DISCOVERY IRELAND

NEW IDEAS – NEW FRONTIERS

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BY MARK DUNCAN AND PAUL ROUSE

PHOTOGRAPHY BY ERIN QUINN
EXCEPT WHERE OTHERWISE NOTED

DESIGN BY MITCHELL KANE

IRISH RESEARCH COUNCIL
An Chomhairle um Thaighde in Éirinn

This publication is dedicated to
Professor Ernest T.S. Walton
Nobel Prize Winner in Physics
(with Sir John Cockcroft), 1951

CONTENTS

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A 49m-year-old fossil beetle from Messel, Germany. The iridescent blue colours of the beetle are produced by very fine layers in the beetle's tough outer coating. Credit: Dr. Maria McNamara.

Dr. Maria McNamara is a former Irish Research Council co-funded Marie Skłodowska-Curie International Mobility Fellow. She has recently been awarded an European Research Council Starter Grant for her project 'Animal coloration through deep time: evolutionary novelty, homology and taphonomy'. She is currently based in the School of Biological, Earth and Environmental Sciences in UCC, where she works at the interphase of the geological, biological and physical sciences.

FOREWORD

This publication provides a welcome and valuable contribution to the discourse at a national and international level on the role and value of discovery research. By exploring the role of curiosity-driven research in both a historical and contemporary context, this publication highlights some of the achievements that have been made by Irish scientists, while shining a spotlight on a small sample of research currently being performed in Irish research institutions.

As reflected in the national strategy for research and innovation, *Innovation 2020: Excellence, Talent, Impact,* the Government recognises that research plays a vital role in maintaining innovation and creativity. With this publication the Irish Research Council has provided an important insight into the role discovery research plays in enhancing an understanding of our world and in the development of new ideas which may in time impact on all our lives. Indeed, publications such as this, together with contributions made by those from within the research community, are strongly encouraged as they provide the public with a greater understanding and appreciation of the importance of research. Through the inclusion of a series of case studies, focusing on researchers at various stages of their careers, this publication allows those outside of the research community to see what motivates researchers to focus on discovery and fundamental research, while also giving important examples of how research has led to new and unexpected knowledge and technologies.

I would like to thank the Council for taking the initiative with this publication. I look forward to further communications of this nature, which serve to enhance the public understanding of the nature of research, and encourage discussion about its importance for Ireland's future.

Damien English TD

Minister of State for Skills, Research and Innovation.

INTRODUCTION

It is a pleasure to introduce this publication which aims to provide insight into the important role that discovery research plays in pushing the boundaries of knowledge and in maintaining a healthy research ecosystem. It is a key part of the mandate of the Irish Research Council to fund research, on the basis of excellence and without pre-determination of the discipline or research topic. Our mandate recognizes the essential role played by discovery research across all disciplines in enhancing Ireland's international reputation as a centre for research and learning. Thus the Irish Research Council supports research that may not obviously or immediately be translated into specific applications, but rather which one day may yield results that could contribute to knowledge and have a significant impact on our world and on our lives.

So by drawing on examples this publication explores the frequently unexpected impacts of discovery research. As set out in the introductory essay, from important technological advancements to successful spin out companies, discovery research has provided a vital foundation on which many of the great successes of Irish science have been built. The second part of this book features researchers and their research projects at a variety of stages of development and progression. These projects were selected from suggestions made by the higher education institutions and only a handful reflecting the diversity of suggestions submitted could be featured. For some, their work is at the early stages; for others, their research has already opened up new, exciting and previously undetected fields of inquiry or opportunities that could not have been foreseen. As Irish scientist, and Nobel Prize winner, Professor William C Campbell said recently 'Often, side projects turn out to be scientifically the most fun. The worm experiment turned out to be very useful, and helped those working on parasitic disease. But it was entirely incidental. I did it because I had a great desire to do it'. This quote and the stories in this booklet underline the point that no two pathways are identical and that discovery research is, above all else, a journey whose precise destination cannot be fixed in advance. They also underline the importance of research in developing the talent, skills and expertise we need. We look forward to featuring a range of work not selected by the authors in due course on our website www.research.ie.

Finally I look forward to working closely with the research community to enhance awareness of the great value of discovery research and would like to express my thanks to the authors for preparing this publication.

