather on deciding how to formulate it. All of our work with Formula 1, Airbus and other companies can be divided into two parts. The first part involves coming up with a mathematical method that allows you to build a model, and to make a program that works the way we intended. The second part involves taking a specific task and data, applying the method we created to this data and solving the problem.

Engineers who work on creating a complex object always have a set of parameters that need to be improved. It takes a very long time to immerse yourself in the specifics of the topic, to talk to the engineer, read something, talk again and formulate the task of analyzing the data in such a way that it meets the needs of the client. That is, tied to the goal that is in the client's head. Usually the project goes through several iterations. First you formulate a hypothesis, then you conduct experiments and you bring the results to the engineer. He says "Yes, that's great but it's not what we need." Then we have to return to the discussion of the problem and start again.

In 2015, you headed the data analysis sector in neuroscience at the Institution for Information Transmission Problems of the Russian Academy of Sciences. Why did you switch from aviation and mechanical engineering to medicine?

I am still engaged in mathematics and data analysis. In medicine, just as in the case of problems in industrial design, we develop analytical methods that are adapted to a particular type of data, for example: an MRI of the brain. We do not cure but rather we try to analyze the data in order to diagnose the disease as early as possible, to simulate its development and to evaluate the effectiveness of therapeutic intervention.

Imagine that a doctor observes an ill patient for a long period of time, for example, one to two years. It is important for the doctor to understand how the patient's disease will develop in the future to be able to carry out effective treatment and prevent the emergence of unwanted symptoms (a very clear example of such symptoms is suicidal tendencies in people with Huntington's disease). Knowing the patient's medical history, our task is to predict the development of the disease in the future. The modern level of information technology makes it possible to gather an extensive database of patients who suffer from a particular disease (Alzheimer's, Parkinson's or Huntington's). You can use advanced methods of data analysis to solve problems in this area. This is what we are doing.

Skoltech Professor Vladimir Zelman said that the ENIGMA international consortium, which deals with the study of the human brain, does not have enough mathematicians. The material that they have gathered needs to be processed.

The Enigma project studies anatomical differences from the norm in brain pathologies and tries to understand where the parts of the genome are located that code the anatomy of the brain. We want to bring modern methods of data analysis to this project but so far this idea is only at the launch stage. This process is not easy and it is not fast because more than 100 centers around the world are participating in the project. The project leaders from the University of Southern California are now doing a lot of

Vladimir Zelman
Skoltech Professor

"A tidal wave of new technology using advances in physics led to the invention of new tools and tests that have enabled scientists to study the brain at work and start the process of deciphering thoughts using powerful computers. The ENIGMA international consortium (which brings together 200 universities from 37 countries), where I serve as coordinator for international cooperation, helps to unlock the mysteries and capabilities of the human brain. I am pleased that Skoltech is our strategic partner and coordinates over 10 centers in Russia and the CIS under this project."

organizational work so that they can use the latest achievements to analyze the colossal data samples that have been collected so far.

The CoBrain project is currently being developed at Skoltech and this project is supported within the framework of the National Technical Initiative. The task of CoBrain is to create an infrasturcture for the collection and analysis of data on the structure and functioning of the brain. We have big plans for cooperation with leading Russian medical centers. After all, we are unable to formulate for ourselves clinical tasks that can be useful to society, so it is important for us to find partners who can help with this. Constant contact is needed between professors, researchers and doctors who communicate with patients every day. We need radiology specialists who have a deep understanding of the MRI process.

We need to build an infrastructure that will help us to process data about the brain from MRI and EEG scans, for example, by using modern methods of machine learning. It is necessary to develop methods of analysis from this data in particular so that in the future, this infrastructure will become a place for scientific medical research and the birthplace of new ideas and start-ups.

You are now working on creating a "brain machine" neurointerface. In the future, a person will be able to control various technical devices using the power of thought?

In fact, this technology has been around for 15 years but it has a significant limitation – it is very slow. Such a system was tried for Twitter, so that a paralyzed person could write by character. But it ended up taking half an hour to compose a single tweet using this method. Speed is the main limiting factor. Our research, therefore, is not aimed at creating such methods; they already exist. Rather it is aimed at accelerating and developing this technology.

Within the National Technical Initiative, there is a project by Alexander Kaplan. This project is devoted to the development of a more convenient system for paralyzed people to interact with the world through a neurointerface, including communications with doctors and releatives. A special headset reads the patient's neurophysical indices and transforms his thoughts into text typed on a keyboard. As a result, an immobilized person can type a text without any effort, using only his mind; the entire alphabet appears on a screen, the person concentrates on looking at each letter and thus prints the text. To make sure that everything works correctly, it is necessary to conduct many experiments and to teach the machine to correctly recognize signals from the brain. The person is shown letters, the activity of the brain is monitored and the data is collected in a catalog.

Do you have time to teach?

I teach at Skoltech and at the Moscow Institute of Physics and Technology, I teach a course called "Introduction to Machine Learning and Data Analysis" with my colleagues. We ran an applied course at Skoltech. We try to teach the students how to work with data so that they can acquire practical skills in constructing models and can use them in their research. This course is for students of different specializations, for biologists, for example. The idea of this course is to abandon the lecture format and focus on practical tasks in the format of a seminar. The tasks are something like this: here is the data and you need to do this with it. We do not give them anything other than the data. Students need to figure out how they will handle this and write their own program for processing. As a final project, we give them a real challenge from the business or science spheres or we ask them to do a project that is connected with their research, using what they have learned.

Could you tell us about a project by one of your students?

Emil Davletov, a Master's student at Skoltech, is studying ultra-low temperatures. During an experiment, a special arrangement compresses a cloud of atoms and it is necessary to observe how quickly this compressed cloud begins to expand. The faster it expands, the higher its temperature.

Using standard technology, it is necessary to make a series of ten photographs using special equipment. It is not possible to take ten photographs during one experiment because the cloud scatters too quickly. We had to conduct ten experiments – in the first, we took a photograph at the start, in the second, with a slight delay after the start and so on. The experiment took a long time as it was necessary to set up and run the entire system ten times.

The idea of the project was: is it possible to achieve a result if only two photographs are taken instead of ten, and then use machine learning methods? It turned out that it is possible. By the end, Emil had received high-quality predictions of the results for the whole experiment.

We can carry out an experiment five times faster, evaluate what happened and in the case of interesting results, carry out a full experiment to get reliable figures. I am pleased that students have begun to apply the knowledge that we gave them.

Ekaterina Khrameeva:

//It would be exciting to find a set of molecules to help us think better//

A research scientist from the Skoltech Center for Data-Intensive Biomedicine and Biotechnology talks about how lipid research helps unravel the mysteries of the human intellect.

Would you mind sharing how your scientific journey began?

I was always interested in both biology and math. Around when the time came for me to go to college, a new faculty of bioengineering and bioinformatics was created at Moscow State University (MSU). Studying there was interesting: we had professors from the biology and the mechanics and mathematics faculties. It worked out as a double education at a crossroads between subject areas. Then I did further postgraduate study at MSU and went on to defend my thesis at the Institute for Information Transmission Problems of the Russian Academy of Sciences (IITP RAS). My postgraduate thesis was supervised by Mikhail Gelfand, who is a professor at Skoltech as well as at the bioengineering and bioinformatics faculties at MSU, and deputy director of IITP RAS. At some point, Professor Gelfand became friends with now-Skoltech Professor Philipp Khaitovich, who later became my supervisor. They started a collaboration, and another colleague, Pavel Mazin, and I went to China. Professor Khaitovich was working in Shanghai back then, heading the neuroscience lab at the Max Planck Partner Institute for Computational Biology. I spent a year in China, and when I returned to Russia, Skoltech had just formed. Professor Khaitovich was invited to be a professor here, and he began to recruit researchers. He created the same laboratory as the one in China from scratch. I was his first researcher. At the time, we weren't working in these buildings, but in the Hypercube. On my first day of work, I arrived at the Hypercube in a Kamaz truck because this was a construction site. Now an entire campus has sprung up, but back then there was just a field and the Hypercube building. That was in 2014.

What are you working on now?

Our lab is studying the evolution of the human brain. We examine how the brain works at various levels – in particular, on the molecular level: Which mechanisms work in the brain? How have they changed? And why have we become so smart compared to monkeys? Secondarily, we focus on the study of development and aging: we look for changes that happen in the human brain during development from infancy to old age, and we compare the same correlations in primates like chimpanzees and macaques. Though it may seem like humans are not all that different from primates, on the molecular

Humans are eternal children. The human brain works the way a primate's would work in the womb for quite some time

There are genetic markers for cancer, but that kind of research is lengthy and expensive, whereas we could suggest a new, cheaper form of diagnostics

level our developmental mechanisms are built completely differently. Humans are eternal children. That is, if monkey infants are born developed and can look after themselves, the human brain works the way a primate's would work in the womb for quite some time. For this reason, all neural processes function for a while just as actively as in the first year of life. Later, with age, it becomes more difficult for us to master new material. There's a physiological reason for it, and it's not that we're lazy or don't want to study. In childhood, the brain is built in such a way that it easily retains new information. This period is very short for primates, while for humans it's prolonged. Humans learn for longer; maybe that's the reason we're so smart. We recently got a new mass spectrometer at Skoltech. It makes it possible to measure metabolite and lipid levels in the brain. Nerve cell membranes are made up of lipids. The speed and quality of nerve impulse transmission depends on the composition of lipid membranes. We have the idea of measuring the lipid composition of human and primate brains of different ages and in different areas of the brain, comparing it all and attempting to establish a link between cognitive abilities and differences in lipid composition.

What is the ultimate aim of this study?
Well, for instance, one can imagine that in a hundred years we'll find some lipid that will make us smarter. In fact, it's unlikely that it will be a single component but, chances are, a set of molecules. It would be exciting to find a set that would help us think better.

Who is going to participate in the project?
All of Professor Khaitovich's group. We have five higher postgraduate students, and at least two will be involved in the project. I'll probably be the leading researcher. There are other researchers; we usually work with as a group, it's never one person per project.

Are there any ideas for future projects?
A very promising project is coming up with the Burdenko Neurosurgery Institute in Moscow. They carry out brain tumor removal surgeries. It's impossible to cut out just the tumor; a certain amount of healthy tissue also gets caught, and these samples are saved. There are samples of different types of tumors, different stages, both early and progressive. We are planning to study the lipid composition of tumors and the surrounding tissue in order to understand how they differ. This kind of search has never been done at the level of lipids, only at the genetic level. The mutations that occur in tumor tissue were compared with healthy tissue. I think it would be a very interesting addition to the overall picture, as this could be associated with existing data at the genetic level. Also, this will provide the opportunity to precisely differentiate types of tumors. This is important to consider for purposes of choosing a course of treatment. We've thought about startups and practical applications. First, we'll do the research, which will help us understand which lipids are common in which tumors. Then, knowing this set of lipids and tumor markers, we can quickly do an analysis during surgery and use these markers to establish the type and stage of the tumor, and the doctor can prescribe a therapy accordingly. It's a very affordable method. There are genetic markers, but that kind of research is lengthy and expensive, whereas we could suggest a new, cheaper form of diagnostics. At Burdenko we have been assured that up to 1,000 samples will be collected over the year. We hope that in half a year's time, we'll already have preliminary results. Several hundred samples will be sufficient to do pilot studies.

