University of Luxembourg

unique

Knowledge pioneers at the heart of Europe

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UNIVERSITÉ DU LUXEMBOURG

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What makes us unique

The University of Luxembourg in a nutshell

The University of Luxembourg is a European research institution with a distinctly international, multilingual and interdisciplinary character. Founded in 2003, we have already built a reputation as being among the best young universities in the world. We are ranked 14th in the Times Higher Education "150 Under 50 Rankings 2016", with a particularly strong performance for our international outlook and citations.

With 6,200 students from 115 countries and academics from 20 countries, our university provides a truly cosmopolitan learning experience. Whether it be English-French or German-French, many study programmes are bilingual, and master's courses taught entirely in English are also on offer. We work with nearly 90 partner universities worldwide, and cross-border study and research is commonplace, thus boosting our international profile further.

A mandatory semester abroad

All bachelor's students study abroad for at least one semester. There is a very personal atmosphere in the classroom and on campus, thus facilitating easy integration into university life.

Situated on the new Belval Campus and on the Kirchberg campus in the Luxembourg City business district, our 240 academics and 600 PhD students work within three faculties and three interdisciplinary centres. Current research priorities are computational sciences and ICT, systems biomedicine, European law, international finance and educational sciences. In 2015, total third party funding was 41.4 million euros. Five grants from the European Research Council, as well as 31 approved Horizon 2020 projects since 2014 are further reasons for us to be proud.

Luxembourg is a hub for innovative knowledge industries such as finance, high-end manufacturing and ICT. As the motor of the national research and innovation system, the University gives strong support to entrepreneurial activities. We are also well connected to European institutions, banks and businesses, technology companies, and Luxembourg's multicultural society. The result is a unique mix of international excellence and local relevance to students and scientists from across the globe.

Voilà! Find out more on the following pages and become part of our inspiring community of knowledge pioneers at the heart of Europe. •

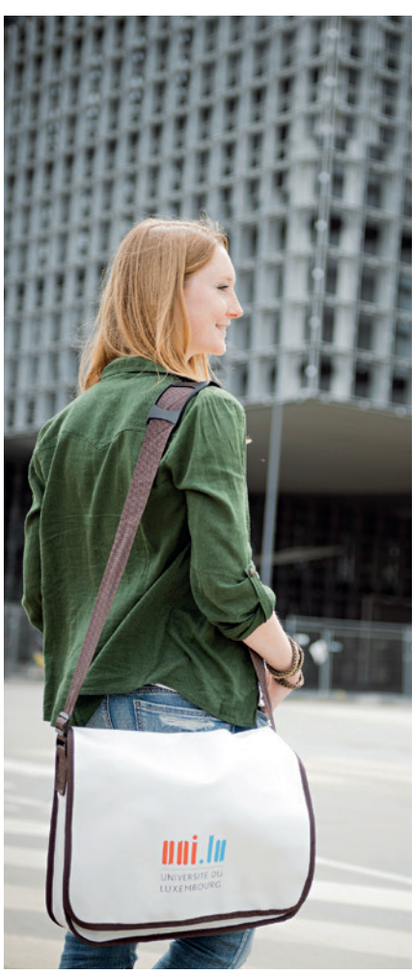


Photo Cover: The new university campus in Belval is a symbol of Luxembourg's vision for the future.

Rainer Klump

We are the gateway to Europe

University President Professor Rainer Klump

What sets the University of Luxembourg apart?

RK *"We have been able to recruit many excellent researchers from all over the world. They are attracted by the pioneering spirit and flexibility of a young university, and the possibility to build up new research teams from scratch, without the need to accept the constraints that are often connected with long-established structures. Another distinguishing feature is our international spirit and multilingualism. In this year's Times Higher Education Rankings, the University of Luxembourg achieved joint first place for international outlook. Also, both the country and the University with about 6,200 students are comparatively small allowing for a personal touch that one can find hardly anywhere else. Finally, the exceptionally high quality of life in Luxembourg, the good access to research funding, proximity to European institutions, and close collaboration with other national, regional and international players help to convince people that Luxembourg is the right choice for their career in research."*

Why is the University especially attractive as a partner for international research projects?

RK *"Nearly all Luxembourgers speak at least three languages. This brings a fundamentally internationalist outlook which attracts many students and researchers. They like that we are open, international and multilingual, and centrally located in one of the capitals of Europe. Partners outside the EU see us as an ideal gateway to Europe. If they want to start partnerships in Europe, they want to do it via Luxembourg."*

What is the University of Luxembourg's research agenda and environment?

RK *"We are the only public university in the country, and as such we are the motor of the country's innovation and research system. With its strong European orientation, the University is a symbol of the European mission of the country. We are also a major player in the national digital agenda in which the Grand Duchy is strengthening its position in the ICT field. This is important because these are exactly the three pillars of our new strategy: the digital mission of the university, the international and European orientation of the university and the sustainable integration into Luxembourg."*

One of the strategic pillars of the university is digitalisation. Can you describe what that means in practice for the work of the university?

RK *"It starts with the digital literacy of students and staff that we are developing and strengthening. From that basis, we have a special focus on big-data related research and computer based modelling that we want to implement in almost all our research fields. This concerns not only classical information science, but also research in natural and life sciences, engineering and physics, as well as the humanities, law, finance and economics. We set ourselves apart from older institutions by having a digital outlook embedded in our research activities. For example, in fields like history I think we can expect a revolution in the coming years where documents and other resources will increasingly be digitalised, with digital tools and big data analysis being used. Therefore, our new interdisciplinary centre will have an explicit emphasis on digital history."*

Can you give examples of how the University uses digital tools for research?

RK *"In life sciences, we are conducting a huge programme where our researchers screen data about patients suffering from Parkinson's disease. They use medical records, as well as information on social, environmental, and other conditions to create models to investigate the factors that contribute to the outbreak of this illness.*

In an up-coming pilot project, researchers will analyse the archives of the Luxembourg-based European Court of Justice. Digital tools will enable them to search for specific key words, identify the main people involved in court sessions, and map decision making processes. Another example is finance. Big data technology can be used to study the huge amount of information available from the investment funds industry. This will help us better understand investing and investor behaviour." •

The Grand-Duchy's vision

The University – motor of a new Luxembourg

Luxembourg is reinventing itself once again. The country moved from being a steel producer to become a globally significant financial centre in the 1980s, and now the country is increasingly an international innovation hub. Government strategy has put research, development and higher education as the cornerstones of economic diversification, competitiveness and creating a knowledge-based society.

Public expenditure dedicated to research in Luxembourg increased from 24 million euros to 380 million euros between 2000 and 2015. The government has a target of national R&D intensity of at least 2.3% of GDP by 2020.

The goal of innovation-driven growth is becoming reality on the Belval research and study campus in the south of Luxembourg. It is a large brownfield site that once hosted the country's largest steel plant, where now a completely new neighbourhood is being created. This project is one of the largest and most ambitious urban renewal projects currently underway in Europe, stretching over an area the size of 120 football pitches. So, where once blast furnaces produced molten steel, now ideas are flowing, thanks to academic research and teaching, surrounded by facilities for start-ups and growth businesses. There are also leisure, cultural and retail outlets in this new, thriving zone.

The "Cité des Sciences" (City of Science) is Belval's lead project. Its first phase has had a budget of 960 million euros for the construction and fitting of more than a dozen new buildings on the grounds of the blast furnace site. It is the location of the main University campus since the summer of 2015, and it will eventually host up to around 8,000 students and 3,000 teaching staff and researchers.