Professor Jane Ohlmeyer
Chair, Irish Research Council

IRISH RESEARCH COUNCIL
An Chomhairle um Thaighde in Éirinn

Greats of Irish Discovery Research

Robert Boyle (1627-1691) Boyle's law	Francis Beaufort (1774-1857) Beaufort wind scale	Nicholas Callan (1799-1864) The induction coil	William Rowan Hamilton (1805-1864) Hamiltonian mechanics
George Boole (1815-1864) Boolean algebra	Sir George Stokes (1819-1903) Stokes theorem	John Tyndall (1820-1893) The greenhouse effect	William Thomson (Lord Kelvin) (1824-1907) Kelvin scale
Margaret Lindsay Huggins (1848-1915) and William Huggins (1824-1910) Astronomical spectroscopy		George Francis Fitzgerald (1851-1901) Lorentz-Fitzgerald contraction	Alicia Boole Stott (1860-1940) Dimensional mathematics
Matilda Knowles (1864-1933) Founder of modern studies of Irish lichens	Maude Jane Delap (1866-1953) Life cycle of jellyfish	Annie Scott Dill Maunder (1868-1947) The little ice age	J.D. Bernal (1901-1971) X-Ray crystallography
Phyllis Clinch (1901-1984) Plant viruses	Kathleen Lonsdale (1903-1971) Proved the benzene ring is flat	John Stewart Bell (1928-1990) Bell's theorem	Lochlainn O'Raifeartaigh (1933-2000) O'Raifeartaigh's theorem

NEW IDEAS – NEW FRONTIERS

Google: a product of pure science. The 'Page Rank' software developed by Sergei Brin and Larry Page emerged from a project publicly funded through the National Science Foundation in the USA.

[!]

'Discovery Research is research that's done for the sake of the science, not for the sake of applications or for economic reasons.' – Jocelyn Bell Burnell, Belfast-born astronomer & discoverer of pulsars, Visiting Professor, Astrophysics, University of Oxford.

'It is the fundamental research that truly advances our basic knowledge, essential understanding of nature and natural processes, and drives the major breakthroughs at the new frontiers of science.'
Colin O'Dowd, Director of the Centre for Climate & Air Pollution Studies at the National University of Ireland, Galway (NUIG)

Where do new ideas come from? If the focus of this question is on the production of those things that we now consider essential to, and for, modern life, then the answer is, most obviously, Discovery Research. From new ideas have flowed new products, new processes and new understandings, which have profoundly altered how people live, work and play.

The context in which Discovery Research is discussed in Ireland has been transformed by changed economic circumstances. One of the great challenges confronting the state in the midst of its financial crisis was to identify a clear roadmap of what needed to be done and what educational characteristics needed to be prized and promoted. For instance, what role would independent thinking, creativity and flexibility play in helping to rebuild Ireland? And how might these values be nurtured in a way that creates and transmits new knowledge? In short, where would Discovery Research sit in remaking of Ireland?

To begin to answer such questions, a clear understanding of what precisely is at issue is required. Professor Colin O'Dowd, Director of the Centre for Climate & Air Pollution Studies at the National University of Ireland, Galway (NUIG), provides the following definition of Discovery Research: 'It is the fundamental research that truly advances our basic knowledge, essential understanding of nature and natural processes, and drives the major breakthroughs at the new frontiers of science.' To fully realise the benefits of Discovery Research, O'Dowd makes the point that the commitment to it must be neither short-term nor shallow: 'Without Discovery Research generating new concepts and advancement of basic knowledge, applied research would, sooner or later, run out of creative ideas to be applied. Although its immediate commercialisation may not be apparent, it underpins the longer-term sustainability of applied research which is driven by shorter-term considerations. Discovery Research is more about solving problems for the future rather than for the present; however, the present applied research would not be delivered without previous Discovery Research breakthroughs.'