Which projects did you work on before Skoltech?
During further postgraduate study, we collaborated with Giessen University (Justus Liebig Universität Gießen) in splicing research. It's an important stage of biosynthesis that is responsible for protein diversity in various tissues. I also worked at MIT, in Professor Leonid Mirny's lab. Together we studied the three-dimensional structure of core chromatin: I created a computer model of the way a two-meter DNA molecule is placed and works in each cell.

Do you plan on staying at Skoltech, or do you have other offers?
I like working here; I don't want to go anywhere else. I've been working at Skoltech for three years now and they've just extended my contract, so I'll stay on for another year at least. I could, of course, look for work in the West. For example, I participate in collaborations with Germany, so I could go there. But my work is computing; I work at a computer, so my trip won't be all that helpful for the project's development. So I only go for short visits.

Skoltech PhD student and drone wiz Evgeny Tsykunov contemplates the future or unmanned aerial vehicles, and what businesses stand to gain from this rapidly evolving technology.

The Skoltech Intelligent Space Robotics Lab is reimagining human-drone interaction. Gone are the days where one would have to rely on a joystick and similar electronic advices to control an unmanned aerial vehicle. Now, we can control them with the help of gestures, or even the tap of a foot.

Skoltech PhD student Evgeny Tsykunov has already made waves in this field of emerging technology with the project LightAir, which strives to make drone technology accessible to non-specialists.

Evgeny Tsykunov:

//A box with a smartphone inside could fly from the warehouse shelf directly to a customer's home//

Tsykunov, his partner Mikhail Matrosov, and a team of developers with their fingers on the pulse have taken their technology on the road, gaining recognition by their peers at prestigious international exhibitions.

During the first trip abroad, to the SIGGRAPH computer graphics and interactive technologies conference, the project was categorized as a promising emerging technology and exhibited alongside the projects of top universities and companies. LightAir went on to secure the Laval Virtual Award.

We caught up with Tsykunov to learn more about his bright young career.

What attracted you to drone tech?

I was lured in by the prospect of doing something new while using limited resources. About 80 percent of our work is related to software development. We take ready-made flying platforms and develop software for them, that can be useful in various industries.

What exactly does the group working on unmanned aerial vehicles do?

We have several sub-groups, and in each one, there are people working on their own fields. For example, one student is working on a project aimed at developing a triple-axis manipulator for a drone in order to enable users to access difficult-to-reach places. To achieve this, the student attaches a robot hand to the drone. This is incredibly innovative; there are only a few similar projects in development around the world. The student and his team started with small, light drones. The hand, or rather the component, was printed on a 3D printer. A drone like that is very mobile. It can fly, grab something, pick something up and move around. We are actively working with various partners, including the logistics industry. They would be interested in transferring certain objects inside warehouses – from storage shelves to transportation – and then on to other premises. For example, a box with a smartphone inside could fly from the warehouse shelf to the store, or immediately to the client.

Which of your projects are you most proud of?

Our most recent project was LightAir, which was created by Skoltech professor Dzmitry Tsetserukou. This project is interesting in that it allows an ordinary user without special knowledge or additional devices like a smartphone or a console, to use and communicate with a drone.

To achieve this, we created a display that appears on the ground via a projection. This can work on any hard surface. We use a 3D scanner attached to the drone to make the display interactive. The user can then issue commands with his or her feet, by tapping on the image of the desired outcome. Generally speaking, interactive projections are currently in very high demand, so this project has attracted a great deal of attention from companies from a range of industries.

How can this sort of technology be used?

In a variety of different ways. We have created six specific applications. There are useful applications, like using a drone to project a map and relevant details on the ground as the user walks down the street. There are fun applications, like

using the floor projection to play a giant piano or a game of virtual football. You could even use it to order lunch. The drone can project the menu of your favorite restaurant, then you select what you want, and then the drone transmits your payment information and then collects and delivers your food. We've also come up with a specific application where users can take selfies with their feet.

What is unique about the project?
We wrote the software for gesture recognition. The concept itself is quite new; while many interactive projections already existed by the time we entered the scene, none of them involved a drone. In March, we were at the Laval Virtual computer graphics forum in France. There, we collected feedback that we will use to finalize the project. For us, it's imperative that users feel comfortable interacting with their drones. Toward this end, we plan to conduct a study to determine which control gestures come most naturally to users.

Why did you decide to focus on the use of feet instead of hands for this project? Surely it must be easier for users to issue commands with their hands, right?
When it comes to issuing simple commands like "stop" or "follow me" or "take a selfie," it's probably easier for a user to gesture with their hands. But if we're talking about human-drone interactions, and about the transfer of graphic information, hand gestures alone are not sufficient. Furthermore, the use of feet instead of hands gives us a bit of an edge; no one else is doing this. Plus, using one's feet to control a drone with the help of the image on the floor is sometimes more convenient and logical.

The scenarios that you mentioned are possible without the use of drones; maps can already be saved on a smartphone, as can games on a console. Why are drones necessary in this regard?
A drone has many advantages, particularly when it comes to convenience. It can carry additional cargo on board, and it can free up the user's hands while accompanying him. It also makes payments easier. If a user orders a pizza, for example, he or she may not want to pay in advance. Once the delivery arrives, the drone can project the payment data onto the floor, making it easy for the user to enter his card information once the pizza has arrived.

Are you working on making it easier for people to fly drones without crashing them?
We are working on this issue in the LightAir project. The drone has four degrees of movement: up-down, right-left, forward-backward, and U-turn. Furthermore, there are varying levels of drone control. Joysticks allow users to control all degrees of movement simultaneously, but they are really complicated, especially for a beginner. There's also the option of high-level management, where you can just say to the drone "fly away from me," "fly to me" or "fly north" and it follows your command. With the LightAir project, we're working on simplifying the command and control process with gestures. For example, a triple leg "tap" to order the drone to fly around a person and shoot a video.

Accumulators are another unsolved problem. Drones can only fly autonomously for a short period of time. Is the Intelligent Space Robotics lab working on this issue?
Not directly, but at the Skoltech Center for Electrochemical Energy Storage, professors and students are working on similar issues. And we are testing their developments.

Are there any other interesting of-the-moment drone developments you'd like to share?
Personally, I am very interested in swarms of drones. This is the subject of my dissertation. I did several related academic projects while earning my MSc. Those projects were related to a search for the most optimal distribution of functions between several drones. For example, say you need to deliver cargo. It turns out that in addition to the fact that the drone is carrying the cargo, it must also use on-board sensors and a computer to understand where it is flying and where to deliver the parcel. In conditions of limited carrying capacity and flight time, it is quite difficult for one drone to perform such complex tasks.

To reduce this burden on one drone, I allocated these tasks to two drones. One of them flies around the territory, checks for dangerous obstacles and finds the parcel's destination. The second drone simply carries the cargo on board and safely delivers it to the desired location, the coordinates of which are obtained from the first drone.

We carried out all of these experiments outdoors, using GPS. We recently created a system of motion capture and it very accurately tracks the movement of the object. With its help and without GPS, you can see exactly where the drone is and accordingly, monitor its position and orientation. Drone data is transmitted over a 2.4 GHz radio frequency. We also had the opportunity to experiment with drones inside of buildings. Toward this end, we're working on developing interactions between individual persons and groups of palm-sized drones. This is another very interesting area of study.

What else can drones be used for, from a practical point of view?
Part of our group is now working on creating a drone that will count inventory. Warehouses are required to carry out regular inventory counts for accounting purposes and to keep track of where everything is. This process consumes a great deal of man power, and often proves costly and inefficient for companies. Drones can do this work autonomously. They can fly, read and record the necessary data. Operators of large warehouses are eager for automated solutions. We work closely with them to make sure we're meeting industry needs in developing this technology.

When will this project reach the commercial stage?
We expect to test the first commercial versions of these drones in warehouses in about six months. Along with the drones themselves, we'll provide our test subjects with software for integration with their warehouse management systems, along with sensors, beacons, orientation markers, and charging stations.

Ekaterina Kotenko-Lengold:

//I was 14 years old when I began studying IT//

The vice president of aerospace startup Astro Digital, who hails from Skoltech's first intake of students, talks about how she was able to make satellite data accessible to a variety of businesses.

Ekaterina, would you mind telling us about your business in a nutshell?

Astro Digital's work deals with the Internet of Things. McKinsey estimates that the economic value of the Internet of Things will reach 11 trillion dollars within a decade. For context, Google in its current form could make that in 150 years. John Chambers, former head of CISCO, said that the Internet of Things would have a stronger effect on society than the Internet itself.

The Internet of Things is a virtual reality, and its components are data, analytical platforms and infrastructure for storage, processing and data transmission. Infrastructure is becoming increasingly simple thanks in large part to Amazon, and this makes it possible to rapidly build a scalable system. Data processing systems, such as neural networks, will also become accessible.

The high-quality data needed to build reliable models are the key problem. And it takes a lot of data. That means you need many stations to gather various information. Sensors can be placed in objects themselves–like the GPS sensor everyone has in their smartphone. You can also use remote sensors. Astro Digital works with remote sensors. Our remote sensors are cameras on satellites at an altitude of 600 km, which gather information from Earth's entire surface.

Which tasks could Astro Digital data help solve?

A lot of them! From evaluating crop production for grain trade to urban planning and tracking illegal construction, all in real time.

Do you have any competitors?

We're certainly not the first or only company to build satellites. What makes us different? We were able to create an extremely cheap satellite group. Our vehicles, about the size of a microwave oven, collect high-quality scientific data that can be used for deep analysis. In addition, this data is received with a high frequency: a fully deployed group can cover the entire Earth daily.

We have fundamentally changed the business model. Satellite data is typically sold in scenes, and the client pays for pixels. We began selling a monitoring solution by subscription: data as a service. We simplified access to it, making a scalable, rapid platform that makes it possible for any application to directly embed data.

How is it that you are already changing the world at 26?

I always dreamed of working on something big and meaningful. Psychologists say that 96% of people dream of something at least once a day. But how many of us turn these dreams into reality? Few. Why does that happen? Because dreams are scary. They're confusing: where to go and what to do. Over the course of my extremely brief career, I have developed a formula for chasing dreams: it consists of three essential elements.

The first and most fundamental is education. I started my academic career 12 years ago. I was 14 years old when I began studying IT. I went on to earn degrees in Economics and Management. A few years ago, I was lucky enough to be among Skoltech's first intake of students, where, supervised by founding president Edward Crawley, I learned how to create innovations and commercialize dreams. That definitely had an impact on me.