Belval Campus – a melting pot

Belval Campus is a melting pot of different academic subjects, opening up new opportunities for interdisciplinary partnerships. This is not only within the University but also with the public research institutes the Luxembourg Institute of Science and Technology (LIST) and the Luxembourg Institute of Socio-Economic Research (LISER), both of which are located in the immediate neighbourhood. And as is typical in Luxembourg, the distances involved are short: everything can be reached on foot.

A second campus is being developed on the Kirchberg plateau in Luxembourg City near many financial businesses and close to EU Institutions, such as the Court of Justice of the European Union, the European Investment Bank, and the secretariat of the European Parliament. This campus will include most of the Faculty of Law, Economics and Finance, together with the Max Planck Institute Luxembourg for International, European and Regulatory Procedural Law.

Thirteen years after it was founded, the University is now working at full capacity. Strategic research priorities include ICT and computational sciences, systems biomedicine, European law, international finance and education.

Nine chairs from industry

Additionally, a new research centre on contemporary and digital history was launched recently. "We focus on a select number of research areas of international importance, which also reflect

Campus Belval: High investments in Luxembourg's research infrastructure.

the realities of Luxembourg's society and economy", explained Prof Dr Rainer Klump, the University president.

Corporate supporters have endowed nine academic chairs. Examples include the SES Chair in Satellite Communications and Media Law, the ArcelorMittal Chair in Steel and Façade Engineering, and the Deutsche Bank Chair of Finance. In 2015, total third party funding amounted to 41.4 million euros. Four grants from the European Research Council and 21 successful Horizon 2020 projects since 2014 are further milestones. "The growing amount of competitive funds the institution attracts are a strong sign of confidence in our strategy", highlights Prof Dr Klump. "Belval Campus will support this strategy and create great opportunities for students and staff. We can all be proud to be the first to help shape this unique knowledge factory." •

The University has signed a cooperation agreement with the Massachusetts Institute of Technology (MIT) for the creation of the Luxembourg Centre for Logistics and Supply Chain Management

Why Luxembourg?

A competitive international business landscape: Luxembourg is among the Top 10 of the most innovative countries in the world (source: Global innovation index 2015)

State of the art research facilities: Luxembourg's research institutions are equipped with cutting-edge technology.

Research is a priority: The Luxembourg Government has increased the annual budgets for research activity tenfold since 2000.

International mind-set: 87% of scientists are non-Luxembourgish nationals. 70% of research publications are co-authored with foreign scientists.

Global collaboration opportunities: Under the INTER programme of the Luxembourg National Research Fund (FNR), researchers based in Luxembourg can conduct scientific collaborations with scientists in around 40 countries worldwide.

Source: Luxembourg National Research Fund (FNR)

Studying in Luxembourg

Multilingual and well connected

While still a young institution, the University of Luxembourg has already gained great recognition from both students and researchers. Multilingual teaching is one of the distinguishing features, with the majority of the subjects taught in at least two languages; French and English or French and German. The University's Language Centre supports students who need to acquire the necessary language skills.

Students from all over the world are attracted by the future employment advantages of a multilingual degree. Students are also encouraged to broaden their horizons by studying in foreign countries, as every undergraduate is required to spend at least one semester abroad. About 500 Erasmus student international mobility agreements with foreign universities make sure that everyone can find the destination that suits best. "We see internationalism not as a goal in itself, rather as a means to further increasing excellence in education and research," explained Jenny Hällen-Hedberg, coordinator of the International Relations Office that has been established to further improve cooperation with other teaching facilities. The success of these efforts is widely recognised. In this year's Times Higher Education Rankings, the University of Luxembourg achieved joint first place in the International Outlook category together with Qatar University.

Cooperation with the industry and European institutions

But the University has more to offer its students than just its exceptionally international nature. Not only is Luxembourg an important financial centre, the country is also home to many European institutions, such as the Court of Justice of the European Union. Naturally, the University makes use of these connections, as about 860 financial and legal experts, entrepreneurs and other practitioners from industry and government complement the academic training with their practical insights. There is close cooperation with the greater region just across the country's borders. This relates to work with economic and academic actors for research and teaching, providing students with a clear advantage as they transition into their professional lives.

Furthermore, the University takes pride in the personal touch that it is able to provide to its students due to its relatively small size and the excellent professor-student-ratio. Collaboration and team work between students is encouraged by innovative teaching methods and supported by the state-of-the-art learning facilities. •

Voices of our students

Oladjo Rachelle Aloko, Luxembourg School of Finance

"There were many reasons why I considered applying to Luxembourg School of Finance at the Luxembourg University. I was convinced that the curriculum was ideal to develop the skills required to succeed in my career in banking and finance. Luxembourg is also well known to be a leading European hub for investment funds. In my programme, we had the privilege of being able to participate in many important financial summits and conferences. We also had access to presentations made by businesses and to networking events. There were also female mentoring opportunities, as well as individualised career guidance. Our professors came from top universities and from around the world and are very experienced."

Tea Sikharulidze, master's in geography and spatial planning

"Out of all the options, I found Luxembourg to be the most attractive based on many criteria. Although the University is new, it offers very good conditions for students with courses conducted in English and with affordable tuition fees. Laboratories are equipped with all the necessary tools for learning. In addition, I really like the student job opportunities made available by the University for its students. In my opinion, the University of Luxembourg is very different from other universities for its multilingual and multicultural environment."

Antony Martini, master's in entrepreneurship & innovation

"One of the major deciding factors for international students is that the University of Luxembourg is closely connected to the local labour market, with one of the highest recruitment rates and the highest wages in the European Union. The master's programmes have limited their size to no more than 25 students each. The aim of such small classes is to guarantee a strong interaction between teaching staff and students."

Panuwat Trairatphisan, master's in integrated systems biology

"The study at the University of Luxembourg is rather different from the study in my former university in Thailand. Here at the University of Luxembourg, we have quite a small number of students, which would benefit both the teachers and the students to have more interaction personally in the class. Another strong point of the University of Luxembourg is that there is no studying fee, just the fee for registration per semester which is very reasonable, especially when compared to studying in the other countries in Europe."

International agreements

Welcome to one of the most international universities in Europe

Italy

Ca'Foscari University of Venice
Università Degli Studi Roma Tre
International School for Advanced Studies (SISSA) in Trieste