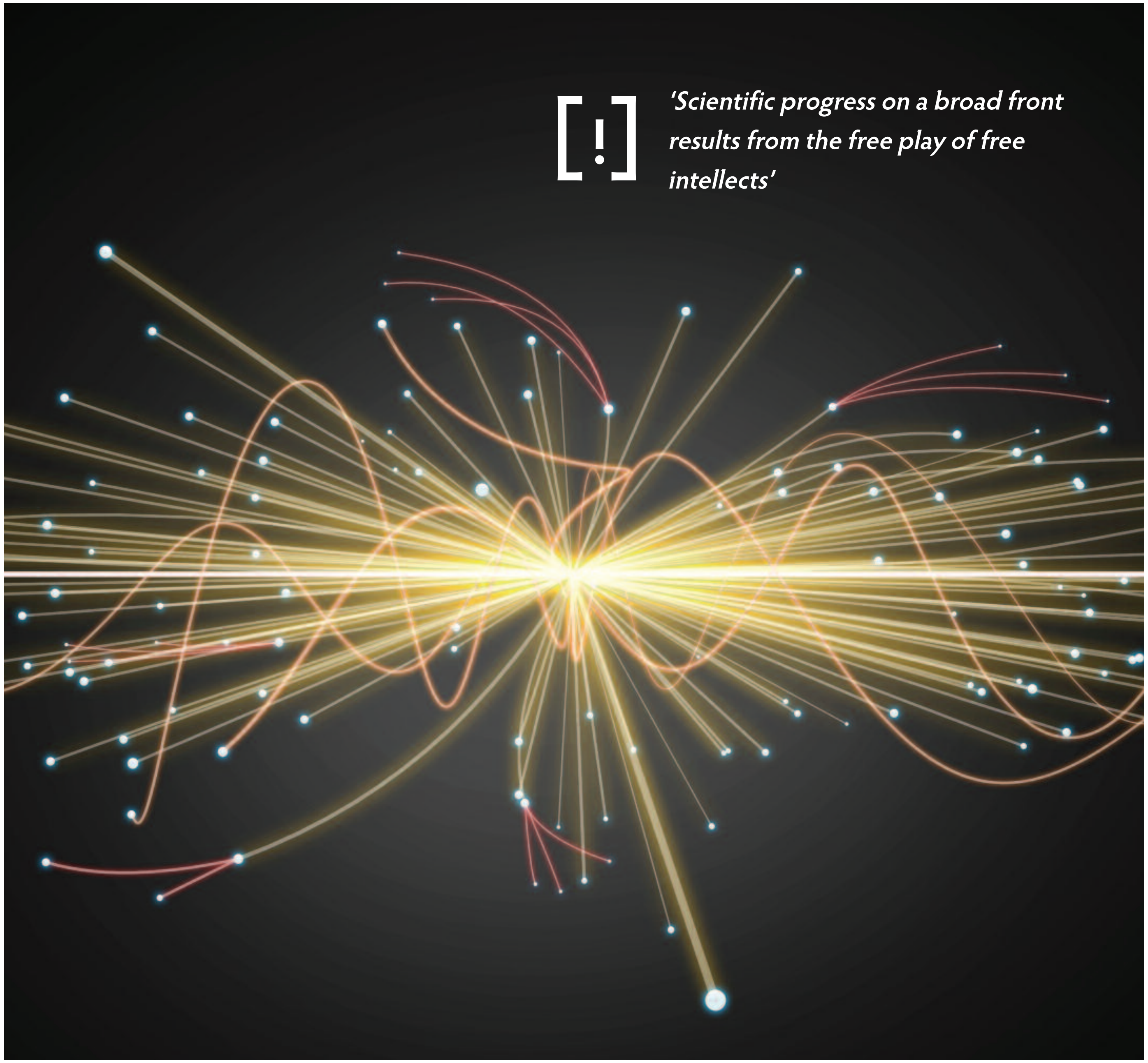
Worldwide Discovery Research, which is primarily publicly funded and conducted in academic institutions, underpins great swathes of the advances across societies. The great modern example is, of course, the piece of pure math that powers Google: the 'Page Rank' software developed by Sergey Brin and Larry Page and funded by the National Science Foundation in the USA. The grants provided to support this research have helped to change the lives of people across the world. Indeed, many of the foundations of modern computer science (Turing machines and even the internet) come from new ideas that emerged from Discovery Research in academic institutions.

And it is one of the great ironies of Discovery Research that so much economic growth comes from research conducted with no commercial purpose. Across the economy – but notably in areas such as pharmaceuticals and the computer industry – entire new sectors, as well as new products, have emerged from Discovery Research. There is abundant evidence to support this assertion, both home-grown and from further afield. In 2008, for instance, the Russell Group of leading UK universities examined the financial returns of their research, an exercise that encompassed 125 commercialisation case studies from 17 institutions. The results were clear-cut: it found that 'the vast majority of the value returned over time originated from more fundamental, basic research'. The implications of such evidence have begun to shift, amongst other things, business-investor behaviour. As if to underline this point, Dr. Alison Campbell, Director of Knowledge Transfer Ireland (KTI), an entity jointly supported by Irish Universities Association and Enterprise Ireland, recalls hosting a KTI commercialisation forum in October 2014 focused on spin-out companies. 'What investors were saying is that they were not looking for solutions to current problems', Campbell says. 'What they were looking for were disruptive ideas and disruptive technology.' Perhaps none of this should come as a surprise. Campbell, who has worked for two decades at the academic-industry interface, doesn't like the forced divide between 'basic' and 'applied'. She observes that much of the research that transitions from the academic into the commercial sphere may at some stage have had roots in research that might be considered as basic or fundamental in character. Indeed, it is not often clear, she says, where Discovery or Curiosity Research ends and when it becomes applied. 'Sometimes when you look at it in hindsight, it appears obvious that research has an application. It's not always the case. Increasingly, when people are involved in Discovery Research they are doing so in full awareness of possible wider industry interest and potential applications, but does that mean it is applied research?'