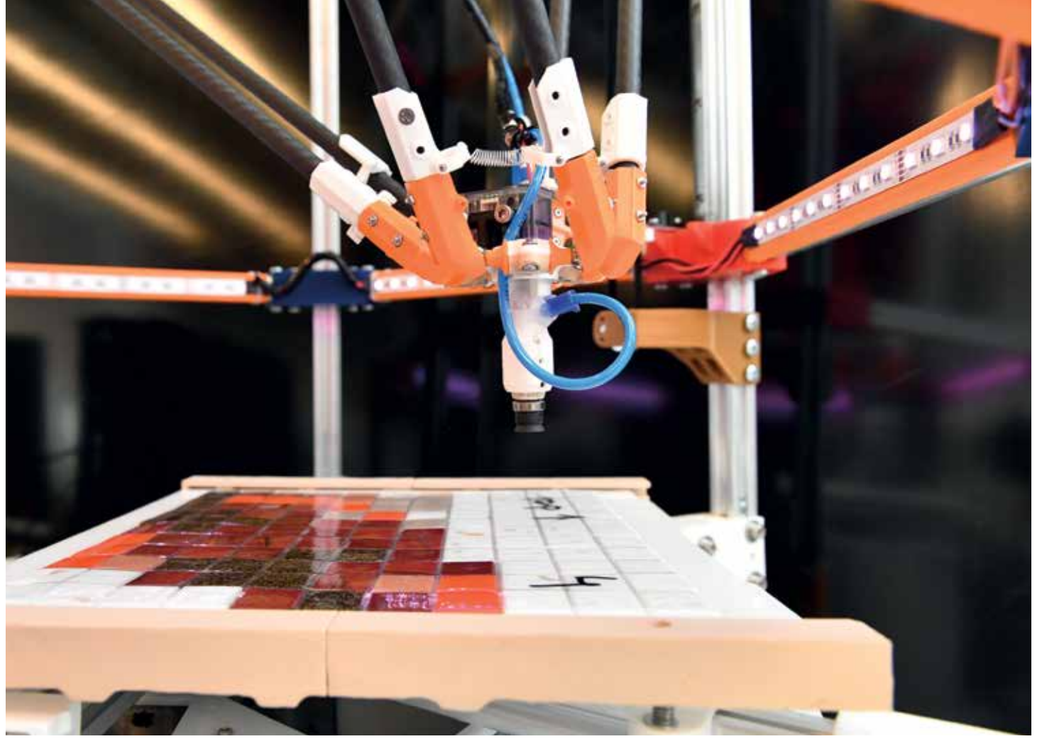
The second element that, thanks to Skoltech, I was also a part of is an ecosystem. It's the environment where we can "grow" our dreams. Institutes such as the Skolkovo space cluster make it possible for young, fragile, unconscious ideas and dreams to land on fertile soil. If you are around people who are busy doing the right thing, everything becomes a lot easier.

Well, and the third element, perhaps the most important, and which can't be forgotten, is extremely hard work. I am often in touch with successful entrepreneurs in both Russia and the West. They all have one thing in common: they are workaholics. They work 20 hours a day, if not 25. There's no formula for success that doesn't include hard work. I think it's important to bear this in mind, even when there are great institutions for development.

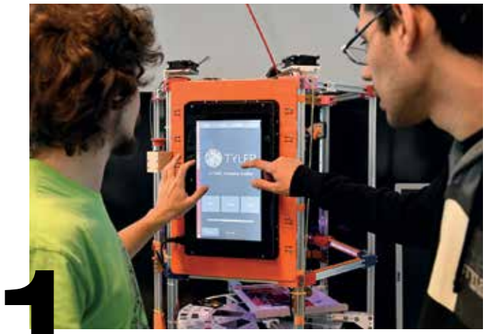
What stage of development is Astro Digital in now?

We recently closed a round of funding and attracted more than $16 million. We launched two test vehicles and two initial vehicles of the main group. Plus, we have developed a platform for data processing and distribution. The full group will total 30 satellites. Astro Digital also has a subsidiary called ImageAiry, which I founded; it's a resident of the Skolkovo space cluster.

5 startups



Bold and successful, these five startups were born and raised in Skoltech, from idea to market



1 TYLER

Tyler is the name of a robot that transforms digital images into mosaics. The team developed the concept behind Tyler shortly before they began their studies at Skoltech. During one of our brainstorming sessions, Andrey Sartison and Dmitry Ermachenkov came up with the idea of a robot that could create mosaics based on a digital image. The guys were thinking specifically about establishing a hardware startup, in light of the competencies they had at the time. Skoltech helped to gather feedback about the idea, develop a prototype, demonstrate it to various experts and present it at the Startup Village 2017. Tyler automates the whole process of mosaic-making and makes it possible to create a 1 m^2 mosaic in four hours — a process that could otherwise take two weeks of work. The team soon plans to begin working with different mosaic studios, interior designers, and real estate developers.

KOMARIK

A device for self-administered injections, created by Dmitry Vasiliev, allows users to automatically inject themselves with hypodermic needles, slowly administer their medication and withdraw the needle at the touch of a button. It is compatible with all syringes available at pharmacies, thus giving patients the freedom of independence. Requests to bring the idea to fruition came from various groups: relatives, medical staff in clinics, hospitals and the patients themselves. The meetings with these interested parties cemented the creator's belief that the device would be in high demand.

3

WICRON

Wicron is a developer and robotics manufacturing company that created the Webot, a Telepresence robot. The product is being used as part of Russia's inclusive education program. The aim is to help people with special needs engage remotely with the education system. Specifically, a person with special needs who is required to stay at home can deploy a remote-controlled mobile telepresence robot to record and transmit video and audio files from educational institutions. The idea was born after talking with the early stage investor Igor Ashmanov and reviewing the commercial prospects of the robotics market. Skoltech provided the laboratory for the project, where the team, Dmitry Suvorov, Roman Zhukov, and Evgeny Prodaikov could test the autonomous version. This is where they began to work on automatic movements, obstacle avoidance, the detection of people, and navigation.

INTOUCH

InTouch is tech that scans your physiology to detect your emotional state. Just one example of how this technology can be used is as an electronic wristband fitted with special biological sensors. The wearer will be able to view statistics about his or her emotional state using a mobile app. By monitoring emotional fluctuations, the user can seek unique solutions, thus leading to an improved quality of life. The idea behind the project evolved from simple beginnings: what started as bracelets for long-distance couples transformed into a technology that can detect a broad spectrum of human emotions, from joy to sorrow, by scanning physiological realities like the user's heartbeat. The co-founders, Anastasia Stelvaga and Alexander Martynov, came up with the idea upon returning to Skoltech from Boston after a study exchange program eager to try something new. Skoltech gave them a timely and vital opportunity – the chance to devote time to project.

5

EASY TEN

Easy Ten is an app created by Nikita Pestrov and Sergei Muratov that helps users learn a foreign language in ten words a day. Its primary distinction is that it was designed for casual learners, i.e. anyone who wants to learn a foreign language but doesn't want to set aside a significant amount of time to do so. The idea for the app came to one of the co-founders while he was studying medicine. At the time, he was trying to learn Czech, but he had hardly any time to study. His wife suggested learning 10 words a day. He loved the idea and eventually it evolved into Easy Ten. The team currently consists of 11 people, and Easy Ten has become a bestseller among educational apps. It is currently available in 11 languages. The team says that they wanted to do something like this even before entering Skoltech, but since arriving here, they have found ways to make the project even better. In particular, they've learned to properly validate the new ideas and develop a system for analytics and data collection. Now Easy Ten is moving in the direction of gamification so that the user will view the learning process as fun, not as hard work.

German-Russian Symposium

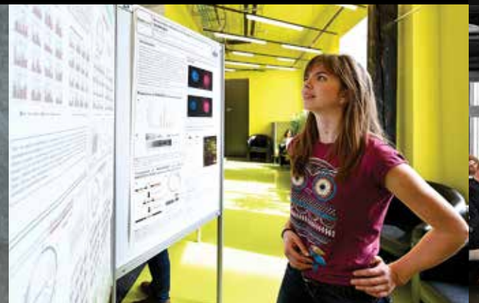
From 11–14 September 2017, Skoltech held the 7th German-Russian Week of the Young Researcher. This year, the annual conference, organized by the German Research Foundation (DFG) and the German Academic Exchange Service (DAAD), under the aegis of the German House of Research and Innovation (DWIH) in Moscow, was dedicated to computational biology and biomedicine. Aimed at strengthening partnership and cooperation between young Russian and German researchers, it was recognized as one of the most successful such conferences in recent years.

Innovation Workshop

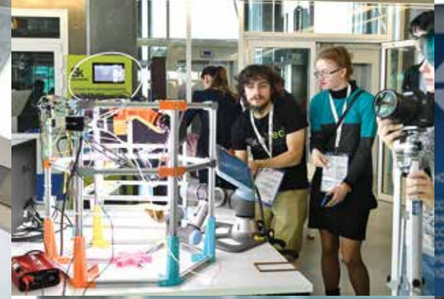
The Innovation Workshop is a course aimed at giving students the knowledge, skills, and attitudes they will need to become successful Skoltech students and innovators.
At first, students are divided into teams and tasked with coming up with a group project that they remain committed to for the course of the workshop. A key element of the course is the cooperation between the student teams and an array of invited experts who watch their presentations, provide valuable feedback and then serve as mentors, helping the students breathe life into their projects.

Shaping the Future

On 25–26 April 2017, Skoltech and the Massachusetts Institute of Technology (MIT) hosted a major joint conference “Shaping the Future: Big Data, Biomedicine and Frontier Technologies.” High-profile speakers included Skoltech President Alexander Kuleshov, MIT President L. Rafael Reif, Deputy Prime Minister of the Russian Federation Arkady Dvorkovich, Skolkovo Foundation President Victor Vekselberg, architect Pierre de Meuron and leading scientists and researchers from Skoltech, MIT, the University of Southern California and other universities and research centers.



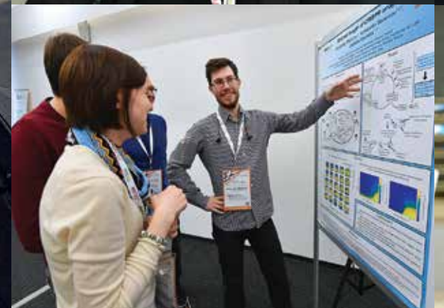

Shaping the Future:
Big Data, Biomedicine
and Frontier Technologies




РЭШ
Российская
экономическая
школа
Skoltech


Shaping the Future:


SKOLKOVOSCHOOL




Skoltech
The Engine of Your Future.