Belgium

University of Liege
University of Namur
University of Mons

Netherlands

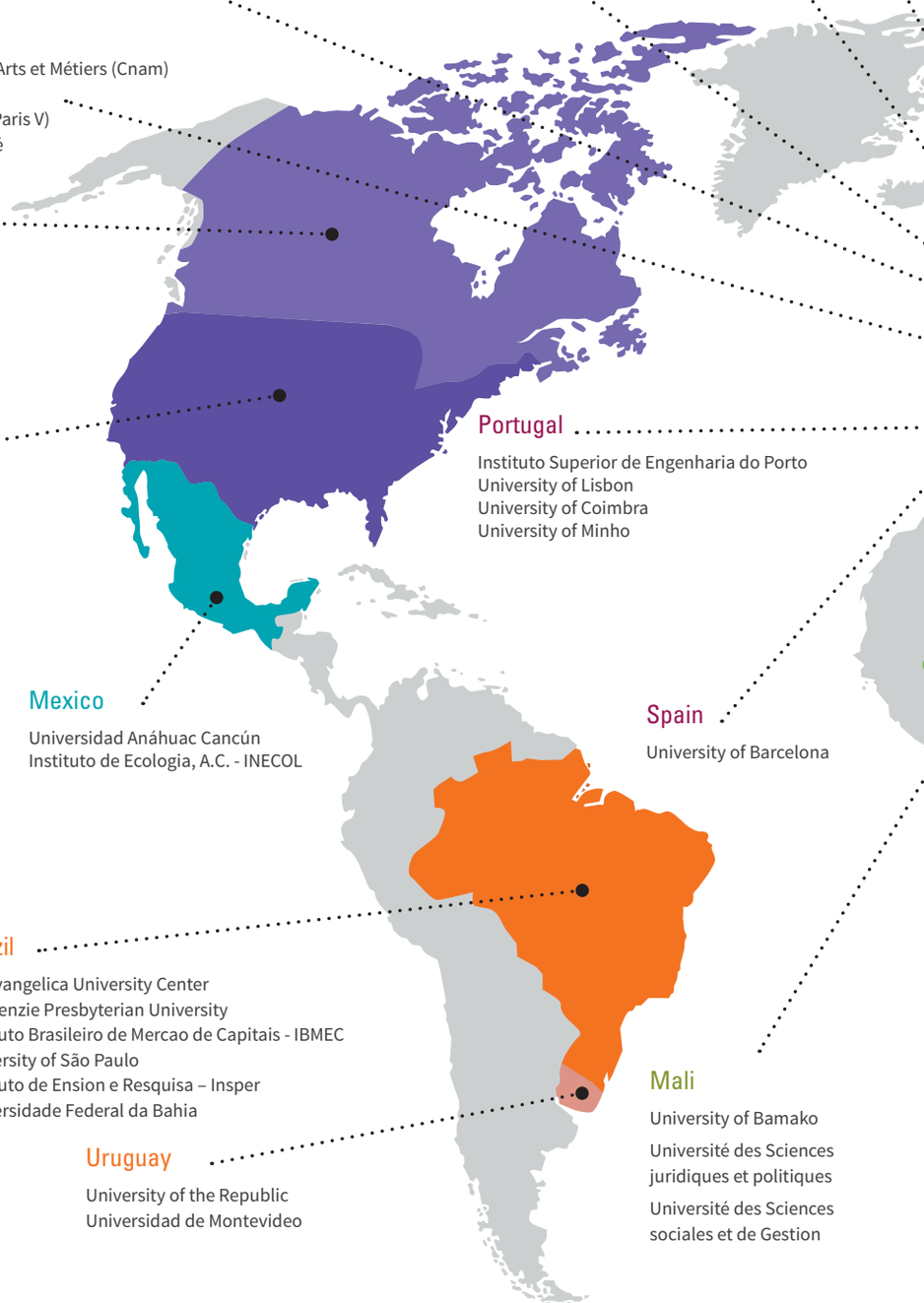
Maastricht University

United Kingdom

King's College London

France

University of Lorraine
University of Strasbourg
Conservatoire national des Arts et Métiers (Cnam)
University of Montpellier 1
Paris Descartes University (Paris V)
University of Franche-Comté



Canada

BCI (Bureau de coopération interuniversitaire)
York University, Osgoode Hall Law School
Université du Québec à Chicoutimi
Université de Sherbrooke
University of Ottawa
Université de Montréal
Université Laval
Université de Moncton

Portugal

Instituto Superior de Engenharia do Porto
University of Lisbon
University of Coimbra
University of Minho

USA

Florida Institute of Technology
University at Albany, SUNY
Lakeland College
Northern Arizona University
Miami University
University at Buffalo
University of Louisville
Johns Hopkins University
Caltech
Marquette University
William and Mary School of Law
University of San Francisco
Columbia University
University of Virginia's College at Wise
The University of Illinois at Urbana-Champaign
University of California Berkeley
Massachussets Institute of Technology - MIT

Mexico

Universidad Anáhuac Cancún
Instituto de Ecologia, A.C. - INECOL

Spain

University of Barcelona

Brazil

UniEvangelica University Center
Mackenzie Presbyterian University
Instituto Brasileiro de Mercao de Capitais - IBMEC
University of São Paulo
Instituto de Ension e Resquisa – Insper
Universidade Federal da Bahia

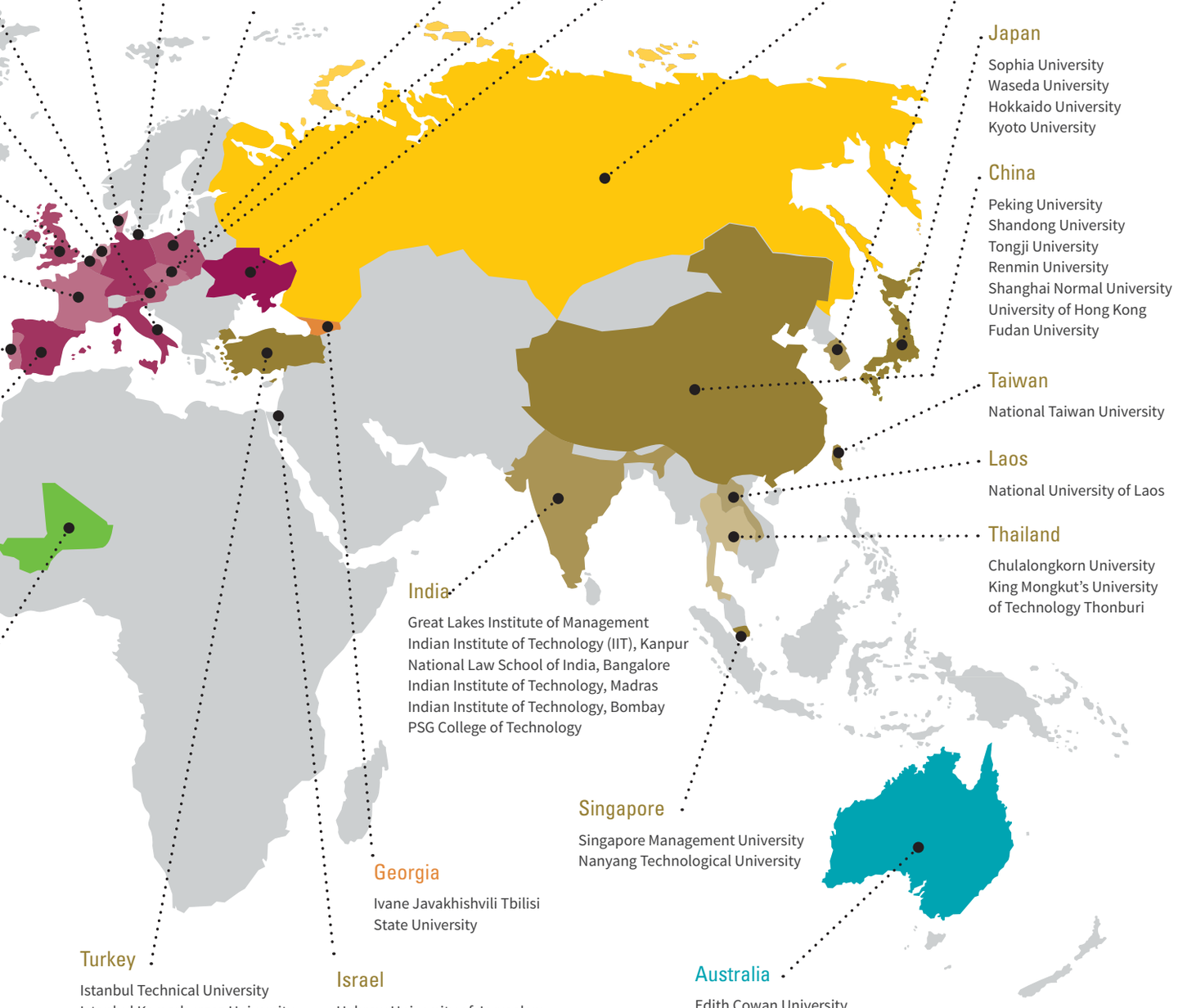
Uruguay

University of the Republic
Universidad de Montevideo

Mali

University of Bamako
Université des Sciences juridiques et politiques
Université des Sciences sociales et de Gestion

The University of Luxembourg has exchange agreements with approximately 90 partner universities around the world. Those agreements allow student exchanges – as all Bachelor students have to spend at least one semester at a university abroad – but also involve research projects and exchange of researchers.



