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Belgium, the land of big breakthroughs

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[1]

Look around your home and you will almost certainly find something that has its origins in Belgium. Though perhaps best known today for beer, chocolate, waffles and the headquarters of the EU, Belgium has long been a big player in science, and discoveries by Belgian researchers, scientists and industrialists have had a huge role in shaping the modern world.

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Leo Baekeland, a Belgian chemist, invented Bakelite in 1907 - a discovery that marked the beginning of the modern plastics industry. Three decades earlier, Zénobe Gramme, an electrical engineer, accidentally stumbled on the first usefully powerful electric motor when he found that his Gramme machine, a kind of direct-current dynamo, would run in reverse. Ernest Solvay [2], another Belgian chemist, developed the Solvay process for the production of soda ash - a substance used in many industrial processes from glass manufacturing to water treatment. Paul Otlet [3], a Belgian visionary, entrepreneur and peace activist, is considered one of the fathers of information science. And, in a country where thinking big about science seems to come naturally, none thought bigger than Georges Lemaitre, a physicist and astronomer at Catholic University Leuven who proposed the Big Bang theory of the origins of the universe.

Lemaitre's university split in 1968 into the Katholieke Universiteit Leuven (KUL) and Université Catholique de Louvain but researchers at both continue to carry out groundbreaking work in many

fields, from astronomy and physics to nanotechnology, wireless communications and neuroscience. The universities have also led to several notable spin-offs, not least IMEC, today the largest research centre on nanoelectronics in Europe.

Researchers at KUL, for example, are coordinating the recently launched Enlightenment (1) project that promises to greatly improve our understanding of how the brain functions, potentially laying the foundations for a range of neuro-inspired technologies.

Combining neuroscience, neuro-engineering and computational methods, the team, which also includes researchers from Canada, France and the Netherlands, are building a technological platform for directly interacting with cell assemblies in the brain. In a series of behavioural experiments, they hope to establish a two-way dialogue between a brain and a computer to investigate whether manipulations of cell assembly activities can delete or create memories.

Better 'brain-computer interfaces' (BCIs) and computers that mimic brain activity are just some of the potential outcomes of an initiative that, as the researchers say, could have 'consequences we can only begin to imagine.'

More specifically, innovative BCI technology is at the core of another project that promises to help people with lower limb disabilities to walk. Coordinated by Belgian company Space Applications Services NV and involving Universite Libre de Bruxelles (ULB) among other European partners, the team behind the Mindwalker [4] (2) project will use innovative dry bio-sensors and non-invasive BCI to control a specially designed orthopaedic device to enable previously wheelchair-bound people to walk. A virtual reality environment will be used for training and the system will ultimately be tested in a series of trials reflecting everyday life environments and situations, such as carrying out simple activities at home, going shopping and interacting with people in the street.

From cryptography to communications and photonics

Another team at KUL, meanwhile, are coordinating the Ecrypt II [5] (3) project, a four-year Network of Excellence on cryptology in which 11 leading players in the field are developing a research roadmap and devising new cryptographic techniques using symmetric key algorithms, public key algorithms and protocols, and hardware and software implementation at three virtual laboratories.

The same team of cryptologists at KUL were behind one of the world's first practical implementations of crypto-biometrics. Working in the TURBINE [6] (4) project, they followed a 'privacy by design' approach that enables people to use their fingerprints to prove who they are while keeping their identity information safe.

'Instead of storing scans of fingerprints, we are using scans to generate a mathematical code that represents an identity. The code cannot be used to restore the original fingerprint sample, it can be revoked at any time and the same fingerprint can be used to generate multiple codes so people can have different identities or pseudo-identities for different purposes,' explains the TURBINE coordinator Nicolas Delvaux.

Meanwhile, fellow researchers at the Université Catholique de Louvain are involved in several pioneering projects in different fields. The university's electrical engineering laboratory, for example, participated in the Newcom++ [7] (5) project to develop a range of new technologies that go far beyond the current state of the art in mobile and wireless communications. Over the coming years, the results of NEWCOM++ should play a key role in providing cheaper, faster and more secure wireless internet access and expanding the capacity, range and functionality of mobile networks.

'The technologies we developed go beyond the LTE (Long Term Evolution) 4G standard now being deployed for mobile communications... they are not next generation technologies, but rather "after-next-generation" technologies,' Professor Marco Luise, the managing director of Newcom++, explains. 'By working on them, we hope to help Europe regain its prominence in the field of wireless and mobile communications.'

Important innovations in various sciences have also emerged from Ghent University and Vrije Universiteit Brussel (VUB). Both, for example, have world-class photonics departments that are working on a range of technologies that promise everything from higher definition television screens to advanced medical imaging systems and bio-medical implants.

The focus on photonics for healthcare is at the heart of the Photonics4Life [8] (6) project, a Network of Excellence including a team from VUB that sought to drive pan-European multidisciplinary research in 'biophotonics', an emerging field that embraces all light-based technologies applied to life sciences and medicine. Their work has led to new techniques for the analysis of cell processes, for non- and minimally-invasive diagnosis and therapy and for point-of-care diagnostics.

VUB, as well as KUL, are also playing key roles in developing new semiconductor technology. In the Copper [9] (7) project, teams from both universities worked on a pioneering approach to semiconductor production using non-aqueous solvents such as liquid ammonia and ionic liquids that allows more transistors - and hence more processing power - to be packed onto computer chips.

'Electrodeposition using liquid ammonia and ionic liquids has been done before, but this is the first time that this process has been used in the semiconductor industry,' explains Professor Jan Fransaer, a researcher in the Department of Metallurgy and Materials Engineering (MTM) at KUL. 'This technique will certainly help enable a continuation of Moore's Law at least for a few more generations.'

The technique is just one in a long line of scientific breakthroughs helped by research carried out in Belgium, where successive generations of scientists have continued to walk in the footsteps of Gramme, Lemaitre and Solvay.

In 1911, Solvay began a series of important conferences in physics and chemistry, whose participants included luminaries such as Max Planck, Marie Curie and a young Albert Einstein. Known as the Solvay Conferences, they are still being organised and, like Belgium itself, are continuing to attract some of the world's greatest scientific minds in their respective fields.

The projects featured in this article have been supported by the Seventh Framework Programme (FP7) for research.

(1) Enlightenment: Exploring the neural coding in behaving animals by novel optogenetic, high-density microrecordings and computational approaches: Towards cognitive Brain-Computer Interfaces
(2) Mindwalker: Mind controlled orthosis and virtual reality training environment for walk empowering
(3) Ecrypt II: European network of excellence in cryptology - Phase II
(4) Turbine: Trusted revocable biometric identities
(5) Newcom++: Network of Excellence in Wireless Communications
(6) Photonics4Life: Network of excellence for biophotonics
(7) Copper: Copper interconnects for advanced performance and reliability

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