PROJECT

Ivan Oseledets:

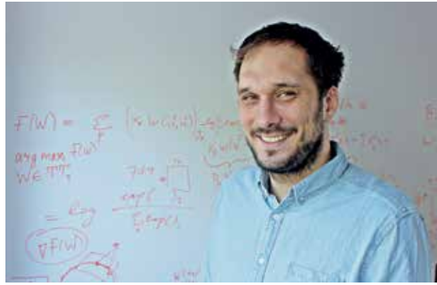
//Soil is a complex system in which chemical, physical and biological processes take place simultaneously//

Skoltech professor Ivan Oseledets talks about an interdisciplinary approach to agriculture, the trials and tribulations of analyzing large data sets, and how 21st century farmers use mathematics

When it comes to large data sets covering many variables, the direct recalculation of all possible combinations and conditions takes months and years of calculations. To record such data, you may need a server the size of Google's, for example. Mathematicians around the world have faced these obstacles when searching for algorithms to compute large amounts of data. Skoltech Professor Ivan Oseledets made a name for himself by finding a solution in 2009, when he published a highly influential paper on tensor trains (a sequence of mathematical decompositions and computations.)

Educational process and project activities at Skoltech are sharpened by interdisciplinarity. Tell us a bit more about Skoltech's current project with RusAgro.

Our main goal with this project is to increase the fertility of soils. This process is influenced by many factors and all of them must be taken into account. Soil is a complex system in which chemical, physical and biological processes take place simultaneously and all of them



are interrelated. We are interested in physical properties, for example, the porosity of the soil, because this affects a plant's ability to retain moisture. This porosity is formed due to the activity of whole communities of different microorganisms, processing residues and

forming the most important organic matter of the soil — humus. Our goal is to make an integral model suitable for fields with a certain soil type, climate, species of microorganism and precipitation level. To do this, you need to understand what to measure, how to do it and why. The latter is no less important because it is impossible to collect all possible parameters. This would most likely be pointless because the parameters could be related to others, or could be the consequences of others, or could have practically no influence on the result.

We started the project fairly recently, and it's meant to last for two years. Because I'm a mathematician, I manage the project. We identified the following key factors for collecting data: relief, soil physics, chemistry and the trace element composition of the soil, and biological components, including the diversity of communities of bacteria, animals, fungi, and plants. We rely on Soviet data to assess historical factors. In many ways, we do this in order to avoid a situation where we discover that something has turned out to be a lost crop after having spent two years analyzing it. All of these things should be foreseen and determined beforehand, not after. The project is not fixed, we are free to adjust the plan, tasks, and input new data, measurements, and results.

Why did you start with relief as a key factor?

This is one of the basic parameters that we could obtain and process relatively easily. We had satellite data on the terrain, albeit not very accurate data, and there was European weather data, which we re-analyzed. In general, all that can be obtained without leaving the office.

We compensate for the inaccuracy of satellite data on the terrain by using a special drone made by the company Geoscan, which is much more accurate. One drone can collect the data we need from a whole field in less than an hour. A field that seems smooth can easily have height differences of 20 meters or more. This affects moisture flow, how snow melts and the supply of nutrients to plants.

We do not restrict ourselves to relief: we went to the fields on two occasions and collected more than 360 samples and each sample was analyzed in ten ways. In comparison with climate data, field data is much smaller but highly accurate. We know exactly how much moisture and how many of the important trace elements are in each sample.

We do not forget that there are professors and agronomists on our team that can predict, for example, a crop failure without any modeling. We already discovered that in the experimental fields, an agricultural company used a very crude technique that ground the top layer of soil almost into a powder and because of this, there are no large lumps in the soil. Water does not remain in such soil and the local agronomist in such a situation will declare that there is a drought. Even through these very simple actions, by changing the type of processing, we can increase yields. We started the first field season with this.

Commercial projects often approach Skoltech to benefit from our expertise, as well as our analytical and processing skills

We carry out all of our laboratory studies in the Dokuchaev Soil Science Institute. We are also creating an agroinformation analysis department there. The support of the institute's director, Andrei Ivanov, has proved instrumental. In the future, we plan to optimize the process and everything will become much more mobile. A mobile laboratory will arrive at the field on a truck and will do everything that is needed on the spot. Combined with the drone, it will be possible to conduct mass research in a relatively short time. At the moment, it is still necessary to work without a mobile laboratory. This is not easy and it is certainly time consuming to take a drill, extract samples, and then transport everything back to Moscow for analysis.

Our goal is to make an integral model suitable for fields with a certain soil type, climate, species of microorganism and precipitation level

What will you do with all of this data?
The biological data will be considered in its simplest form, as a set of variables of different types. We will rework all of this into equations and a laboratory model so that we can answer further questions: what will happen if we add more fertilizers, change the precipitation regime, and so on. This is a very rough and unclear model but it will give us an idea of which parameters should and should not be monitored. To work with such a model, it needs to be calibrated and for this, long-term field experiments are necessary. But we do not have that much time, so we are preparing to create laboratory models at the new Skoltech campus which will open soon, and this will give us a little more data and indirect signs.

Do you focus on other projects?
There is a project at the Massachusetts Institute of Technology (MIT) that I really like. It's called MIT Open Agriculture. It's extremely simple: a camera is placed somewhere, a plant is planted there, along with sensors, and extremely informative data is obtained.

We are planning to order a lysimeter in Germany. This is a laboratory set up. A soil monolith can be loaded into it and it is possible to analyze the processes occurring within it. Skolkovo is no stranger to the lysimeter. The Nemchinovka agricultural research institute once had its experimental fields at Skolkovo and it achieved record harvests here. To this day, the remains of the lysimetric station still exists on the territory. It is usually said that it was the only one in the Soviet Union – at least the only one with huge gas caps.

How much is spent on your studies when compared to classical laboratory tests?
An agroproject can last indefinitely and you can invest any amount, but we are trying to do multifaceted work on a limited budget. We are a far cry from the costs of biologists. As they say about biologists: "When in doubt, buy yourself a sequencer." We, like them, spend a lot of time and energy on laboratory and field equipment. The drone already mentioned for the collection of relief data costs almost 1.5 million rubles. Data analysis requires computers with powerful graphics cards, the more, the better. We now have 14 graphics cards, we will soon have at least six more. Still, we're a long way away from having enough. What kinds of cards they will be will be based on the task: Tesla cards support double precision. Titan is cheaper and in tasks that require single precision, is in almost no way inferior.

What about the funding situation?
Thanks to Skoltech's capabilities, we have internal financing. This is a critical point, especially at the beginning of the project. We have some grants from Russian scientific funds, and before that, I had received a grant from the Education and Science Ministry of Russia. There are also external sources of financing. For example, we analyze data for commercial projects, which often approach Skoltech to benefit from our expertise, as well as our analytical and processing skills. They always find whatever they were looking for. And even taking into account the fact that Skoltech is not the cheapest option when compared to typical Russian academic institutes, companies still believe we offer the best value for money.

Artem Abakumov:

//The electric vehicle market will be worth 4.5 trillion dollars by 2030//

Artem Abakumov, a professor of the Center for Electrochemical Energy Storage, tells us about our battery-powered future.

What is your area of scientific expertise?

Inorganic chemistry – materials chemistry, solid state chemistry – crystallography and transmission electron microscopy. I can draw up a design of a material using knowledge of its crystal structure, electron structure, and chemical principles. And not just draw up a design; I can also find ways to synthesize the material, and investigate its properties and crystal structure. Specialists in this line of work are rare the world over.

What do you do at Skoltech?

Our Center creates materials for electrochemical energy storage. My field of expertise is metal-ion batteries. Do you use metal-ion batteries?

Yes, in my phone…

That's right, but now we want to move on from using metal-ion batteries solely in handheld devices to powering electric cars with them: we want to switch from fossil fuels to renewable energy sources. Cars need a much more powerful battery with properties that go beyond the existing technologies. To compete with the internal combustion engine, we need a battery that can power a car for at least 600 miles. What's more, the battery can't take up all the free space inside the car or weigh and cost the same as the car itself. The process of creating the right batteries starts with the study of materials.

The same is true for electricity storage systems in power supply networks. You need more than just batteries; you need large, reasonably-priced batteries with long lifespans. Otherwise, the

Our main objective for the next 5-10 years is to launch the production of materials for batteries in Russia

energy industry won't use them. Electric transport and electric power are the two main driving forces behind the technology. Projects like this cannot be fully implemented in isolation: they are the combined objective of in-depth cooperation between different organizations and various specialists across a wide range of disciplines.

Do you have a lot of competitors?

We do, just like in any other field of science that is inspiring global changes in the market and attracting significant funding. The Electric Vehicle Market is expected to be worth USD 4.5 trillion by 2030. It is obvious there will be a lot of competition.

How feasible is the use of this kind of technology in Russia?

In Russia, energy resources and ecology are not such hot button issues as they are in the West, but there are niche markets. There are a lot of vehicles with a limited mileage range, for example, in public transport. Kitting them out with electric motors and installing charging stations at the start and end of routes is much easier than building a nationwide network of charging stations for personal transport vehicles.

Tell us more about the specific objectives of the Center for Electrochemical Energy Storage.

Our objectives can be broken down into purely fundamental ones – understanding how complex electrochemical systems based on the reversible intercalation of metals work, for example. There are tons of questions about the nature of chemical compounds, the nature of cation diffusion in a solid, and how electron structure affects the properties of these compounds. They are all fascinating fundamental questions but they also have practical applications: they help us understand which materials have real potential and which, perhaps, will never work at all.

Our main objective for the next 5-10 years is to launch the production of materials for batteries in Russia. There are companies working on designing batteries in Russia but no one is mass-producing the "heart" of these batteries; i.e., the cells. Without these materials, we will not be able to produce batteries ourselves and will always have to rely on imports. This is unacceptable: it means we will depend on foreign manufacturers to develop electric transport.

We are setting up our own startup to mass-produce electronic materials. I think we'll be able to supply the market with small quantities, about several hundred kilograms, of cutting-edge cathode materials in the next 2-3 years. We plan to cooperate with other companies that assemble cells based on new materials. We have also planned how exactly we will cooperate and conduct tests, etc. We submitted our project to the Skolkovo Foundation and got positive feedback. Our startup, Russtore, is going to be a Skolkovo resident.

What is the difference between your projects and those undertaken by competitors in the West or Asia?

We are one of the few groups worldwide that creates materials with a real understanding of how they work, right down to the atomic level. This means we can make informed choices. You can work by trial and error or you can work using the principles of how materials work and what you need to do to create viable ones.

Tell us how the areas of application define your specific objectives.

For example, hybrid cars need a battery that quickly charges and then discharges energy when powering acceleration, pulling away from standstill, recapturing energy from the wheels and braking.

Overall energy density is crucial in electric vehicles. This means that cars alone need two distinct types of material: one with a high specific energy density, and the other with a high charge-discharge rate.

Safety is paramount in certain types of transport. Imagine a scenario where the use of aircraft engines when taxiing at airports is banned because of noise pollution – this will happen sooner or later anyway. Airplanes will need an energy source that can power them as they taxi from the airport to the runway. Diesel is not a viable option: you need an electric motor. Lithium batteries that may potentially explode mid-flight will never be a popular choice. They had to shelve a similar project in the Boeing Dreamliner because there was a problem with lithium-ion batteries. You can sacrifice some power capacity in the hope of guaranteeing the battery is not pushed beyond its limits.