Germany

Technical University of Berlin
Technical University of Darmstadt
Technical University of Dresden
Technical University of Munich
Saarland University
University of Trier
University of Bonn
Heidelberg University
University of Applied Sciences Saarland (HTW)
Trier University of Applied Sciences

Czech Republic

Charles University Prague

Russia

St. Petersburg State Polytechnical University
Steklov Mathematical Institute Moscow
Omsk State Medical Academy
Tambov State University
National Research University Higher School of Economics

Austria

Technical University of Vienna
University of Vienna
University Innsbruck

Ukraine

National Technical University
of Ukraine – Kyiv Polytechnic Institute
Yaroslav Mudryi Nation Law University

Denmark

DTU Space

Poland

Polish Academy of Science
Warsaw University of Technology
University of Warsaw

Korea

Hanyang University
Korea University

Japan

Sophia University
Waseda University
Hokkaido University
Kyoto University

China

Peking University
Shandong University
Tongji University
Renmin University
Shanghai Normal University
University of Hong Kong
Fudan University

Taiwan

National Taiwan University

Laos

National University of Laos

Thailand

Chulalongkorn University
King Mongkut's University
of Technology Thonburi

India

Great Lakes Institute of Management
Indian Institute of Technology (IIT), Kanpur
National Law School of India, Bangalore
Indian Institute of Technology, Madras
Indian Institute of Technology, Bombay
PSG College of Technology

Singapore

Singapore Management University
Nanyang Technological University

Georgia

Ivane Javakhishvili Tbilisi
State University

Turkey

Istanbul Technical University
Istanbul Kemerburgaz University

Israel

Hebrew University of Jerusalem

Australia

Edith Cowan University
University of Newcastle

Research(ers) in Luxembourg

Excellent support and a clear strategy

The University of Luxembourg already ranks among the best 180 universities in the world, only 13 years after its foundation in 2003. The University achieved an outstanding 178th worldwide in the 2016/17 edition of the Times Higher Education Rankings. For Computer Science, it was placed as high as 58th. An excellent performance was the category "Citations", a clear indicator of the high quality of the University's research.

An important part of this success is the strategic decision to define research priorities and focus on those areas. "A university always has to make sure it has a healthy mixture of defined focuses and free areas," says Prof Ludwig Neyses, vice-president for research. "Alongside our six core fields – educational sciences, international finance, European law, computational sciences, ICT and systems biomedicine plus a recently created centre researching Luxembourgish and European history – there are several other thematic fields in which we are international leaders."

Big data applications for research

As digitalisation is one of the major pillars of the University's long-term strategy, it has invested heavily in its High Performance Computing capabilities. "An increasing number of scientists need support to get to grips with big data, including those who have never before used high-performance computers," said Prof Pascal Bouvry, senior advisor to the University president for high-performance computing strategy. From biologists conducting genome research and material researchers, to economists modelling social mobility, researchers are increasingly discovering the vast possibilities of big data applications for their work. In addition to providing five petabytes of storage capacity and supercomputers to crunch the numbers, the University has started a cross-disciplinary working group to develop mathematical models to describe the challenges inherent in these research projects.

Easy access to funding

Similarly, the University's research support department helps researchers to acquire funding from national, European and private sources. The department not only advises scientists to find the best-fitting funding schemes for their projects, they also give practical help and advice with the application process. Currently there are 29 "Horizon 2020" projects, four grants from the European Research Council (ERC), and a high success rate with the Luxembourg National Research Fund (FNR). Plenty of evidence that this work is bearing fruit.

From the outset, the University managed to recruit highly talented scientists from all over the world. In addition to the good living conditions here and the international atmosphere, researchers are attracted by the outstanding research environment and competitive salaries. •

Voices of our researchers

Dr Gavin Robinson, postdoctoral researcher, European Law

"I first came for the fully bilingual (French/English) courses, and the proximity to EU institutions, chiefly the Court of Justice of the European Union, which I was able to visit on a regular basis. Having seen first-hand the excellent conditions for doctoral researchers here, I decided to apply for funding.

I would say the distinctive feature of Luxembourg is that it is on the move: researchers of all levels are encouraged to keep abreast of developments across Europe and the world, and to build and maintain networks beyond borders."

Stéphane Bordas, professor, Computational Mechanics

"I am an adventurous person, and setting foot in a ten year old university whose main priority is computational sciences and digitalisation was an obvious motivator for me. I immediately noticed the immense potential of this institution, which harbours some of the best researchers in fields that were key to the development of computational sciences.

The idea of setting up its main research priority in computational sciences is a major point in favour of the University. This will enable it to set itself apart from competitors, and create, at the heart of Europe, a unique hub for scientific computing.

The national research council is very well connected to other research councils worldwide, which makes it straightforward to collaborate with other countries. The political class and other decision makers are highly accessible, making it possible to influence high level policy and have a say in the direction in which the country is going. This is highly motivating."

Zuogong Yue, PhD student, Systems Control Group

"The Luxembourg Centre for Systems Biomedicine at the University of Luxembourg offers versatile possibilities to put your theoretical work into practice. The outcomes of my studies are no longer limited to being published in academic papers but are real case-studies in biomedicine. Even though every day I deal with frosty mathematics or programming languages, I feel that my work stays close to biomedicine and helps to improve the lives of patients."

Research in Material Science

Wonder-material liquid crystals: from robotic muscles to reactive textiles

Prof Jan Lagerwall

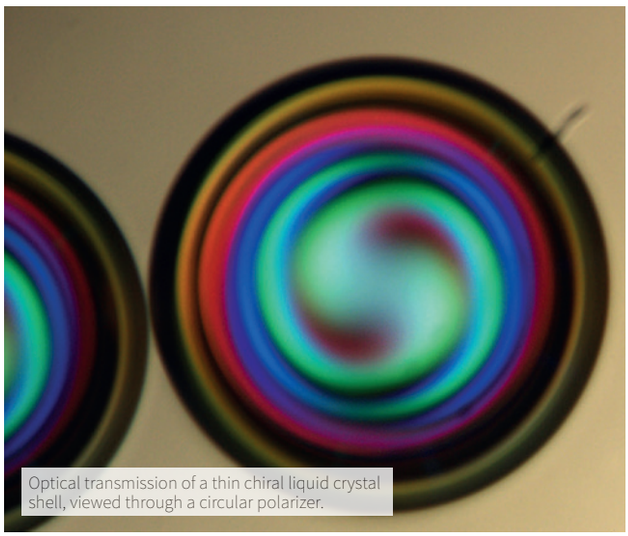
Discovered in 1888 by the Austrian Friedrich Reinitzer, liquid crystals were just a scientific curiosity for nearly a century until electronics manufacturers used them for digital displays in the 1970s. Recently, researchers at the University of Luxembourg have been looking into a number of fascinating potential new applications for the material.

Prof Jan Lagerwall of the Physics and Materials Science Research Unit at the University of Luxembourg is a highly renowned international expert on liquid crystals. Originally from Sweden, he leads an international team of researchers investigating new ways to harness their unique properties.

