

Think big

Innovation and research are forging our future. We look at the key projects and people in Catalonia seeking answers to the questions of today and tomorrow.

By Hannah Pennell

BCN SMART
ALWAYS

By Eulàlia Iglesias

►1BC

BARCINO, A ROMAN CITY

On top of what was called Mount Taber, the Romans built Barcino. Two large perpendicular streets, *Decumanus maximus* and *Cardo maximus*, converged in a huge forum. Today's Barri Gòtic neighbourhood has echoes of the grid layout of the time.

►11TH CENTURY

LET THEM HAVE WATER

Just outside the city, you can still see a section of the Rec Comtal, one of BCN's first hydraulic projects, built to replace the abandoned Roman aqueduct. Its glory days began in the 11th century, when it carried water to crops, businesses and fountains.

BARCELONA AND CATALONIA ARE HUBS OF SCIENTIFIC RESEARCH INTO A VARIETY OF SUBJECTS, INCLUDING HEALTH, ENERGY AND TECHNOLOGY

In 2010, the Catalan regional government, created the CERCA Institute of Catalan Research Centres, an umbrella organisation incorporating over 40 different private centres that aims to encourage flexibility, efficiency and the recruitment of top scientists. Here are details of seven of the key research projects currently underway in Catalonia.

01. TOTAL EXPOSURE

The word *exposome* was coined in 2005 by cancer epidemiologist Dr Christopher Wild to describe all environmental (not genetic) influences that humans are exposed to from conception. At the Centre de Recerca en Epidemiologia Ambiental (Centre for Research in Environmental Epidemiology, or CREAL), the EXPOSOMICS project is one of several related to the exposome currently being carried out in Europe, and aims to predict individual disease risk related to the environment. This will be done by characterising the external and internal exposome for common exposures (eg, air and drinking water contaminants) during critical periods of life, including in utero. The four-year project (coordinated by Paolo Vineis of Imperial College, London) is developing a personal exposure monitoring (PEM) system that includes sensors, smartphones, geo-referencing and satellites. It will collect data on individual external exposome and will also analyse biological samples (internal markers of external exposures) using multiple 'omic' technologies ('omic' refers to fields of biology, such as genomics). www.creal.cat

02. JUST BREATHE

Childhood is a critical period for brain maturation and mental development, and there are many factors that may affect this process. Several studies of animals have generated the hypothesis that ultrafine particles in city air may interfere negatively with brain development. As such, discovering the level of pollution in schools and understanding its role in child health is one of the key challenges of our time. Once it has been identified, this knowledge will help us create healthier environments for future generations. At CREAL, Jordi Sunyer Deu is the lead investigator of the BREATHE (Brain Development and Air Pollution Ultrafine Particles in School Children) project, whose objective is to study the impact of air pollution in cities on the cognitive development of children. Taking part in the investigation are kids in their second, third and fourth years (ages seven to nine) from 40 Barcelona primary schools. www.creal.cat



03. FIGHTING MALARIA

Mozambique is among the top ten countries with the highest malaria burden in the world. Estimates suggest there were 4 million malaria cases there in 2013. Coordinated by Dr Clara Menéndez at IS Global, the Mozambican Alliance Towards Elimination of Malaria (MALTEM) is focusing on getting rid of malaria in the south of the country, in Maputo, Gaza and Inhambane provinces, by 2020. With funding from a partnership between the Bill & Melinda Gates Foundation and the "la Caixa" Foundation, technical, operational and financial support will design and scale up new strategies for the Mozambican National Malaria Control Program. The hope is to reach the roughly 4 million people in the key area, which had approximately 600,000 malaria cases in 2012. The project will feature the adoption of targeted evidence-based elimination plans and a 'learn by doing' approach that will incorporate data from rigorous evaluation as it is generated, and put it into action. In the long term, the goal is to expand malaria-elimination efforts across the rest of the country, with the development of a national elimination strategy. www.isglobal.org

04. GREENER HOSPITALS

Hospitals can sometimes seem like small towns, operating large-scale infrastructures

that are used by hundreds, and sometimes thousands, of patients, staff and visitors each day. In many European countries, hospitals are housed in old structures that rank them among the least energy-efficient of public buildings. At the Institut de Recerca en Energia de Catalunya (Catalan Institute for Research into Energy, or IREC), the Green@Hospital project seeks to integrate the latest ICT solutions in order to obtain a significant energy saving in existing hospital buildings, through better management of energy resources and a consequent reduction in energy loss. The three-year project has six main scientific objectives, including the development of a standard benchmarking model for energy measurement in hospitals, and the development and integration of an internet-based energy management and control system (EMCS) for multiple building systems at the component level. Four different hospitals in Europe have been chosen to run a pilot scheme to demonstrate the validity of the proposed solutions under actual operational conditions. www.irec.cat

05. BIGGING IT UP

At CIMNE, the International Center for Numerical Methods in Engineering, the Large-scale Scientific Computing Group is developing novel finite element (FE) formulations for solid mechanics and fluid dynamics (turbulent incompressible and compressible flows). Headed up by Santiago

►1599

LET THERE BE LIGHT

As the 16th century came to a close, the city got its first public lighting system, albeit one that used precarious open flames. It wasn't until the 18th century that oil lamps were introduced. And in 1842, Barcelona became the first Spanish city to have gas lights.