Another challenge is developing a battery that will work in the Arctic regions: a key advancement for Russia. All drivers know that at –30°C, battery capacity drops drastically.

We need materials that function at low temperatures. This brings us back to the fundamental questions: How does diffusion occur in a solid? How does temperature affect diffusion? Is it possible to create a material that will function at low temperatures?

Life creates myriad challenges; the smallest details of application are vital. We need to find a solution to every problem. We're working as hard as we can to do so.

Through the prism of a romanesco

The Skoltech artifact session is an event where Skoltech scientists talk about their research using symbolic objects. Creativity is welcome!

KIRILL ABROSIMOV

PhD student, Skoltech Center for Energy Systems

This Romanesco broccoli represents our knowledge of new trends in energy systems. New technologies will drastically affect the structure of power systems. A hierarchical tree structure is giving way to more complex and intricate structures, where every local consumer generates and stores energy at the same time. This system reminds us of a fractal — a self-similar structure. Examples of that structure in nature are snowflakes, clouds… and the Romanesco broccoli.

IGNASI LLUCH I CRUZ

PhD, Skoltech Space Center

This artifact is a radio that can change its parameters. This is a good example of the technologies that will soon appear in space. At our lab, we make complex engineering systems. Everything starts with a small device like this, and goes to large satellites, which are very expensive, so you have to be sure that nothing will break. Our next step is systems collaboration, connecting large and small satellites, so that systems can share their power and carry out more missions.

PHILIPP KHAITOVICH

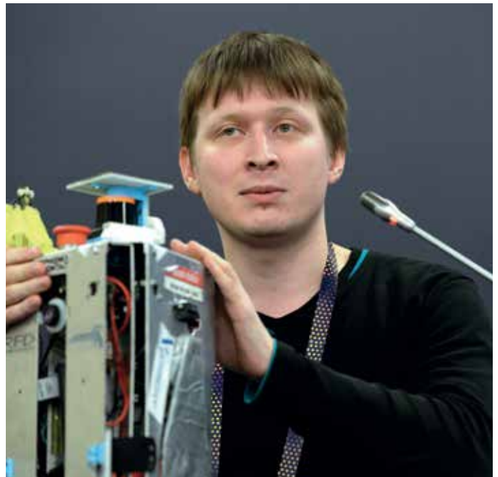
Professor, Skoltech Center for Data-Intensive Biomedicine and Biotechnology

I've brought a samovar, as training is also communication, which is a very important part of the scientific process. It often happens in bioinformatics that students, along with professors and staff members, love sitting at their computers for hours and avoiding direct communication. But we all know that the best ideas are born in discussion. That's why it's very important to conduct seminars, socialize, and travel to conferences. Likewise, in order to tear people away from their computers, we use various tricks, the samovar included.

ARTYOM PAVLOV

PhD student, Skoltech Space Center

This robot was created by our students to participate in the Eurobot competition. It might not look like much, but it embodies all the paradigms used in "grown-up" robotics: a wheelbase model, a high-level computing module android, distance sensors, infrared and ultrasonic sensors, a laser scanner, an odometry sensor. It's important that students realize through practice what robot development is, and are then ready to use their ideas and skills to develop them into a commercial product.



IVAN OSELEDETS

Associate Professor, Skoltech Center for Computational and Data-Intensive Science and Engineering

My artifacts include a shovel and chernozem [black soil], which was brought back from Skoltech's first joint expedition with the Russian Academy of Sciences' Institute of Soil Science. In the field, the shovel is our main experimental device. Our scientific group is interested in agriculture. It's our future, but high technology and innovations are not used in it. You can comprehend the essence of fertility. To do that, you have to take a shovel, dig, and study. Soil is a complex, heavy stochastic system, and no one knows how to obtain our domestic chernozem, or how to restore fertility. We've taken samples, we'll draw up recommendations and receive our first findings in spring 2018.

#PEOPLECREATE
#STARTUPS
#RESEARCH
#FORUMS
#SCIENCEDRIVENBUSINESS
#INNOVATIONS
#NEWMATERIALS
#COLLABORATIONS

people create

#4

CLOSE UP

Georgii Bazykin

AREA: EVOLUTIONARY GENETICS

POSITION: ASSISTANT PROFESSOR

DEGREE: PHD IN ECOLOGY AND EVOLUTIONARY BIOLOGY

PLACE OF WORK: SKOLTECH CENTER FOR DATA-INTENSIVE BIOMEDICINE AND BIOTECHNOLOGY

#biggenetics Legendary geneticist Theodosius Dobzhansky famously said: “Nothing in biology makes sense except in the light of evolution.” I am in complete agreement. It’s absolutely true. Geneticists have learned to understand the mechanisms of a lot of specific things but we are only just starting to explore general patterns using cumulative data: What can life be? What can it not be? How did it turn out the way it is? One of our areas of focus is evolutionary genomics. We are trying to understand how important a role Darwinian selection plays. In school we’re taught that evolution took place through natural selection, but when comparing genome sequences, it is difficult to identify any traces of it. We are looking for ways to find them.

#armsrace The evolutionary genomics of pathogens – viruses, bacteria, fungi – is an arms race: the human body evolves, pathogens evolve in response, and they evolve faster than us. This is especially true for RNA-viruses, such as influenza and HIV. I’m particularly interested in the predictability of virus evolution. This knowledge allows us to develop vaccines. In the six months it takes to produce a vaccine, we try to guess which strain of influenza will be next. If we

guess correctly – the vaccine will be effective; if we miss the mark – it'll be ineffective.

In medicine, a lot is linked to natural selection; it's the same with pathogens. As soon as we start to tackle something – a bacterium with antibiotics, a virus with antiviral drugs or even insects with insecticides – we then play a role in selecting out the most resistant specimens to these drugs and insecticides. The laws of nature start working against us. We have all heard about resistance to antibiotics: it has progressed to such an extent that there is talk of whether antibiotics will still be viable in 10 years. It's a scary prospect to think we could revert back to the days when you could die from a small cut.

#copypaste As each cell divides, a "text" of three and a half billion letters – our genotype – is copied, reprinted and a duplicate text is passed onto the daughter cell. As a rule, there are no errors, or detectable errors. If a typist copying a text of three and a half billion letters never made a typo, we would be amazed. Our body has this ability and we now know how: there are several biochemical mechanisms that track replication accuracy. If you break down the components of the mechanism, accuracy drops by a factor of ten, a hundred or even a thousand. Cells will still divide and reproduce but they will be more likely to become a cancerous tumor. Analyzing the data involved, it's possible to understand which breakdowns of which biochemical mechanisms can lead to such mutations and thus perhaps discover how to prevent them.

#population Most statistical analyses require tens of thousands of samples from tens of thousands of patients. No laboratory in the world can sequence that many samples alone: it is always undertaken as part of an international collaboration. There are large databases that we have access to. However, occasionally we research interesting cases independently. For example, right now we are collaborating with a Spanish group to study the effect of germline mutation accumulation in those with a damaged protein, which increases the rate of mutations in cancer. We know that these people quickly accumulate somatic mutations, but can nevertheless live until puberty and have children. Their children will apparently bear numerous mutations transferred from their parents. Usually, each parent passes on several dozen mutations to their child. Perhaps, these children will have hundreds of mutations. If enough data is available, we will be able to study these children and "see" what a person will look like in several decades or centuries. Does it mean that as years go by we will increasingly suffer from headaches or will the color of our faces be different? This project makes it possible to peer into the future.

#tobeornottobe Medical genetics studies the mutations people were born with and thus already had when seeing a doctor. We have launched a project on sequencing the genetic factors behind miscarriages; we will investigate the radical mutations that cause a pregnancy to fail. We are familiar with some of these mutations: for example, if one of the chromosomes is removed or an extra copy is added to any chromosome, in the overwhelming majority of cases, the pregnancy will not be successful. It transpires that a lot of miscarriages happen in this way. However, it has yet to be studied what was wrong with the genes of those miscarriages, which were karyotypically normal with a normal set of chromosomes. We want to sequence about a hundred mother-father-unborn-child samples and understand what kind of genetic architecture can lead to such a radical phenotype. This will also make it possible for us to understand what part of the genome plays a key role in the mutation being incompatible with life. In the future, it's possible that these studies will improve prenatal diagnostics, an area undergoing rapid development.

#virus The viruses that frighten us the most are actually the viruses that we know most about. The more we know about something, the easier it to study it in greater detail. In this sense, HIV and influenza are model subjects. We have immense amounts of data on their sequencing. A particularly important area of focus for Russia and the world at large is quickly understanding how epidemics work. We don't know the factors behind large-scale epidemics that can take numerous lives. The only thing we can be sure of is that a large-scale epidemic will happen simply because epidemics happen all the time and occur with increasing speed. We just don't know whether it'll be atypical pneumonia, Ebola, or something else entirely. Therefore, we need to be prepared to understand what happens in terms of days and weeks. When swine flu hit in 2009, data on the first influenza sample was published in Nature incredibly quickly: just a few weeks after it was catalogued. It turns out that we can learn a lot about an epidemic by simply reading the genomes. This is a wonderful example of when theoretical ideas become both applied and absolutely vital in learning how to rapidly respond to an epidemic. Thus, we now have a much better understanding of how epidemics materialize than we did 10 years ago.

#development I started out as an ecologist but quickly realized that in science it's important to pursue studies in areas that are current and at the leading-edge, not just what you love. 50 years ago, ecology and evolution were equally important. We had mathematical ecological models that demonstrated how species should interact with each other. Then there was a breakthrough in evolution – huge amounts of data appeared that you could use to check any theory. This did not happen in ecology studies so we don't have a method of testing how the billions of organisms interact with each other. When this develops, ecology will regain its importance alongside evolutionary biology. When I started out, it soon became clear that all the action was elsewhere so I switched to evolutionary biology and have been studying it ever since. I don't regret a thing. It's incredibly interesting!

Natalia Berloff

AREA: MATHEMATICS, QUANTUM MATERIALS

POSITION: PROFESSOR

DEGREE: PHD IN MATHEMATICS

PLACE OF WORK: SKOLTECH CENTER FOR PHOTONICS AND QUANTUM MATERIALS

#quantumhydrodynamics Quantum hydrodynamics is an area of science that studies fluids and states where classical hydrodynamics meets quantum mechanics. It happens in disparate systems: in liquid helium and cold atoms, in semiconductors and magnetic systems, in equilibrium and systems out of thermodynamical equilibrium. In my research I am trying to understand and exploit the appearance of coherence in such quantum systems.

#quantumsimulator We are currently working on creating a polariton simulator – an analogue simulator capable of solving a special class of optimization problems that underlie many technological, biological and social problems, but that cannot be solved by a classic computer. Modern supercomputers can only deal with a small subset of such problems when the dimension of the function to be minimised is small or when the underlying structure of the problem allows it to find the optimal solution quickly even for a function of large dimensionality. Even a hypothetical quantum computer, if realized, offers at best the quadratic speed-up for the "brute-force" search for the global minimum.