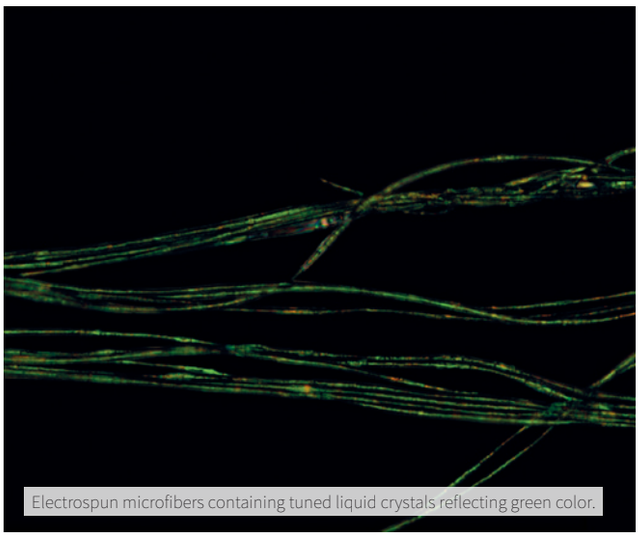
Intermediate state between solid and liquid

"Liquid crystals are in an intermediate state between solid and liquid. While they flow like a liquid, they retain some of the properties of solids," explained Prof Lagerwall. The reason for that is the arrangement of molecules: Unlike in a regular liquid, the molecules in a liquid crystal mostly point in the same direction. However, they don't organise on a lattice like in a solid state. Thus, it is possible to use subtle stimuli to change the order of the liquid crystal, and thereby its macroscopic properties. For example, the optical properties in a liquid crystal display change when an electric field is applied.

In one of the main research projects of Prof Lagerwall's team, they experiment with liquid crystalline elastomers (rubbers) which can be brought out of the liquid crystalline state using external impulses, such as heat or light. The



Optical transmission of a thin chiral liquid crystal shell, viewed through a circular polarizer.



Electrospun microfibers containing tuned liquid crystals reflecting green color.

resulting molecular change alters the shape of the entire object. The process can be reversed by switching off the external impulse.

Robotic rubber skin

Prof Lagerwall and his colleagues are currently working to harness these effects for use in engineering. One potential application is robotics. The contraction and expansion of the material could enable the construction of artificial "muscles" for robots. "The special thing is, you do not need motors, the material is its own engine. But in order to harness this, you have to learn how to control the movement," explained Prof Lagerwall.

"However, we are currently not focusing on solutions to replace existing robots, but to complement them. Robots often have difficulties performing certain simple tasks. For example, when picking up an egg they either apply too much pressure and squash the egg, or too little and the egg slips through," he added.

His solution is a liquid crystalline rubber skin that adapts to the objects, just like human skin. With the help of such an active skin, robots would be able to handle tasks that are currently beyond them.

Security applications

This is only one of many potential applications for the technology. The research unit is investigating these with colleagues from other universities and the Interdisciplinary Centre for Security, Reliability and Trust (SnT) of the University of Luxembourg. The researchers have explored how the optical properties of liquid crystal spheres can be used to prevent counterfeiting of valuable objects. As the spheres reflect specific colours and light in the same way as butterfly wings, the interaction between the spheres generates unique colourful patterns. Because the configuration of those patterns depends on the random arrangement of crystal spheres, they are practically impossible to copy.

Therefore, they could be used to create tokens that ensure an object is original and not counterfeited, comparable to a watermark on a banknote or a hologram on a credit card. "It is so hard to copy these patterns that even we would not be able to produce the same pattern twice," says Lagerwall. This technique of authentication has potential applications in a vast variety of fields, ranging from hardware and drug packaging to artworks and personal identification.

Wearable technology is another avenue being explored by Prof Lagerwall and his team. They have been experimenting with electro-spinning techniques to produce fibres containing liquid crystal for use as clothing material. As liquid crystals can change their optical appearance when they come into contact with certain gases, those fibres could, for example, be used in certain professional settings. "Factory workers or soldiers could be made aware of dangerous substances in their immediate surroundings if their clothes were to change colour", explained Prof Lagerwall.

In 2015, Jan Lagerwall was awarded with the prestigious "Consolidator Grant" by the European Research Council (ERC). He and his team are using the funding to further explore the fascinating possibilities of liquid crystals. •

Research in Economics and Law

A unique view on migration

New economic, social, political and geographical forces are driving global population movement. Voters and decision-makers require dispassionate analysis of these trends to better understand the related challenges and opportunities. Migration is a major topic for discussion in Luxembourg given that nearly half the resident population are non-nationals. The country's multilingual University reflects this diversity, and is therefore particularly attuned to research in this area.

There are currently eight University of Luxembourg economics professors in the Centre for Research in Economics and Management devoting at least some of their time to probing different dimensions of international migration. Michel Beine, a Professor in International Economics, specialises in this topic, generally taking a global, macro-economic perspective. For example, his recent work has studied the impact of immigration on economic outcomes, the determinants of economic migration, and the impact of climate change on global mobility.

Reducing economic imbalances

For example, he has demonstrated how economies can address economic imbalances and boost stability by attracting workers from abroad. "Some economies risk over-dependence on natural resources," he commented, "with native populations attracted to work in a sector which lacks long-term sustainability". Immigration can correct this imbalance. In another paper, he concluded that climate change played little or no role in driving international migration between 1960-2000.

Part of Prof Beine's work is with prestigious international partners (including the London School of Economics, Harvard, the University of Amsterdam and the University of New South Wales, Australia) to build a database of global immigration policies in nine key countries. This resource will help academics and decision makers determine best practice.

Studying the legal aspects of migration

Dealing with population movements has generated substantial new statutory and case law, as well as administrative procedures. Understanding these details is a particular focus in the University of Luxembourg's Research Unit in Law. "Our decision to make the legal aspects of migration a research priority resulted from many of us having chosen independently to concentrate on this area," commented Silvia Allegrezza, Associate Professor of Criminal Law. Moreover, there are working groups with colleagues from economics and political science, with the ambition to broaden further this interdisciplinary work. The result is a unique approach to understanding and comparing the details of European Union law, administrative law, fundamental rights, international law, criminal law, labour law and the philosophy of law.

The research unit is also part of a global effort to record and classify different national legal and administrative approaches to immigration. This work is exemplified by participation in the Odysseus Academic Network, a database of global legal and administrative texts and procedures. "This resource is helping the international research community understand the diversity of approaches used to address this key challenge," explained Prof Allegrezza. •

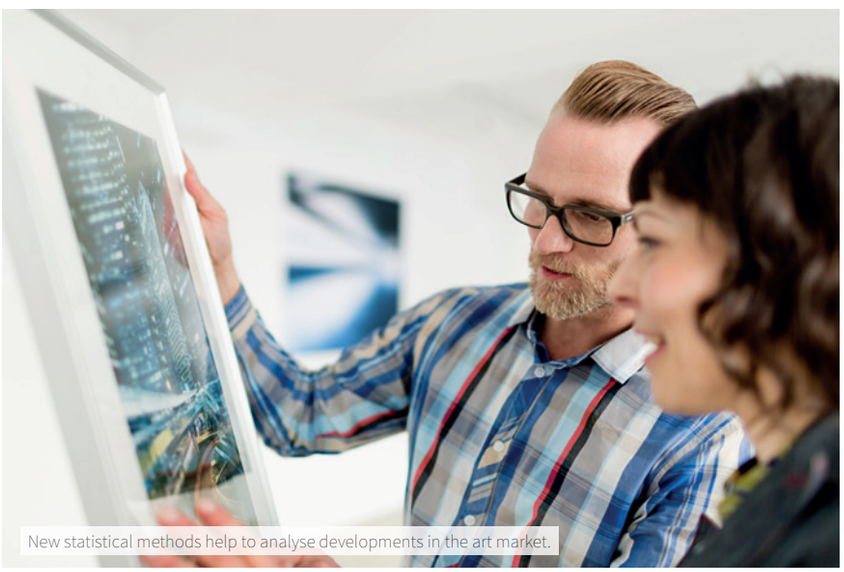
Prof Michel Beine

Prof Silvia Allegrezza.