►1775

CITY OF THE DEAD

Bishop Josep Climent ordered the construction of the Poblenou cemetery – the first to be situated outside the city walls – bringing to an end burials in parish grounds, which had become the source of all manner of illnesses and epidemics.

►1835

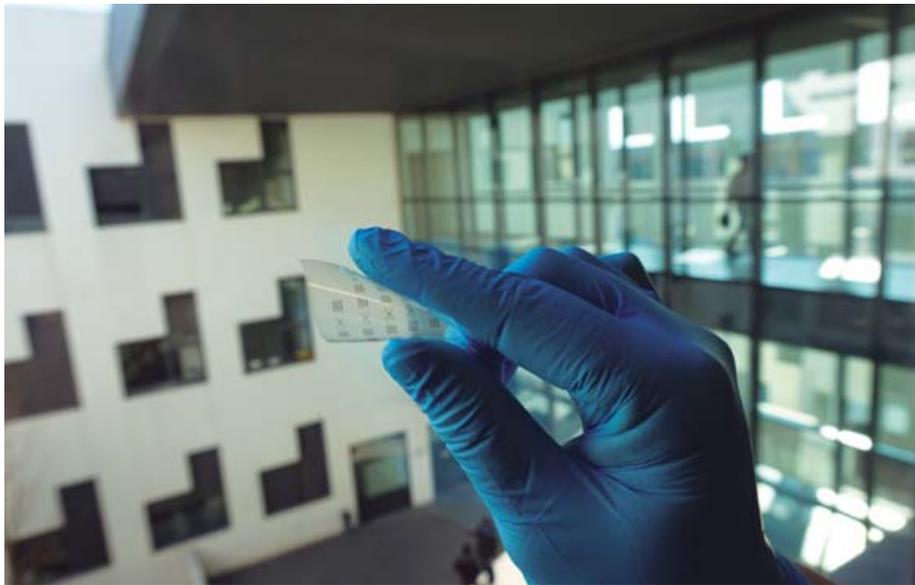
FEWER CONVENTS, MORE SQUARES

Riots, such as those in the city in 1835, and various property seizures put an end to the proliferation of convents in Ciutat Vella. On the former church lands, the Boqueria and Santa Caterina markets, the Liceu opera house and Plaça Reial were built.



06. LESS IS MORE

At the Institut Català de Nanociència i Nanotecnologia (Catalan Institute of Nanoscience and Nanotechnology, or ICN2), Arben Merkoçi heads up a team that is devising a versatile, low-cost and customisable method for patterning graphene oxide (an oxidised form of graphene – the strongest material in the world and extremely thin, but also very expensive – made by the powerful oxidation of graphite) onto a myriad of flexible substrates, or base materials, including textile, paper, adhesive film and PET (see image, below left). The process uses wax-printed membranes whose benefits include long-term stability and infinite shaping capability on such materials, enabling for the transfer of multiple electronic devices such as supercapacitors, solar cells, biosensors and LEDs. In addition to graphene oxide, this approach might be suitable for other electronic materials such as gold nanoparticles, carbon nanotubes and quantum dots. What's more, depending on the materials and their concentration, the technology (which involves a three-step method of printing, filtering and pressing) can allow for the creation of transparent devices. www.icn2.cat



07. HEART OF THE MATTER

Created in 2007 by the Nephrology Unit at the University Hospital Arnau de Vilanova in Lleida, and forming part of the Institut de Recerca Biomèdica de Lleida (Lleida Institute of Biomedical Research, or IRB), UDETMA is an innovation model that aims to decrease the incidence of cardiovascular diseases. This will be done by using sensitive diagnostic tools to identify atherosclerosis disease (which affects the arteries with the deposit of fatty materials), and then establish and implement individual prevention guidelines for patients. Among its current projects is 'El Bus de la Salut' ('The Health Bus'), which sees an adapted bus fully equipped with diagnostic tools and managed by healthcare professionals moving around the region of Lleida, with the aim of testing almost 10,000 people over three years. UDETMA is also undertaking a multicentre prospective trial, Nefrona, on cardiovascular morbidity and mortality in Spanish patients suffering from chronic kidney disease. Finally, it offers training services to cover the gap in diagnostic techniques for nephrologists, endocrinologists and primary care doctors for the diagnosis of subclinical arterial disease and prevention of cardiovascular diseases. www.udetma.com

Badia (see page 25), one of the group's main focuses is the scalability of the whole simulation process on today's largest supercomputers. Among its current projects is one entitled Fortissimo, which is exploring multi-physics simulation of high-temperature superconducting devices; another, Numexas (which is due to be completed in September 2016), looks at numerical methods and tools for key exascale computing challenges in engineering and applied sciences. The

seven-person group's research has been applied to magnetohydrodynamics applications in fusion reaction and it's now facing the challenging simulation of 3D printing processes. All of the group's developments are implemented in its own open source code, FEMPAR, which has proved sustained scalability up to half a million processors and 2 million MPI tasks on the JUQUEEN supercomputer. www.cimne.com



►1860

THE GREAT CERDÀ PLAN

The renovation and expansion (*Eixample*) plan of Ildefons Cerdà is the most important local urban transformation of the past few hundred years. Barcelona escaped its medieval prison (1854 saw the city walls demolished) to grow into the future.