We tried to look at the optimization problems from a different angle. We decided to use polaritons – the particles that appear as a result of quantum superposition of photons and electrons. Polaritons are created by shining a laser at stacked layers of selected atoms such as gallium, arsenic, indium, and aluminum. The electrons in these layers absorb and emit light of a specific colour. Polaritons are ten thousand times lighter than electrons and may achieve sufficient densities to form a new state of matter known as a Bose-Einstein condensate, where the quantum phases of polaritons synchronize and create a single macroscopic quantum object that can be detected through photoluminescence measurements and point to where the optimal solution is.

#background In 2006, a joint article by scientists from Grenoble, Lausanne, Boston, Cambridge, and Oxford was published in Nature magazine. This study was the first to demonstrate the Bose-Einstein condensation of polaritons. The article was the dawn of a new era in the study of the interaction of light and matter. Polariton condensation in semiconductor microcavities creates coherent quantum states with surprising properties, in which quantum effects manifest themselves at macroscopic distances. In 2015, in their article published in Science magazine Toby Cubitt and Gemma De Las Cuevas proved that there are universal spin models of very simple structure, and any other optimization problem can be mapped into it. Surprisingly, polariton condensates located at the nodes of an arbitrary graph realize the absolute minimum of one such universal model – the XY model. Therefore, a solution to the most impossible tasks could become a reality!

Maël Brossard

FIELD: PHOTONICS

POSITION: RESEARCH SCIENTIST

DEGREE: PHD IN QUANTUM LIGHT AND MATTER

PLACE OF WORK: SKOLTECH CENTER FOR PHOTONICS AND QUANTUM MATERIALS

#idea Why not take the world's most powerful renewable energy, photosynthesis, and flip it on its head to create efficient green energy sources? This was the premise of the very first day of my PhD at Southampton University in 2010. I was tasked with studying Förster Resonance Energy Transfer (RET), a process that allows for efficient energy transfer at the nanoscale. In plants, light is absorbed by a photo-absorber such as chlorophyll. The absorbed energy is then transferred onto various other molecules in a complex chain until it can be transformed into a form that the plant can use, such as sugars. RET is a critical part of this conversion process, and is as such one of the foundations of life on Earth.

#overcoming While my initial project was to simply mimic photosynthesis to make new types of solar cells, using molecules as light absorbers and semiconductor structures as means of extracting the photo-generated energy, I slowly realized that such a process could never compete with existing technologies. This was a pretty tough realization, understanding that years of hard work and many long weekends in the lab were probably not going to lead very far… But a strange cocktail of tenacity, insight and pure luck allowed me then to discover a completely unexpected way to use RET to create novel types of solar cells! While studying high-quality solar cells made of III-V materials, I realized I could strongly enhance their properties by depositing nanocrystalline quantum dots onto their surfaces.

#success Faced with exciting new results that didn't seem to make much sense, I spent the next few months trying to optimize the structure and racking my brain to understand how such results were even possible… I ultimately discovered that the nanocrystalline absorbers were enabling a new surface carrier recycling process! In solar cells, blue and UV photons of high energy are absorbed near the surface of the device, where they cannot easily contribute to the photocurrent. Using this hybrid system, I could use RET to transfer energy from the top surface of the solar cell to the quantum dots, which could reemit at lower energy. These photons could then penetrate much deeper into the device, giving you useable energy! This breakthrough happened on 17 June 2014, a day forever marked in my mind.

#bridge In 2016, I came to Skoltech on the back of this saga of hope, despair, excitement and confusion (the scientific process can be quite the emotional rollercoaster!). I am now the manager of the hybrid photonics labs, which focuses on topics very close to my PhD research. Being at Skoltech has given me the freedom to advance the hybrid photovoltaics technologies I pioneered and to learn new management skills while working on establishing industrial applications. For me, this is the perfect place to further myself and try to bridge my ideas with the real world.

Alessandro Golkar

AREA: SPACE RESEARCH

POSITION: PROFESSOR

DEGREE: PHD IN AERONAUTICS AND ASTRONAUTICS

PLACE OF WORK: SKOLTECH SPACE CENTER

#myspace Ten days after graduating from university, I left Italy to start a PhD at the Massachusetts Institute of Technology (MIT) in the United States to pursue studies in systems engineering for human spaceflight missions and contributing to architecting studies for the NASA Constellation program. Since then, I have joined the ranks of the Italian expatriates around the world and have gained experience working in robotic space exploration and space-borne Earth observation.

#profile I started my career at Skoltech back in 2012 as one of the university's first faculty members. As the Institute consisted of little more than a handful of people and laptops at the time, I was sent back for a year-long faculty development program (FDP) at MIT. The FDP has been one of the greatest experiences of my academic career so far; I was able to develop my academic profile, start a research portfolio, and create the courses that I would go on to teach in Moscow in the following years.

#uberforsatellites The pivotal project I started during my FDP, which is still my primary line of work today, was the idea of federated satellite systems, or in other words, satellite sharing – the "Uber for satellites," so to speak. Spacecraft are complex and expensive machines that are used for a variety of purposes – observing the Earth, enabling data, voice, and video broadcasting, and allowing us to know how much traffic we will find on Kutuzovsky Prospekt on our way back from work. The cost of launching those machines is worth more than their weight in pure gold – literally. One would imagine, therefore, that people would use their spacecraft at all times to amortize the costs. Not at all. Many satellites have excess capacity all the time. In other words, they are not used at 100% of their functionality during every day of their useful lifetimes. This represents an aggregate sunken cost of many hundreds of millions of rubles every year. The idea of federated satellite systems is to allow secondary users to utilize an operator's spacecraft on demand for short periods of time, and possibly aggregate heterogeneous satellites together to deliver the short-term services needed by an occasional user.

#plans My students and I keep finding significant uses of this concept, as well as technological challenges to solve. We are paving the way to enable such a concept through conceptual feasibility studies and early technology demonstrations. We are building the theoretical underpinning of satellite federations, and developing an understanding of how such federations could be used someday to serve emerging needs in high growth fields of knowledge in the space industry. We influence the space industry with our ideas through our annual Federated Satellite Systems Workshop, and by participating in international research consortia and externally sponsored research projects. The year 2016 saw a large space system integrator considering the implementation of federated satellite systems in their future projects in the field of Earth Observation, as well as many organizations worldwide expressing interest in the subject. We have started making our dent in the space world.

Dmitry Koroteev

AREA: OIL RECOVERY, BIG DATA

POSITION: PROFESSOR

DEGREE: CANDIDATE OF TECHNICAL SCIENCES

PLACE OF WORK: SKOLTECH CENTER FOR HYDROCARBON RECOVERY

#journey When I was the director of the Department of New Technologies at Gazpromneft, we worked out a strategy for the technological development of the entire Gazpromneft exploration and production unit. Then I plunged into the world of modern digital technology, big data and the analysis of big data. I attended a refresher course at the Massachusetts Institute of Technology on big data and compiled a strategy for using predictive analytics and machine learning in oil and gas production. I now work in this area at Skoltech. We are recruiting a portfolio of industrial projects related to big data for the optimization of various technological processes

#onthehorizon Our training courses are built differently than those in other oil universities. We established higher-level foundations and focus in detail on a variety of areas. All of our courses are taught in English and almost all of them have been jointly developed with Western universities that are well-known in the oil industry: Heriot-Watt in Edinburgh, Texas A&M, the University of Calgary, West Virginia University, etc. An entire branch of our educational program introduces the methods of progressive modeling and machine learning (Big Data).

#students I teach a course in Reservoir Simulation and Geostatistics. Several of my students have gained very successful work experience with Gazpromneft and BP Russia. They have done interesting work with a concrete, practical application in the processes used by oil companies to plan the development of deposits. One wrote an algorithm for the automatic interpretation of well test data. Previously, this was a time-consuming, man-power intensive process. After two months of practical work, he replaced a large number of routine operations with machine learning algorithms. A second student did similar things but sped up the methods of classical hydrodynamic modeling of reservoir currents. And a third student developed from scratch a technique for predicting the effectiveness of hydraulic fracturing based on data from previous work. This technique proved much more accurate than its predecessors, based on physical modeling and the experience of geologist-developers. In short, teaching at Skoltech is new, interesting, wonderful!

#bigdata We have teamed up with Gazpromneft to work on four projects related to digital methods for various aspects of oil and gas production. In addition, I am working with Zarubezhneft, with BP, and plan to work with Total. Our colleagues from the Skoltech Center for Computational and Data-Intensive Science and Engineering (CDISE), including Maxim Fedorov and his team, are involved in all of our projects with Gazpromneft. I believe that the future of Big Data includes the oil industry. We want to develop an IT platform for predictive analytics for oil and gas production processes. It will be a library of algorithms that can take data from a certain process and create forecasts. This is a global dream that we are all moving towards.

Edward Crawley

AREA: AERONAUTICS, ASTRONAUTICS

POSITION: PROFESSOR, FOUNDING PRESIDENT OF THE SKOLKOVO INSTITUTE OF SCIENCE AND TECHNOLOGY

DEGREE: PHD

PLACE OF WORK: SKOLTECH SPACE CENTER, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

#ISS The first time I came to Russia as an exchange student from the Massachusetts Institute of Technology (MIT), I studied at Leningrad State University. I returned in 1980 to work at the Moscow Aviation Institute. Even then, joint plans for cooperation between Russia and the United States in outer space were being created. In some ways, I managed to influence the development of events. In 1993, I was included in a commission under US President Bill Clinton that was to determine the future of NASA and the International Space Station. I did everything in my power to unite the space station that the Americans were building with the Russian program. After six months of work, a space station came into being, which is today's International Space Station.

#thefuture I am positive about possible cooperation between Russia and the United States in space. This is a step into the future life of mankind beyond Earth. We can only achieve this if all countries work together. Therefore, the main question today is whether the leaders of all nations and countries will rise above the political tension of the moment and look into the distant future and see the opportunity to cooperate – not compete – in outer space.

#GDP MIT is an educational institution that produces students who have a major impact on the GDP of the United States. The net contribution by companies that were founded by MIT alumni is more than $2 trillion, which is 10% of the country's GDP.

#neweconomy There is an opportunity in Russia to create a new economy based on knowledge because there is a wonderful intellectual foundation. Science and education continue to be strong in Russia and we need to understand how to reflect this in the education of students so they become entrepreneurial scientists, innovator scientists who not only know science and mathematics well, but who also know how to transform this knowledge into products and goods that will bring economic benefits. We must build a bridge from the scientific to the industrial sphere. I consider it very important for a scientific organization to act flexibly and controversially, and to anticipate the needs of society.

#interchange Mutual understanding is a consequence of the exchange of opinions and the movement of people in space. This is a concept that we understand at Skoltech so we invite scientists and students from different countries to come here. Skoltech also sends professors and students on business trips to foreign universities. Security and future cooperation between countries is based on a stable economic foundation and we try to participate in the creation of this base.