Research in Finance

Financial analysis and the art market: Is there a bubble?

The fascination of soap bubbles is that they shimmer magnificently but, when they burst, they leave a sticky mess behind. The notion of bursting bubbles is a good analogy for a process in markets, namely an unusual rise in prices followed by a sudden collapse. To help make better predictions and bring greater clarity of these events in the art market, Prof Roman Kräussl, Prof Thorsten Lehnert and Dr Nicolas Martelin, all of the Luxembourg School of Finance at the Faculty of Law, Economics and Finance, have developed a new statistical method founded on a solid basis of data that should bring greater clarity to the art market.



New statistical methods help to analyse developments in the art market.

"For our research project, we analysed more than one million auction records from the past 36 years," said Prof Kräussl. The art index he has developed reveals price trends on the art market more accurately than ever before. Previously existing indices are based on far less data, but the new index also includes works that have been auctioned only once. It is based on all publicly available data from the world's most important auction houses.

New analytical method

Market bubbles depict a dramatic increase in prices relating to a product that offers no intrinsic value of its own anymore, and so becomes an object of speculation. The art market is especially susceptible to such trends in pricing, since the prices of artworks cannot be measured against classical values such as production or material costs, but are instead measured against aesthetic requirements, status or a collector's passion.

With their method, Prof Kräussl's team were able to detect the bursting of a bubble in the early 1990s. After an unusual rise, prices plummeted, they found, but the market rebounded surprisingly quickly. "Since you can never tell how long the rising phase will be for prices on the art market, our new research approach is an important instrument for creating a point of reference. We believe that the art market is currently overheating. In such a situation, the probability that a bubble exists and that it is about to burst is high," the world-leading art market expert suggested. •

Prof Roman Kräussl

Researching inequality and equality

Luxembourg – the ideal education laboratory

Many aspects of our lives are determined by the level of education we achieve. Studies have shown that education not only affects a person's income and status, but also their health and even life expectancy. Schools help educate the workforce of the future, and they are also crucial for social integration and building a coherent population. This is especially important for a country like Luxembourg where 47 percent of the population are foreign nationals. Over the coming decades, the share of foreigners is expected to increase even further through continued immigration, as the country's population is projected to almost double by 2060 to 1.1 million.

"In Luxembourgish schools we have a very high proportion of migrants. What other countries are afraid of, is already a reality in Luxembourg," says Andreas Hadjar, Professor of Sociology of Education, and member of the Institute of Education and Society at the University of Luxembourg. In this context, it is crucial to make sure that all citizens have equal access to education. "It is important to do research in this area, because certain groups of people show lower educational achievements or even run a high risk of dropping out of the system with the possibility of being unemployed for life. From a macroeconomic perspective, it is essential to develop talent reserves that might otherwise be lost," Prof Hadjar explained. "Given the high proportion of migrants living in Luxembourg and cross-border commuters, Luxembourg's economic prosperity very much depends on migration and mobility".

Researchers from the University of Luxembourg investigate the impact of equality on educational attainment.

Alienation from school

In his research, Andreas Hadjar investigates the reasons for the connection between social background and educational attainment. Students from working class or migrant families, for example, are less likely to qualify for university. He investigates how differences in individual decision making processes and family resources trigger such developments. In an on-going research project, Prof Hadjar and his team will interview 1,000 students in Luxembourg over a three-year period to determine the social factors that cause alienation from school and education. They will ask pupils about their performance in school, the time they spend studying, episodes of delinquency in school, social background, the value they and their family attribute to education, teaching methods of individual teachers, and school conditions.

In addition to individual and socio-economic factors for differing educational success, Prof Hadjar and his team look at school systems. They conduct cross-country comparisons with large sets of data to analyse the impact of different educational structures on inequality. "We have seen that the early separation of students in a multi-track school system, such as the German one, fosters inequality," explained Prof Hadjar.

"If you want to reduce inequality, the class composition is crucial.

Disadvantaged students benefit the most if there is a balanced mix of students from middle class and working class or migrant families in order to increase the overall motivation." Additionally, support structures, such as social workers or a second teacher who is present in class to help weaker students, prove very effective.

— Prof
Andreas Hadjar

Barriers to inclusive schooling

"For example, in Finland or in Iceland about a quarter of all students receive additional resources to achieve their learning goals," explained Prof Justin Powell, who also works in the Institute of Education and Society. He also researches inequalities in education systems, but the focus of his work is understanding the barriers and facilitators to inclusive schooling. "It's a fallacy to assume that learning in homogeneous groups is better. All learners benefit from diversity in peer interactions" he said. "Stronger students benefit when they assume the role of teachers, working in small groups, with all students improving their understanding as they work on projects and share with others what they have learned." Prof Powell dedicates his research to the question of how schools and school systems need to be shaped so that they are able to educate every student under a single roof. Therefore, he studies and compares successful models of inclusion in different countries as well as obstacles to school integration across time and place.

Both researchers see Luxembourg as the ideal "laboratory" for their research on inequality and equality in education. Not only does the country have a diverse population with a high level of migrant families from different backgrounds. The relatively small size of the country also makes it easier to study the effects of reform processes on schools. "Luxembourg is an incredible laboratory to investigate diffusion and transformation processes that are constantly taking place, in research as well as in politics and administration," said Powell. Working at the only public university of the country, it is easier for researchers to be heard by decision makers in Luxembourg's education system, thus findings can be more easily translated into policy advice.

Within the University, researchers benefit because their colleagues and students have diverse origins. Here, the different educational traditions and concepts of the German, French, and anglophone systems come together, allowing for fruitful discussions. "Intercultural comparisons arise regularly, encouraging scientific paradigms to clash, with fundamental debates taking place regularly. Normally, you only benefit from such intercultural exchanges at international conferences. In Luxembourg, this is our daily routine," Prof Powell concluded. •

"Intercultural exchanges are our daily routine"

— Prof
Justin Powell

Research in information technology

Digital physiotherapy for stroke victims

A personalised exercise regimen is represented graphically by an animated human figure on a PC or a tablet computer. A personalised exercise regimen is represented graphically by an animated human figure on a PC or a tablet computer. A personalised exercise regimen is represented graphically by an animated human figure on a PC or a tablet computer.

Patients recovering from a stroke often need to follow precise rehabilitation regimes to regain motor functions and prevent a second attack. Unfortunately, many people find it difficult to repeat accurately the exercises they have been set without direct support from a physiotherapist. Also, there is a temptation to skip repetitive, boring exercise sessions. Smart video technology from the University of Luxembourg is set to provide a solution.

Regaining physical mobility after a stroke is a physical and mental challenge. Physiotherapists create re-education programmes to help patients relearn motor functions damaged by the stroke. During one-to-one sessions, they make sure exercises are conducted correctly and provide encouragement. Once at home patients are expected to maintain physical activity independently, but many find it difficult to judge if these exercises are being performed correctly. Moreover, the hundreds of hours needed to relearn simple things can be demoralising, sometimes leading patients to fail to follow their rehab programmes. Performing exercises incorrectly and inefficiently tends to slow, or can even prevent, recovery.

Ensuring ideal exercise

Video and information technology being developed by the University of Luxembourg's Interdisciplinary Centre for Security, Reliability and Trust (SnT) could help. They are working on a system in which a personalised exercise regimen is represented graphically by an animated human figure on a PC or a tablet computer. The patient would seek to replicate these movements, and while doing so an estimation of their body position would be represented on screen using measurements obtained with a 3D camera. In real time the patient would receive feedback about whether they are performing the exercises adequately. For example, the "digital physiotherapist" might ask the patient to extend an arm at a certain angle, and if this movement was not completed correctly the patient would be informed instantly and encouraged to do better.