By way of example, Campbell cites the case of OxyMem, an Irish company that spun out of University College Dublin with a technology to bring process-efficiency and reduced energy-use to the wastewater treatment sector. Energy-intensive and costly, the aeration process at the core of wastewater treatment had remained effectively unchanged for a century and that's what made the technology developed in the UCD laboratory of Professor Eoin Casey so 'disruptive'. OxyMem devised the world's first commercially available membrane-aerated biofilm reactor (MABR) technology, the effect of which is to dramatically reduce the operating costs for wastewater aeration. This is clearly a wonderful success story, yet it is not, Campbell insists, a straightforward lesson in the virtue of commercially focused or applied academic research. 'These were scientists at UCD who had been working for years at waste-water treatment, but they didn't do so with a view to having it applied. They were interested in biofilms, which then had application in water treatment. The other key point is that they were doing their research for years before they realised the potential of it.' Indeed they were: the reality is that the story of OxyMem began long before its establishment as a company in 2013, its origins being more accurately rooted in the pioneering research undertaken by Eoin Casey in UCD, which began in the 1990s. Casey himself acknowledges that the research that ultimately led to OxyMem's breakthrough technology was, at source, 'curiosity-driven'. Yes, he may have been thinking about application, but this was 'at the back' of his mind. 'I was engaged in engineering research that was driven by fundamental and blue sky thinking', Casey remarks. 'It doesn't mean that all research is like that, but mine was.'

That years of curiosity-driven, basic research should sit behind a successful spin-out company like OxyMem is hardly remarkable. In fact, achievements in innovation in all of the most successful countries of the world are typically built on a bedrock of excellent basic research. This is the norm, not the exception – the history of Irish science, for example, is adorned by individuals whose achievements are celebrated not because they yielded any immediate economic benefit, but because their research discoveries proved far-reaching and transformative in nature. Consider George Boole, the first professor of mathematics at what is now University College Cork, who, in the mid-nineteenth century, famously wrote *An Investigation of the Laws of Thought*, included in which was his system of Boolean Algebra. This system is now applied in the design and operation of computers and switching circuits. Consider, too, the Waterford-born Nobel Prize winner for Physics, Ernest Walton, who, alongside John Cockcroft, designed and built the first successful particle accelerator, which enabled them to disintegrate lithium, or split the atom, in the early 1930s.

Boole and Walton are but two names from a extensive cast of Irish scientists whose work, ground-breaking and internationally significant, raises issues that go to the very heart of the debates around research and its funding that are now widespread throughout Europe – and beyond. These debates centre on competing ideas concerning the purpose



Particles colliding in the Large Hydron Collider of research and the extent to which different types of research should be publicly funded. Speaking at the Royal Irish Academy in Dublin in November 2014, Professor Jean-Pierre Bourguignon, President of the European Research Council, posed a straightforward question that neatly encapsulated the policy-making dilemma that arises: 'What is the balance between supporting "blue sky" research and near-market development?' In answering his own question, he noted the contribution of individuals such as Alfred von Harnack, Richard Burdon Haldane, Abraham Flexner and Vannevar Bush in arguing for the expansion of governmental support for research in the early and middle decades of the twentieth century. More than that – and critically – these individuals, eminent all, argued that researchers should be free from any pressures that might encourage bias and should be essentially autonomous. Flexner's 1939 manifesto *The Usefulness of Useless Knowledge* was a landmark moment in the journey and so, too, was Bush's *Science, The Endless Frontier*, which argued:

> Scientific progress on a broad front results from the free play of free intellects, working on subjects of their own choice, in the manner dictated by their curiosity for exploration of the unknown. Freedom of inquiry must be preserved under any play for Government support of science.

In the later decades of the twentieth century increasing state support for research led to inevitable questioning of the value for money and purpose of publicly funded research. A principal consideration in all this was the extent to which research was contributing to society and to the needs of the state: should researchers be measured by their capacity to contribute to 'politically determined goals' and should research be planned and organised to meet such goals? These questions have sat at the centre of public debates on research for decades now, the priorities often shifting in line with prevailing economic circumstances. In buoyant economic times, the pressure to serve short-term, politically driven objectives abates, only to strengthen again when resources become scarce. The result is that the policies of individual states in respect of research and innovation have, over the decades, passed through several cycles. That states should fund research to contribute to the public good is agreed by all. Nonetheless, in the wake of the recent global financial crisis, public funding for universities in many countries has fallen – sometimes steeply – and with it has come a diminution in investment in research of all kinds. The story is far from uniform, of course, and the pain has not been felt everywhere. Indeed, according to the European Universities Association's (EUA) Public Funding Observatory, a small number of European countries – most notably Germany, Norway and Sweden – experienced sizeable increases to the public funding of universities since the onset of the international financial crisis in 2008. By contrast, other countries – Ireland included – experienced severe cutbacks. The effect of all this has been the creation across Europe of what the EUA has called an 'entrenched disparity between countries where public funding to higher education continues to rise, and countries that disinvest in the field.'