#worldpeace It is necessary to work diligently to ensure that the world is stable and to ensure that serious conflicts do not occur. The technological potential that we harness can seriously damage the world. And all of us, especially scientists, should influence the situation in such a way that science and education systems contribute to stability.

Albert Nasibulin

FIELD: NANOMATERIALS

POSITION: PROFESSOR, NANOMATERIALS LABORATORY DIRECTOR

DEGREE: PHD IN PHYSICAL CHEMISTRY

DIVISION: SKOLTECH CENTER FOR PHOTONICS AND QUANTUM MATERIALS

#nanostructures Day after day, physicists and chemists are discovering a new world by gathering structures with various traits and ranges of application from atoms and molecules, like some infinite jigsaw puzzle. These 3D models consist of three fundamental carbon nanostructures: graphene, fullerene, and a nanotube. Each of these nanostructures has only been discovered in the recent past, and all of them have quickly become the focus of intensive research the world over. They are at the core of our studies in the Skoltech Nanomaterials Lab. With the help of these materials, researchers hope to create the new world of flexible, elastic, and transparent electronics of the future.

#chemistrybuff At school I took a long time to decide between mathematics and chemistry, but my passion for experiments won out. I was interested in just about everything, from making gunpowder and causing cool chemical reactions to turning metals into gold and pressing flowers. I was able to fairly accurately reproduce the recipe for Russian Forest cologne, which was all the rage at the time. But my desire to get into the chemistry faculty at university was driven by my longing to do something useful for humanity, such as making a device that would make it possible to obtain milk without a cow, from grass and water. In 1989, I entered the chemistry faculty at Kemerovo State University. Over time, my childhood dreams faded away and I became interested in physical chemistry. In 1996, at age 24, I defended my PhD dissertation on the binary nucleation of supersaturated glycerin vapor in the vicinity of the phase transition lines.

#homeland In June 2014, we moved from comfortable, convenient and predictable Finland back to Russia. We were fraught with anxiety. For my wife and I, Russia is our homeland, but our children, though they spoke Russian well, were very different from Russian schoolchildren. For that reason, we decided that it would be easier to adapt to the new country if, in the first year, we sent the children to a Finnish school in Moscow. With the opening of the Skolkovo Gymnasium in 2015, our children transferred there. My son faced his final examinations in two years, and, considering that his level of knowledge of Russian was far from the requirements for 10th-grade students, and the level of mathematics at the Finnish school was a year and a half to two years behind, he had to work very hard to catch up with his peers. He was one of the gymnasium's first four graduates.

#pioneers Our nanomaterials laboratory was the first experimental laboratory that opened at Skoltech. That was in August 2014. Now, the group working under my direction is one of the leading research laboratories in the world. This is a unique environment for interdisciplinary research and high-level collaboration. The primary areas of research are the synthesis of carbon nanomaterials and their application in transparent, flexible, and elastic electronics and photovoltaics.

Andrey Osiptsov

AREA: OIL RECOVERY

POSITION: PROFESSOR

DEGREE: CANDIDATE OF PHYSICAL AND MATHEMATICAL SCIENCES

PLACE OF WORK: SKOLTECH CENTER FOR HYDROCARBON RECOVERY

#depths I am engaged in the improvement of hydraulic fracturing technology. When oil is extracted from a well for a long time, the wellbore zone gradually becomes contaminated, permeability falls and so does the oil production rate. In other words, the flow from the well to the surface decreases. By pumping slurry into the well under high pressure in the rock, a fracture is created and filled with something called a proppant. River sand was used for this previously, now it is solid ceramic particles. As a result, highly conductive channels are formed to transport oil or gas from the depths of the formation along the fracture to the well, and then to the surface. Thus, oil recovery rates increase.

In Russia, there was a state request for the creation of domestic hydraulic fracturing technology which would outperform foreign analogues. I am engaged in the creation of mathematical models of hydraulic fracturing technology and the introduction of these models into simulators that are used for the design and planning of fracturing operations.

#bigdata One of the relatively new movements in oil production is the use of methods of Big Data and machine learning. If the simulator is based on a mathematical model, that is, the physical conservation laws expressed in the partial differential equations, than it should build a predictive model using Big Data methods on the basis of the relationship between the input and output data that characterizes the process. For example, there is an impressive set of input parameters that characterize fracturing technology: the condition of the formation before the fracturing, the profile of the well, the geomechanical parameters of the rock, the fracture injection parameters, and the flow rate of the well after fracturing. My colleagues and I are studying the approach in which, based only on data analysis, it is possible to optimize the process and give recommendations on the optimal design of fracturing technology. At Skoltech we are now actively developing approaches to the combination of physical modeling and machine learning methods, in partnership with the Skoltech Big Data Center and in cooperation with key oil and gas companies, including Gazprom Neft.

#perspective The media often raises the topic of the imminent decline of the oil and gas era and the rapid rise of alternative energy sources. Scientists working in this field are more conservative than journalists. The global demand for energy is constantly growing. When using alternative sources of electricity, such as wind or the sun, there is a problem of cyclical generation, storage and the transportation of energy without losses to places of consumption. At the same time, the volume of hydrocarbons that can potentially be extracted, particularly from non-traditional low-permeability reservoirs, is growing, thanks to the continuous development of geographical exploration and enhanced oil recovery techniques. So the rumors about the end of the hydrocarbons era are somewhat premature. Our task is to extract hydrocarbons – including those on Russian territory – as efficiently and carefully as possible to preserve nature for future generations. And the technologies that I develop help in this.

CLOSE UP

Konstantin Severinov

AREA: MOLECULAR BIOLOGY

POSITION: PROFESSOR, CREI DIRECTOR

DEGREE: DOCTOR OF BIOLOGICAL SCIENCES, PHD

PLACE OF WORK: CENTER FOR DATA-INTENSIVE BIOMEDICINE AND BIOTECHNOLOGY

#brand Russian scientists garner respect worldwide. We are known as the scientists that launched the Sputnik satellite. After Sputnik took its maiden voyage into space, the Americans got nervous and U.S. President John F. Kennedy launched a number of initiatives that changed the curriculum at American schools and colleges. Children began to study technical subjects differently and the teaching methodology in technical universities changed. At Rutgers University, where I am also a professor, there are a lot of senior professors that know a few phrases in Russian because in the early 1960s they voluntarily studied it at school or in university. Russian scientists are a brand that's possibly even mightier than Coca Cola.

#livelong We have never lived as long as we do now. Life expectancy started to increase in the early 20th century, mainly due to the advent of urban sanitary infrastructures: e.g. toilets and water pipes. Water purification became commonplace. In general, very mundane, everyday reasons. Horses fell out of widespread use, previously having been largely behind the spread of tuberculosis; in this sense, cars are a blessing. Finally, we discovered antibiotics.

#mastersoflife On a planetary level, humans have a huge impact, but in terms of overall biomass – we are a drop in the ocean. There are far more bacterial cells on Earth. Bacteria appeared on Earth long before us and will continue to exist when we die out.

#reproduction People want to have children. Unfortunately, not everyone can: there are tons of diseases that prevent couples from having children. In the 1970s, we saw the first "test-tube babies" conceived outside the womb. Hundreds of thousands of people, and their children alive today wouldn't have been born if we had gotten bogged down in pointless arguments about whether IVF is good or bad.

Children from three parents – a hotly-debated concept – is also a way to give people with certain diseases the chance to have healthy children. Alongside the genes that we inherited from our father and mother (which are in our chromosomes), there are a small number of genes in the mitochondria, a.k.a. the powerhouse of the cell as they are called in Russian textbooks.

The mitochondria is a former bacterium that still has a small number of "bacterial" genes. Each of us inherits mitochondria and the genes within it from our mothers. Some women have defective mitochondrial genes. Therefore, it's certain that the children they have will not be healthy. An innovative technology has been created that enables us to obtain a fertilized egg that will develop and grow into a child with chromosome genes half of which come from the father, half from the mother, and mitochondrial genes from a third person – a second woman.

#enigmasofhistory We also now have technological knowhow that allows us to genetically identify the remains of ancient people. With unsoiled, intact, properly preserved bone samples, you can look into history spanning back 50-70 thousand years. It's now possible to determine the exact plague pathogen people died from during the Black Death in the thirteenth century, figure out which particular viral mutation claimed so many lives during the Spanish pandemic at the end of the First World War, or identify the mutation responsible for Tsarevich Alexei's hemophilia.

None of this is technically complex; you just need samples. Soon, geneticists will set about raiding historical museums for samples.

#otherpeople The major contribution made by Russian scientists (working closely with German colleagues) was the discovery of the third branch of mankind, the so-called Denisovans, whose remains were found by Russian scientists in the Denisova cave near Novosibirsk.

The German scientists determined the individual's genome and it turned out that it is equally distinct from both the Neanderthal man and modern man. It is not a race but a separate, third subspecies of the genus Homo (man), and there was a time when all three species lived on the planet simultaneously.

Modern humans have genes from both the Denisovans and Neanderthals but the quantity varies from person to person. Skoltech Professor Philipp Khaitovich published an article in the journal Nature Communications on the analysis of Neanderthal genes found in modern humans. It was found that Neanderthal genes are more common among the genes that facilitate the digestion of certain types of food — meat, in particular.

#incorporesano Right now, I'm really into sport. Back in my university days, I used to think people were divided into two camps – the sporty guys and the thinkers. I used to think playing sports was a sign of worthlessness. Now I understand that sports both lend structure and really help us think. I realized this in America where I played a lot of tennis and loved skateboarding.

#harmony The problem is that when you make choices, you always cut yourself off from other opportunities. As the quote says: niche specialists are like gum boil: they are very one-sided. A lot of my American colleagues in science can write well-written, convincing texts about their area of study in their grant applications because they studied English literature at university and only took up biology at the postgraduate level. As I see it, this is the right way to approach things: seeking out your profession in adulthood having made a well thought-out, grown-up choice.

CLOSE UP

Stanislav Smirnov

AREA: MATHEMATICS

POSITION: PROFESSOR

DEGREE: PHD IN MATHEMATICS / AWARDS: FIELDS MEDALIST (2010)

PLACE OF WORK: SKOLTECH CENTER FOR ADVANCED STUDIES

#ouruniversities Skoltech's task is to modernize our education. It is important to understand that, on the one hand, any university in the world is a very conservative entity. European universities, ever since they were founded about a thousand years ago, generate new knowledge and teach students, meaning their fundamental tasks haven't changed. On the other hand, scientists are society's main innovators. Even if they are conservative, they will be the first to change things. If, in Soviet times, our universities were at the cutting edge of science, since then we have fallen behind by nearly 30 years. We would like to finally catch up.