►1902

SEWER SYSTEM

The Romans had a waste water system, but it wasn't until 1891 that the first modern sanitation plan was created for the city. The works began in 1901, and the inauguration was on September 24, 1902, feast day of Barcelona's patron saint, Mercè.

MEET SOME INFLUENTIAL MEMBERS OF BARCELONA'S SCIENTIFIC COMMUNITY, AND LEARN ABOUT THEIR GROUNDBREAKING WORK

Josep Peñuelas



The recent subjects of study by this leading environmental scientist include climate change, atmospheric pollution and the structure of terrestrial plants and ecosystems. Peñuelas is the director of the CREAM-CEAB-CSIC-UAB Global Ecology Unit and is also a research professor on the National Research Council of Spain. He appears on the Thomson Reuters list of Highly Cited Researchers in areas such as plant and animal sciences and geosciences, has worked in over 50 centres and universities around the world including Oxford and Stanford, and has received numerous awards, both national and international.

Maria Lois



Based at the Center for Research in Agricultural Genomics (CRAG) at the Universitat Autònoma de Barcelona, Lois and her group, which has become a benchmark in the sector, are looking at how SUMO

(small ubiquitin-like modifier) conjugation regulates protein function as a tool for controlling plant growth and seed development. Her work also involves looking at how to transfer this knowledge into the science of soil management and crop production, exploring its commercial aspects, and the possibility of creating a bio-based industry. In 2016, she is organising a workshop in Barcelona with leading plant scientists, engineers and architects on ways to achieve zero waste as a societal challenge.

Daniel Maspoch



This Catalan scientist is a research professor and group leader of the Supramolecular Nanochemistry and Materials Group at the Institut Català de Nanociència i Nanotecnologia (ICN2). He graduated in chemistry from the University of Girona and obtained his PhD in materials science at the University Autònoma de Barcelona and Institut de Ciència de Materials de Barcelona. Following a period at Northwestern University with professor Chad A. Mirkin, he came to ICN2 and founded the group he now heads up. He has authored over 80 scientific publications and five book chapters, as well as filed eight patents and established 14 contracts with private companies.

Ben Lehner



An AXA research professor of risk prediction in age-related diseases since 2014, Lehner, in that same year, took up his current role as senior leader of the Genetic Systems group at the Centre for Genomic Regulation at ICREA (the Catalan Institution for Research and Advanced Studies). His work involves using model

organisms (yeast and worms) and computational analyses to understand what can, and cannot, be predicted from the biology of an individual from their genome sequence. Lehner has won various awards, including a European Molecular Biology Organisation Gold Medal, and Lilliane Bettencourt Prize for Life Sciences, both in 2016.

Santiago Badia



In 2014, Badia was given an ICREA Àcademia professorship by the Catalan regional government, a distinction awarded based on excellence in research. His field of expertise is numerical analysis and computational mechanics; he often combines the two sectors, covering a wide spectrum of topics. For instance, he is an active researcher in the development of novel finite element (FE) techniques for complex problems. Recently, his research has been oriented to the design of extremely scalable FE solvers that will efficiently exploit the exascale supercomputers of the future. He is team leader of the Large-scale Scientific Computing Group at the International Center for Numerical Methods in Engineering.

Elisabeth Cardis



Cardis is a research professor and head of the Radiation Programme at the Centre for Research in Environmental Health (CREAL), where she's worked since 2008; the main focus of her investigations is non-ionising radiation. Cardis has coordinated numerous EU projects in the Quality of Life, Environment, EURATOM (European Atomic Energy Community) and INCO (International Scientific Cooperation) programmes. She has also collaborated with global organisations such as the WHO and national committees in countries including Spain and France.

► THE 1920S GOING UNDERGROUND

In the 1920s, the Sarrià railway line was taken below ground while the Gran Metro (nowadays L3) and Metro Transversal (L1) were inaugurated – big steps forward towards an underground public transport system connecting all areas of the city.

► CLOSE OF THE 20TH CENTURY OPEN TO THE SEA ONCE MORE

The recovery of the seafront as a public and leisure space was one of the milestones of the Olympic Games project. In recent years, the city has increasingly reconnected with its often ignored natural spaces, from the Mediterranean to Collserola park.

► 2014 BCN SMART CITY

Within the Barcelona Smart City project, innovative solutions, often based on technology, began to be applied across the city for the management of services and resources to improve the quality of life of Barcelona's residents.