That Ireland should fall into the latter category is a stark reminder of how much the economic environment has changed since the Celtic Tiger era, when large-scale investment in research transformed both the higher education sector and Ireland's reputation as a knowledge-based society. The country's research landscape was fundamentally reshaped by a range of initiatives, most notably the HEA's Programme for Research in Third Level Institutions (PRTLI), which launched in 1998. The years that followed saw an extraordinary evolution in the higher education and research system. Extensive funding was directed towards the establishment of Ireland as a centre of research and innovation excellence by the aforementioned PRTLI, the newly established Science Foundation Ireland and the Irish Research Councils: between 2000 and 2008, for instance, government funding for research in Ireland rocketed from €290m to €938m. This was joined with significant philanthropic donations from private investors. What resulted was an investment in infrastructure, in equipment and in people. It ensured that Irish institutions attracted high-level researchers from around the world and its success was attested in an international independent assessment which characterised it as 'not just unique, but fair, far-sighted and effective'. In the immediate aftermath of the Irish financial collapse of 2009 and the devastation it wrought on the domestic economy, there was an entirely reasonable review of many aspects of how the state conducted its affairs. In the course of this scrutiny, the money the state invested on research was properly examined. In line with the prioritisation of job-creation across public policy-making, investment in research was shaped to focus on the need to maintain and increase employment. Above everything else, investment was predicated on the need to demonstrate near-term economic return. For certain research areas, it essentially meant that securing funding was no longer realistically achievable.

'Research is a continuum. It has no artificial barriers dictating it is basic if it sits on one side of a line and applied if it sits on the other.'

In March 2015, more than 800 research scientists put their names to a public letter that raised important questions about the nature and the future development of investment in research in Ireland. The letter noted that the

> current investment in applied research is welcome and forms an essential part of an overall strategy to generate economic return from scientific research. However, without a continued parallel investment in longer-term, fundamental research there will be no discoveries to capitalise on. By their very nature, such discoveries are not predictable and cannot be prescribed by what the government calls "oriented basic research". Equally unpredictable are the areas in which important discoveries will be made. Basic research should be funded on the criterion of excellence alone to ensure a credible and sustainable scientific infrastructure.

Ultimately, the critique offered by the signatories to the letter – among whom were many of the leading scientists working in Ireland, as well as leading Irish scientists working overseas – was rooted in the belief that existing policy, whilst understandable in the context of Ireland's economic difficulty, would ultimately damage Ireland in the longer term. Writing in *The Irish Times*, the science journalist Dick Ahlstrom got to the core of the matter when he commented:

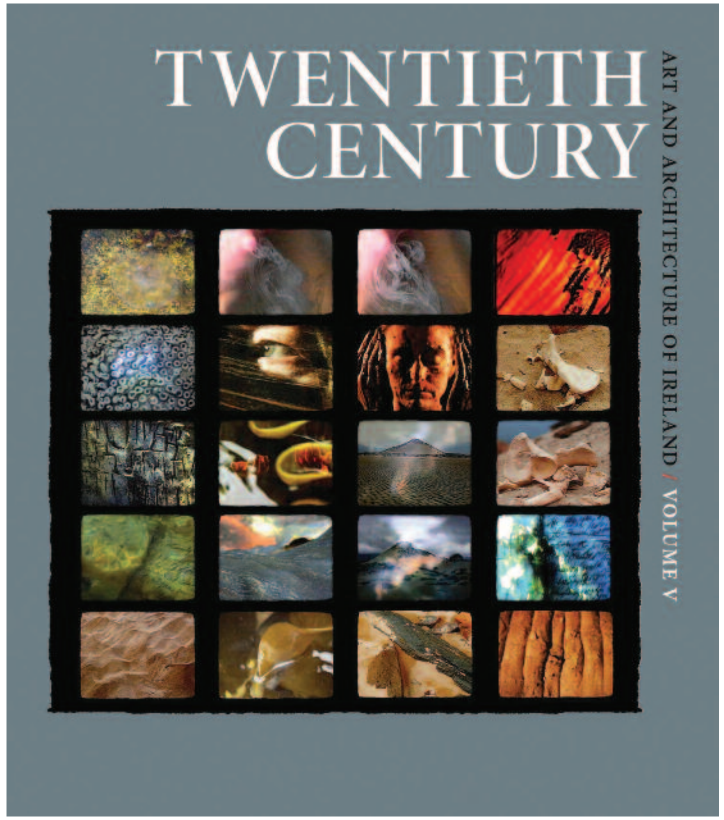
> The scientists who signed the letter are not asking that money be stripped from applied and translational research and transferred to basic research. They argue that in order for Ireland to have a fully functioning research ecosystem, both research areas need funding. Research is a continuum. It has no artificial barriers dictating it is basic if it sits on one side of a line and applied if it sits on the other.