#inpractice Skoltech is closely linked to innovative sectors of the economy with practical applications of science. Naturally, a significant part of fundamental science has always been focused on application, but in the past 40 years,

the period from development to application has shrunk significantly, and we would like universities to get involved. In Russia, that process has failed to develop for a long time because of changes in the economy; before, research used to be commissioned by the government.

#hereandnow I am spending this year primarily at Skoltech. This year is supposed to be free from my organizational work and teaching. I'd like to dedicate more time to science. I have several research projects: in pure mathematics, mathematical physics, and recently I began a very exciting project with biologists.

#puremath The country clearly needs young mathematical centers like our Center for Advanced Studies, and there has been much talk about it in recent years. Among the oldest and most famous centers in the world is the Institut des Hautes Études Scientifiques in Paris [IHES] and the Institute for Advanced Study at Princeton [IAS]. One was founded in the 1950s, the other in the 1930s, serving as a workplace for Albert Einstein and Kurt Friedrich Gödel. This model is so successful that in virtually any self-respecting university, a center like it has appeared in the last 30-40 years. For example, the US National Science Foundation opened the Institute for Pure and Applied Mathematics [IPAM] 15 years ago. There are several private centers not attached to universities. We had a similar project in the Soviet Union in 1985 – an order by the Central Committee [of the Communist Party] was released on the development of mathematical research and teaching, and the establishment of the Euler Institute in Leningrad. The Institute exists to this day, but the plans in its creation were much more ambitious. There are only several conferences a year there, and they are currently engaged in discussion about how to expand their activities. So, we've been planning to create these centers for a long time, but that didn't happen because of perestroika.

#rejuvenation A lot of talented young people are moving to mathematics right now. If you look at the incoming classes in mathematics at the Saint Petersburg State University and Higher School of Economics, where I serve on the advisory board for mathematics, there are many very talented and enthusiastic students from all over Russia. Skoltech does not have undergraduates, but incoming graduate students are just as good. Naturally, they have a lot more choice than in Soviet times, when people chose math because it was a prestigious yet safe choice. The problem isn't a national shortage of interested young people – there are plenty, and the leading schools are good at what they do, and many regions have schools like that. The issue is more likely in teaching the basics at the bachelor's level in a modern way, and then starting work in science at the graduate level. But the young people here are great!

#mentors The main thing in fields like this is good research advisors who can work on modern problems. This is a major challenge right now, as Russian science in the past 30 years has become somewhat insular. That doesn't mean that we don't have leading scientists, it means that we don't have cutting-edge research. That needs to be fixed.

#past In Russia, students are still taught to count hundreds of integrals by hand, even though now, of course, engineers don't count integrals, they work with big data. Those are completely different skills. Even when a mathematician counts integrals, a computer system would normally do it for them. It is important to properly understand how this system works in order to formulate a task for it, as opposed to counting everything by hand, like they did 50-60 years ago.

#future Skoltech, like many other Russian universities, has started to work with talented schoolchildren. This is beneficial for both the universities and, first and foremost, for the schoolchildren. These kinds of projects can provide children with career guidance. Even the most talented student acquires knowledge about the work of biologists from school biology courses, which are by no means the best or the most cutting-edge. The same is the case with math. In these courses, they don't talk about how scientists work, or about how mathematics can be applied to modern life, about the way engineers apply it today. Some of the new projects try to change the situation by building that bridge between schoolchildren and universities.

Keith Stevenson

AREA: MOLECULAR CHEMISTRY

POSITION: PROFESSOR, ASSOCIATE PROVOST, CREI DIRECTOR

DEGREE: PHD

PLACE OF WORK: SKOLTECH CENTER FOR ELECTROCHEMICAL ENERGY STORAGE AND CENTER FOR ENERGY SYSTEMS

#symbol When asked to describe my research with the aid of a simple artifact, I chose a monkey wrench (also known as the Ford wrench and adjustable spanner wrench, in general terms). This wrench is a versatile multi-tool used to assemble, construct, fasten and tighten many things. In particular, it was an early invention that became a standard issue tool with every Ford Model A due to fact that it could help maintain many things on one of the first mass produced broadly affordable automobiles. Now this tool is an essential for any builder, tradesman, or fixer who wishes to construct, repair, or manufacture products. The Monkey's Wrench is also the title of one of my favorite books written by Italian writer and chemist Primo Levi. The story is told by a narrator, a chemist that swaps stories with a builder (rigger) that solves a technical industrial problem of true grit; and also details how the chemist saved his Italian paint factory from economic disaster at the hands of a Russian anchovy canner. I read this book just prior to going to graduate school and was influenced by the stories of how a chemist can be a creator, an innovator and builder of many things.

#assembling As a chemist by trade, I use the periodic table to discover new molecules and materials. In reflection, I realize that my defining trait – both as a scientist and as a person – is the fact that I am a natural builder. I am a builder and a chemist, whose work and life are one in the same. I have handcrafted many things. As a hobby, I have built houses and garages, furniture, toys, and more. As a kid, I would use various tools to take things apart and then put them back together to function in new ways. When I was five, I made what I like to refer to as a "chopper trike." To me, building is a creative endeavor where I use my intuition and my tools to create something truly original. As a chemist as well, I have used many tools to discover new molecules and materials, to build new scientific instruments, and to elucidate new material properties and the mechanisms that govern their functions. I have also built world-renowned educational and research programs, as well as large centers of scientific excellence.

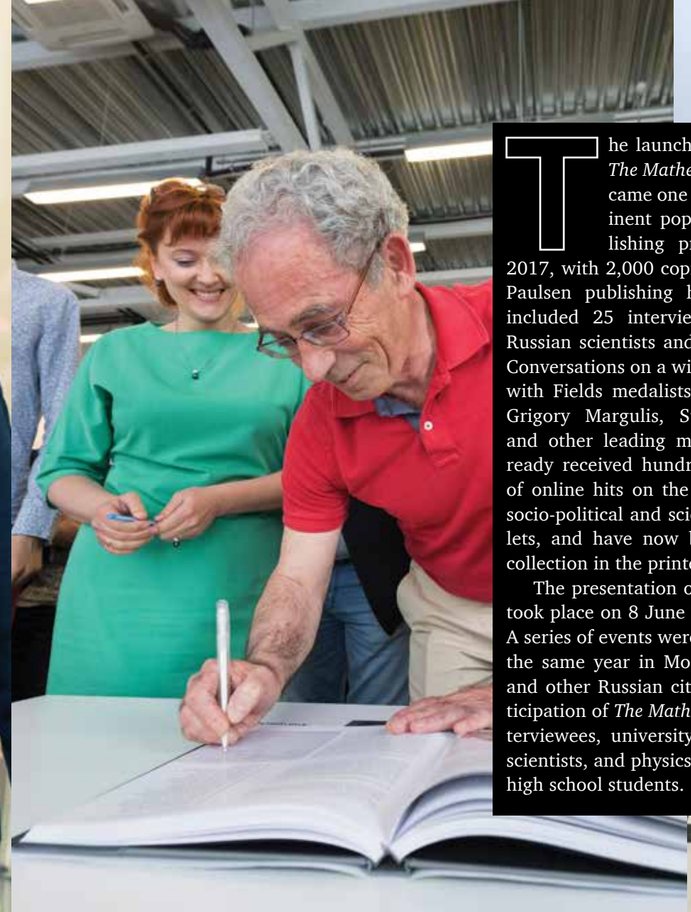
#hereandnow Right now I'm building a Skoltech center with several new "wrenches" for electrochemical energy storage that will train a new generation of builders to support the growth of the energy industry in Russia and the world. We will demonstrate materials, devices and systems that provide the basis for innovative opportunities for the creation of advanced energy technologies.

People and time

The launch of the book The Mathematical Walks was the culmination of a fruitful collaboration between Skoltech and the Institute for Information Transmission Problems of the Russian Academy of Sciences

"In recent years, mathematics has not only become important, but an absolutely vital, key element in the development of multidisciplinary areas of knowledge, becoming the main driver of progress, an interface through which humanity interprets the achievements of basic science. But I would measure the potential success of this book in the number of kids that choose this profession, just as I chose it in my day."

ALEXANDER KULESHOV
PRESIDENT OF SKOLTECH,
RAS ACADEMICIAN



The launch of the new book *The Mathematical Walks* became one of the most prominent popular science publishing projects of spring 2017, with 2,000 copies printed by the Paulsen publishing house. The book included 25 interviews with leading Russian scientists and mathematicians. Conversations on a wide range of topics with Fields medalists Sergey Novikov, Grigory Margulis, Stanislav Smirnov and other leading mathematicians already received hundreds of thousands of online hits on the pages of leading socio-political and scientific media outlets, and have now become a unique collection in the printed edition.

The presentation of the new edition took place on 8 June 2017 at Skoltech. A series of events were held throughout the same year in Moscow, Kazan, Ufa and other Russian cities, with the participation of *The Mathematical Walks* interviewees, university students, young scientists, and physics and mathematics high school students.

#NEWUNIVERSITY
#BESTCAMPUS
#EASTERNRING
#HERZOG&DEMEURON
#UNIQUEPROJECT
#BESTPLACETOSTUDY
#MOVING2018

new university

#5

THE NEW SKOLTECH CAMPUS, THE EASTERN RING COMPLEX, IS LOCATED ON THE GROUNDS OF THE SKOLKOVO INNOVATION HUB (MOSCOW).

PROJECT BY ARCHITECTURAL FIRM
HERZOG & DE MEURON (SWITZERLAND)

GENERAL CONTRACTOR:
PUTEVI UŽICE (SERBIA)

TOTAL AREA OF THE FIRST STAGE
OF DEVELOPMENT: 11.35 HA

EASTERN RING COMPLEX:

TOTAL AREA OF BUILDING: 133,979 M2
NUMBER OF STORIES ABOVE GROUND LEVEL: 3
NUMBER OF STORIES BELOW GROUND LEVEL: 1
HEIGHT OF BUILDING: 22.42 M
DIAMETER OF BUILDING: 280 M
CIRCUMFERENCE: 880 M

1ST STAGE COMPLETED:
SPRING 2018
PLANNED INAUGURATION OF FIRST STAGE
OF NEW COMPLEX:
2018

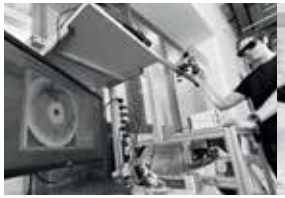
200 professors
360 postdocs and researchers
1200 MSc and PhD students

2022

great science
excellent education
changing the world
people create
new university


Город будущего
Город будущего
Город будущего

YOU CAN ENROLL IN ONE OF THE FOLLOWING 10 MASTER OF SCIENCE PROGRAMS:



Advanced and Digital Engineering Technologies

Biotechnology

Computational Science and Engineering

Data Science

Energy Systems

Materials Science

Mathematical and Theoretical Physics

Petroleum Engineering

Photonics and Quantum Materials

Space and Engineering Systems

- Full-time (2 years)
- ENG Instruction in English
- FREE Tuition-free
- Moscow, Russia

Details and application:

msc.skoltech.ru