There would be several advantages to such a system. Most obviously, recovery is hastened if patients follow accurately the exercises designed for their precise needs. Moreover, the system would transmit data to doctors and therapists instantly, keeping them up-to-date with progress on the accuracy and frequency with which exercises were being carried out, and the extent to which a patient's motor functions were being recovered. Exercises could be amended in light of this data and extra encouragement given to the stroke victim. There is a strong psychological element to this. Patients are more confident when they know they are exercising in an optimal fashion, and there would be clear evidence of even small gains of increased mobility.

International, interdisciplinary

"Developing a system that is both therapeutically and technically sound is complicated, and requires careful input from a range of experts from different disciplines and countries," explained Dr Djamila Aouada, the head of the SnT's Computer Vision Laboratory in the SIGCOM group of SnT director Prof Björn Ottersten. Her team is part of a seven-country consortium working on this project. Known as STARR: Stroke, Technology and Risk Reduction, it brings together about a dozen groups of medical practitioners, and technical researchers and developers. Supported by the EU's Horizon 2020 programme, the three-and-a-half-year project began in February 2016.

The SnT brings IT and electrical engineering expertise to the programme, work which enables a computer linked to a 3D camera to track and analyse body position accurately and easily. Traditional systems require patients to attach sensors to their bodies, but the Computer Vision Laboratory is developing a solution that can avoid this laborious, off-putting step.

"We have been working for several years on enhancing the performance of 3D cameras in order to use them for activity recognition in real-world conditions," explained Dr Aouada. Data received from standard, commercially available, moderately priced 3D cameras is processed efficiently, resulting in a highly accurate 3D digital portrayal of bodily movements. They are also addressing technical questions about data privacy, and the creation of interfaces that are easy to use for patients and medical practitioners.

Regular contact is maintained with the rest of the project consortium, with input required from medical practitioners, therapists, psychologists and others. "The computer vision team here at SnT is a mixture of people with backgrounds in electrical engineering (which is my case) and computer science," explained Dr Aouada. This project exemplifies the SnT's dedication to working with people from different cultures and academic specialisations, a philosophy that has seen it play a central role in the University achieving a ranking of 58th for Computer Science in the Times Higher Education World University Ranking •

— Dr Djamila Aouada

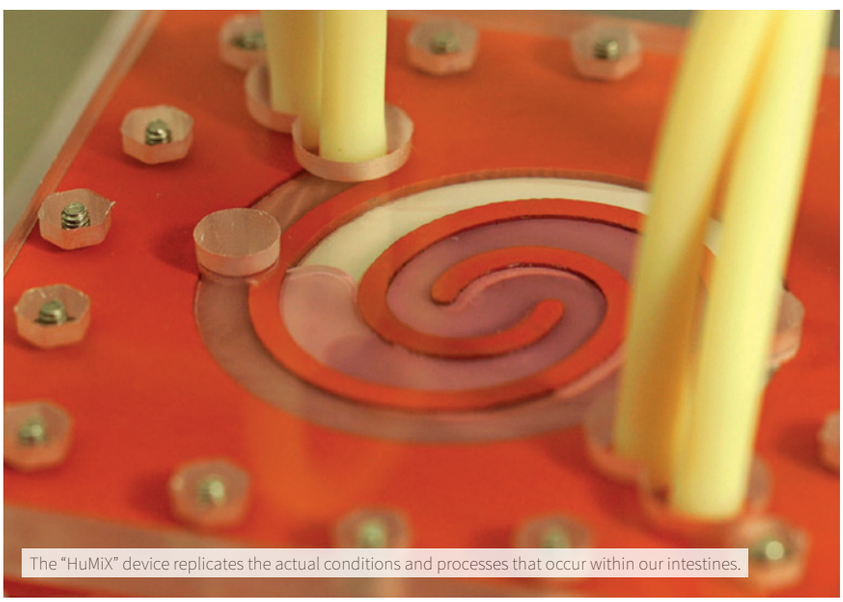
Technology Transfer

SnT scientists are expected to conduct both long-term, high-risk research, and to engage in demand-driven projects. Along with the Partnership Program, through which SnT works in collaboration with 32 private and public organizations, generating 4 million euros annually, the Technology Transfer Office (TTO) ensures that SnT is at the heart of efforts to build a vibrant innovations ecosystem in Luxembourg.

The path from research results to commercially-viable solutions is long and challenging; to enable SnT researchers to overcome the many obstacles along the way, the TTO gives would-be entrepreneurs in-depth support, from identifying opportunities and formulating business plans to obtaining funding and securing intellectual property. Over the last two years the TTO has managed a dozen proof of concept projects (in which prototypes are developed), four of which have gone on to be launched as spin-off companies. This approach demonstrates that scientific excellence and socio-economic impact can thrive in tandem.

Biomedical research

Revolutionising understanding of the gut



The "HuMiX" device replicates the actual conditions and processes that occur within our intestines.

Many biologists now believe that our physical and mental health may be affected by bacterial interactions in the gut. Cancer, obesity, depression, asthma, Parkinson's disease and more could all have a root in activity in the digestive tract. We are closer to unlocking these secrets thanks to a recent methodological breakthrough led by the Luxembourg Centre for Systems Biomedicine (LCSB) at the University of Luxembourg. As well as opening new scientific opportunities, this is an important step for the country's emerging biotech industry. Food scientists, drug researchers and academics need reliable systems for mimicking conditions in the human digestive tract. The gut is thought to have substantial influence on our well-being, leading some to call it "the second brain". Researchers need a new way to observe closely what happens when bacteria encounter food and medication, as traditional methods have serious limitations. "Growing cultures in a Petri dish can only give us basic understanding, and testing in germ-free animals contends with their physiology being different to that of humans, as well as the ethical concerns," explained Prof Paul Wilmes, head of the LCSB Eco-Systems Biology Group.

Unique experimental system

After more than four years work, his team perfected a unique experimental system that closely replicates real life circumstances. It enables intestinal cells and bacteria to be cultivated and to interact as they do in vivo. The research team dubbed this device "HuMiX", which stands for "Human Microbial Cross-talk". It has a square polycarbonate frame that is about the size of a beer mat and a few millimetres thick. This supports parallel semi-permeable membranes that create three chambers. Human gut cells grow in the middle layer, fed by nutrients flowing in from the upper chamber, with bacteria cultivated in the lower chamber. This system allows material to interact as it does in our bodies.

This "gut on a chip" system breaks ground in important ways. "Before HuMiX, nobody had been able to co-culture human and microbial cells while ensuring that the microbes grow under anaerobic [oxygen free] conditions as is the case in the gut," explained Prof Wilmes. "All the dynamics in HuMiX are driven by the same physical conditions and processes which you also encounter in vivo," he added. The devices are placed in an incubator during experiments, and work is on-going to increase capacity to facilitate both academic and commercially-driven research. Several patents have been requested.

Researchers are now able to analyse the complex interactions between human cells and bacteria, predict their effects on health or disease onset, and examine the action of probiotics and drugs. "HuMiX enables us to study the molecular interactions between hu-

The LCSB at the University of Luxembourg is accelerating biomedical research by closing the link between systems biology and medical research.

man and bacterial cells that until now had been inaccessible," Prof Wilmes explained.

Interdisciplinary capability

The LCSB's interdisciplinary systems biology expertise and global connections were key to making this breakthrough. "I had long thought about how to study interactions between the human system and microbes and was aware of the limitations of animal models," Prof Wilmes noted. The "lightbulb" moment came following discussions with Prof Frederic Zenhausern of the University of Arizona, an institution with close links to the LCSB. "Frederic was working on microfluidic systems, and after talking to him I began to think of how these approaches could be harnessed for co-culturing human and bacterial cells under in vivo-like conditions," he added.