Failure to meet the need for balance in the distribution of funding jeopardizes the very idea of Ireland as a knowledge-led economy and society. More specifically, it weakens Ireland's capacity to become a credible location in which new ideas and knowledge might be generated. 'We're in risk of eating our own seedcorn', says Belfast-born Jocelyn Bell Burnell, Visiting Professor of Astrophysics at the University of Oxford. Interviewed for this publication in the wake of her appearance at Dublin's *Inspirefest* event in June 2015, Burnell, whose discovery of pulsars in the 1960s is recognised as one of the great astronomical discoveries of the 20^{th} century, added that without adequate support for basic research 'you become dependent on other countries for the ideas that are going to get applied. So you're in parasite mode.' This is neither a sustainable nor a cost-free strategy. It comes with consequences. While Burnell suspects that Ireland risks losing some its brightest brains through an overly strong emphasis on applied funding, she is adamant that Discovery Research is key not only to the up-skilling of the existing workforce, but to the long-term goal of attracting young people into science and related fields. Pointing to her experience in the UK, where the admission system to university includes a personal statement about why students want to study a particular discipline, she notes the almost gravitational pull of the exploratory, open-ended nature of scientific inquiry. 'We find that in many of the sciences, it's things like astronomy, particle physics, quantum physics, relativity, that turns them on as teenagers and gets them into science in the first place. And then they go on from there in all sorts of directions - technology, engineering, computing, and other bits of science.'

The issues raised in national and international discussions about research policy are not the preserve of any single subject-area, of course. The concerns voiced by Ireland's scientists, and echoed by Burnell, are shared by those working across the entire spectrum of Irish academia, including those within the disciplines encompassed by the humanities and social sciences. Theirs is also a perspective that needs to be borne in mind. As Professor Mary E. Daly, President of the Royal Irish Academy, explains: 'The research carried out by philosophers, archaeologists, historians, and scholars of literature help us to understand what it means to be human. By understanding our history and culture – both national and global – we can better engage with the contemporary and with the future. The humanities and the arts can provide a bridge between science and technology and society.' Professor Daly stresses the point that notwithstanding the reluctance of humanities scholars

> to claim a direct economic return on their research … such research has the capacity to enhance Ireland's image and national standing. Projects such as the Royal Irish Academy's five volumes on *Art and Architecture in Ireland* (2014) mean that Ireland's significant contribution to the visual arts, from the early medieval period to the present, will be recognized internationally. As President of an Academy that includes the humanities and the natural sciences, I am very conscious that science and humanities share a common commitment to the importance of open-ended, basic research, and both recognize that the most exciting and most transformational research is often unexpected.

Given the shared nature of the vision of the role of research – basic and applied – among those working across very different disciplines, it is hardly surprising that the points emphasized by Daly and the large cohort of campaigning Irish scientists reverberate throughout the various



submissions made by higher education institutions and other stakeholders, including the national business and employers confederation, IBEC, who, in the spring of 2015, responded to the Irish Government's call for input into the development of a new *Strategy for Science, Technology and Innovation*, stating that 'you have to ensure you have this continuum from basic research through to the commercialisation of discoveries. You need a balance, it is not one or the other.' These submissions balanced current concerns with an acknowledgement of past achievements. The Irish Research Council noted the success of Irish higher educational institutions, as a group, in terms of research performance: in the decade from 2003 to

2013, Ireland ranked in the top twenty countries for research impact and in the top 1% in the world in 19 of the 22 Essential Indicator Fields. Most impressively, in the disciplinary area of immunology, Ireland ranked first in the global index on research impact. However, between 2011 and 2012, for the first time in over a decade, Ireland's relative performance dipped in terms of publications output and overall impact.

Above all else, the submissions made by the research community and other stakeholders underlined three critical points: firstly, the importance of research as a facet of higher education and its importance in developing human capital – independent thinkers, creators, and problem-solvers who can be flexible; secondly, the importance of maintaining a balanced research ecosystem and; thirdly, the rewarding of excellence wherever it may be found or however it might be directed. The danger inherent in this approach to funding was averred by, amongst others, the Dublin Institute for Advanced Studies (DIAS). It emphasized the importance of paying more 'attention to the need for investment in underpinning basic science. Prioritisation must not mean that only the priority areas have any prospect of funding, or the educational system will become badly distorted to the ultimate detriment of the priority areas themselves.' To that extent, the broad thrust of the approaches favoured by Ireland's higher education sector accord with best international experience, as revealed by a January 2014 report commissioned by the UK Department of Business Innovation. It carried out an exercise benchmarking global RDI systems and identified the common traits of the most successful systems, among the most important of which was a 'balance between curiosity driven research ("pure") and needs driven research ("applied")'.

'We find that in many of the sciences, it's things like astronomy, particle physics, quantum physics, relativity, that turns them on as teenagers and gets them into science in the first place'

The reference here to 'curiosity' is crucial. The word surfaces repeatedly – and with good reason. For the discovery of the unexpected through research is firmly rooted in the principle of the pursuit of knowledge through academic curiosity. Undertaking a project based on that principle accepts that a predetermined outcome is impossible. It must be equally accepted that some such research might end with little or no impact, just as other research reveals dramatic new possibilities that change the way people live and how societies operate. The very nature of research is that it is impossible to know in advance what might be its outcome and, consequently, its impact.

In her celebrated commencement address to the students of Harvard University in 2008, the author J.K. Rowling spoke at length about the importance of being willing to fail and of the benefits failure can bring in its capacity for liberation. Rowling, best known for the stellar success of the *Harry Potter* series of books, spoke of the fear of failure and how she sought to vanquish that fear. It was not, she said, that failure was fun, but that it ultimately was an essential part of the process of life and work: 'It is impossible to live without failing at something, unless you live so cautiously that you might as well not have lived at all – in which case, you fail by default.' Alongside the willingness to fail, Rowling extolled 'the crucial importance of imagination' and how the capacity for change was rooted in 'the power to imagine better'. In highlighting the inseparability of success with failure, Rowling might have been speaking for any researcher in any discipline embarking on the uncertain path of Discovery Research. As Jocelyn Joyce Burnell says of the lot of scientists: 'You are bound to fail … or have setbacks. The important thing is what you learn from it. But a lot of science is probing, seeing if this is the right way through, is that the right way through. You meet a lot of dead ends.' However, without this probing, without asking questions, without exploring the unknown, no new revelations or big advances are possible. Early in 2015, as if to underline this point, a Trinity College Dublin-led team of international scientists revealed details of a molecule whose anti-inflammatory properties could lead to a new treatment of a broad range of inflammatory diseases including multiple sclerosis, Alzheimer's, Parkinson's disease, gout, asthma and diabetes. The discovery of this 'marvel molecule', which blocks a key driver of inflammatory diseases, was trumpeted by Professor Luke O'Neill, already the winner of a Boyle Medal for Scientific Excellence, as among the most exciting of a career that has, he readily acknowledges, only occasionally been rewarded by major scientific breakthroughs. Tellingly, he remarked: 'I have been in the research business for 30 years and you usually end in failure, but this time we seem to have hit upon something truly transformative.' Philip Watt, CEO of the Medical Research Charities Group agrees, going so far as to suggest that the advances made by O'Neill and his team send out 'a beacon of hope that major new and innovative therapies will emerge for those with inflammatory diseases over the next few years'.

If there is a lesson to be drawn from such examples, it is perhaps this: that exploratory research - in times of boom or bust - should be considered vital to guard against neglect of the basic foundations of future prosperity. This requires policy that is grounded in a long-term perspective and a willingness to acknowledge that not every piece of research can be translated into measurable economic gain – nor need it be. Instead it builds knowledge within society. As Máire Geoghegan-Quinn, then European Commissioner for Research, Innovation and Science, aptly put it in November 2012:

Intellectual inquiry is a valuable and worthwhile pursuit in itself.

The legacy of investment in infrastructure during Ireland's boom years ensures that research facilities and centres of innovation provide a foundation for future progress. That progress – and the country's future – will be determined, in part, by the nature of the research funded in Irish institutions. The weight of academic opinion is clear as to the direction that should be taken. It comes down to choices, though those are not about prioritizing applied over Discovery Research, or vice-versa. Ultimately, what matters is striking an appropriate balance between the two. It is about creating a 'research ecosystem' that provides for a range of supports, enabling excellence to thrive. The benefits of such an approach will be felt by individual researchers, their students and their institutions, but mostly, past experience tells us, it will be felt by the economy and society as a whole.

The new national strategy for research and innovation, Innovation 2020; Excellence, Talent, Impact, *was launched by the Government in December 2015. The new strategy commits to 'establishing a competitive fund to support qualified researchers to undertake project-based, frontier research'.*

PEOPLE, PROJECTS, PERSPECTIVES

Playing call-back to attract frogs. Credit Dr. Karen Siu-Ting

Dr. Karen Sui-Ting is a current Irish Research Council co-funded Marie Skłodowska-Curie Postdoctoral Fellow. Her research, which combines field work, molecular biology, genomics and bioinformatics, is on the evolution of Poison Arrow frogs and their unique toxin producing abilities.