A successful application for funding was made to Luxembourg's National Research Fund, and work began in 2011. Several researchers were involved at the LCSB, but also the University of Arizona and the Luxembourg Institute of Health. Four years and about a dozen versions later, HuMiX was launched officially with the publication of a research paper in Nature Communications.

Scientific and commercial opportunities

Prof Wilmes is leading a research team at the LCSB that (along with a team at the University of Arizona) has exclusive, advanced use of HuMiX's leading edge technology. For example, they are currently investigating the molecular mechanisms by which high-fibre food are thought to prevent colorectal cancer. Then there is the work to commercialise HuMiX.

"An example of how it could be used is to enable food companies to design personalised probiotic formulations," explained Dr Pranjul Shah. An engineering post-doctoral researcher and one of the co-inventors of HuMiX, Dr Shah is working to bring the technology to market. He speculated that supermarket shoppers might one day be able to purchase foods that can counter disease symptoms such as obesity, stress, ulcers, diabetes or cancer. Pharmaceutical companies also see a potential. "For example, at the moment they have no means of knowing how certain drugs are metabolised in the gut and how microbes specifically affect the active compounds," he added.

The team is building business partnerships and working to secure private equity backing. Substantial interest is coming from Boston and Silicon Valley in the USA, as well as numerous players across Europe. Competition is fierce, but given HuMiX's revolutionary nature, the team are confident that this blockbuster product is putting Luxembourg on the map in the global biotech industry. •

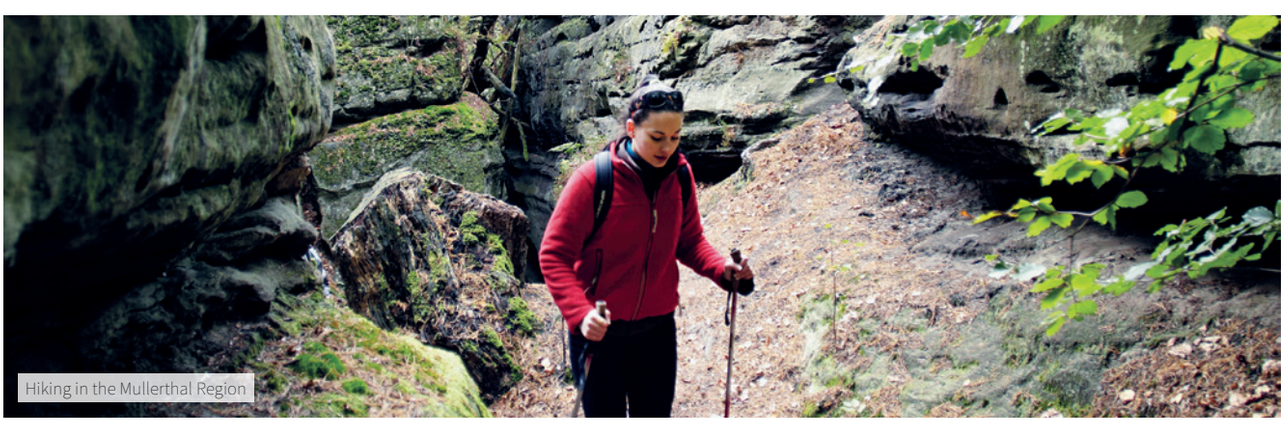
Prof Paul Wilmes

Dr Pranjul Shah

Living in Luxembourg

A smart nation in the heart of Europe

Luxembourg city snow covered in winter



Hiking in the Mullerthal Region

Luxembourg is situated at the very heart of western Europe between France, Germany and Belgium. Luxembourg is one of the most intercultural and international societies in the world, with over 170 nationalities living together. Almost 70% of the residents of the cosmopolitan capital are non-Luxembourgers and, nearly half of the entire population (46.7%) are non-locals. Multilingualism is an integral part of Luxembourgish culture. In addition to the country's three administrative languages Luxembourgish, French and German, it is common for people to use English at work and in their social lives.

Luxembourg has an exceptionally high standard of living, and one of the highest levels of GDP per capita in the world. The national workforce has grown each year by 3% on average over the past 30 years. The Grand Duchy is ranked by INSEAD as one of the Top 12 most innovative countries in the world, with substantial public/private efforts to create world class IT infrastructure. In short, there is a concerted effort to build a «Smart Nation», a country that is multilingual, cosmopolitan, hyper-connected, enterprising, and well trained.

A serene environment

Luxembourg is a safe bet. Not only is the national debt triple-A rated, it has a very low crime rate and is judged to be one of the safest countries in the world, according to the World Quality of Living 2016 report by the consultancy Mercer. The more than half a million

inhabitants promote diversity in all its forms: cultural, linguistic, and religious. The country has supported and integrated migrants and their children for well over a century. Thus, people come to Luxembourg from every corner of the world not only to earn a living, but also to raise a family in ideal conditions. In addition to excellent local public and private schools, there is an array of established international educational institutions. Growing up in Luxembourg is a rewarding experience, as children are able to learn several foreign languages at an early stage, while families enjoy well-resourced social protection and health care.

In 1994, Luxembourg City's historical centre was classified as a World Heritage Site by UNESCO. With its combination of modern architecture from world class architects, centuries old fortifications and underground bastions, Luxembourg City is the political, economic and cultural capital. Symbolically, the museum for contemporary art "Mudam", an impressive glass and stone structure, is located right next to the Fortress Museum, a restored eighteenth century fort detailing the country's history. The "Philharmonie" has established a strong musical reputation, and is a unique architectural construction with 823 striking white steel facade columns. In Esch-sur-Alzette, the modern architecture of the University is embedded in the industrial landscape of a converted steel plant. Together this represents both Luxembourg's economic past and future. The small Moselle town Schengen has a central place in the history of European unification, as the place where the treaty was signed that abolished most internal EU border checks.

The Kirchberg plateau is the location of many EU institutions and global financial service companies. This multi-use zone also features restaurants, shops, a shopping mall, a major cinema complex, and venues for cultural and artistic events.

A pleasant place in a stunning setting

Living is easy, particularly during the summer. People congregate at the numerous pavement cafés and bars after work, before maybe taking in an open-air movie or a concert. The diversity of social and cultural life continues to grow with the population. Whether it is family excursions to well curated museums, clubbing until dawn, participating in team sports, and hiking or biking in the forests or by the Moselle river, Luxembourg offers a wide range of leisure activities for all tastes.

Luxembourg is also perfect for exploring western Europe, as it is only a few hours away from major European cities, such as Brussels, Paris, Frankfurt am Main and Amsterdam. •

Total Area	2,586 km²
Population	576,249 inhabitants *(46, 7% non-Natives)*
Capital	Luxembourg City *(115,227 inhabitants)*
Languages	French, German, Luxembourgish and English
Currency	Euro
Political System	Constitutional Monarchy/ Parliamentary Democracy
GDP Nominal Per Capita	$104,359

Key facts and figures of our University*

6,200
Students
Total

600
PhD students
Total

Ranked **178**
worldwide
in the Times Higher Education (THE) World University Rankings 2016/2017
· Most International University in Europe
· 3,100 international students

41.4
Million €
Total Third Party Funding

5
Grants
from the European Research Council

3
Faculties
Faculty of Science, Technology and Communication

Faculty of Law, Economics and Finance

Faculty of Language and Literature, Humanities, Arts and Education

31
Successful Horizon2020 projects
(since 2014)

3
Inter-disciplinary research centres
SnT - Interdisciplinary Centre for Security, Reliability and Trust

LCSB - Luxembourg Centre for Systems Biomedicine

Luxembourg Centre for Contemporary and Digital History

*Statistics from 2016

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LUXEMBOURG
LET'S MAKE IT HAPPEN