'It's all about curiosity. If you are working as a research scientist you invariably come across things you are curious about. Often you encounter things you don't understand and you ask why does this or that happen? In academia one is frequently doing exploratory research, trying to answer questions. In my case, I am interacting with research students trying to enthuse and apply this curiosity to science. It is much easier to use this curiosity in Discovery Research than in Applied Research in my opinion. For student development, discovery science is a great way to develop a curious mind. It develops in graduate students the ability to solve problems and develop skills that ultimately can be used throughout their scientific careers.'

Professor Tony Pembroke, Industrial Biochemistry, University of Limerick

STORMS ON OUR SUN, NEW SUN FORMATION - SO WHAT?

An ultraviolet image of the solar atmosphere. The bright areas are known as 'active regions' and are composed of twisted and stressed magnetic fields that can produce violent releases of energy. This energy release can heat the solar atmosphere up to temperatures of well over 10 million degrees celsius. The heating and energy release is known as a 'solar flare' (Solar Dynamic Observatory)

For anyone working with even a passing interest in solar astronomy, the so-called Carrington event constitutes a defining moment. It occurred on the afternoon of 1st September 1859, when amateur British astronomer Richard Carrington pointed the brass telescope in his private observatory outside London skywards. What he saw when he trained his attention on the sun surprised him and he began to sketch a cluster of large spots which appeared to pock-mark its surface. As Carrington was doing this, to his astonishment, 'two patches of intensely bright and white light erupted' in a brilliant, if short-lived, display. Within minutes, these fireballs had faded, but over the hours that followed a series of peculiar phenomena were observed in various parts of the world: telegraphic services were interrupted, paper spontaneously caught fire and night-time skies were illuminated – as if it were daylight – by colourful auroras.

What Carrington had observed was a 'solar storm', explains Dr. Eoin Carley, a Trinity College Dublin (TCD) solar physicist who is currently an Irish Research Council Marie Skłodowska-Curie Fellow based at the prestigious Paris Observatory. These solar storms arise, he says, because the sun, as well as radiating light and heat, has also been found to discharge huge eruptions of hot gas, which can hurtle billions of tons of matter in the direction of the earth. In the 156 years since the Carrington event, these solar storms have been keenly observed, as have their effects, in the form of radio-wave disruptions, on the earth. Until relatively recently, however, what eluded scientists was a fundamental understanding of how these explosions on the sun were created.

Eoin Carley has been central to resolving this mystery. In 2013, together with colleagues in TCD and international partners in University College London and the University of Hawaii, Carley and his collaborators published an article of such significance it was given front-cover prominence in the journal *Nature Physics*, which is to his specialist field what *Rolling Stone* magazine is to rock music. For the very first time, they showed where solar storms originate on the sun and the specific processes by which they produce radio bursts that may impact the earth. In short, what they did was to bridge the gap between observation and understanding. To establish a link between solar storms and disruptive radio bursts was 'a big jump forward', Professor Peter Gallagher, Carley's Ph.D. supervisor at TCD and corresponding author for the *Nature Physics* article, told journalists in 2013. 'We always thought that the shockwave from solar explosions was generating radio waves but we were never able to take pictures of them and then look at the radio signature at the same time.'

In many ways, research of this kind highlights the blurriness of the lines that divide pure and applied research. For it is only by going back to examine the very source of these solar storms, by exploring the fundamental physics of explosions on the sun, that any lessons can be applied from them. And, as Carley points out, the potential application of this knowledge is of great significance to everyday life, such is our interconnected and communications dependant world. Because we now have a better understanding of what causes particles to come from the sun, we are better equipped to predict future storm arrivals on earth. This means that scientists should be able to predict, and therefore possibly even prevent, the disruptions to our communications networks that have, in the past, caused radio blackouts, dropouts on mobile phone calls and lost signals on GPS devices.

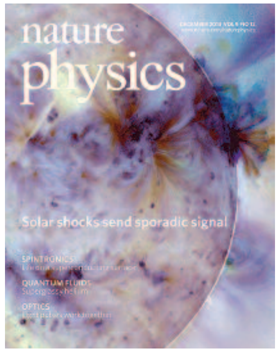
When asked why it has taken so long for scientists to reach their current level of knowledge, Carley is at once succinct and convincing. The answer is distance. 'You're always remote in astrophysics - there are no direct measurements', he says. 'The sun is 150 million kilometers – or 92 million miles – from earth. This makes it difficult to determine, from afar, what exactly is happening on the sun.' Change the perspective, he says, and 'it's like being in space, observing a hurricane on earth and attempting to comprehend what drives the storm.'

Developments in technology have certainly helped to shrink the vast distances involved and the research team of which Carley was a part was able to avail of some of the most sophisticated observation and detection techniques. High-resolution images were sourced from two NASA spacecraft – the Solar Terrestrial Relations Observatory and the Solar Dynamics Observatory – and the ultraviolet images these produced were combined with radio bursts from antennae located at TCD's Rosse Observatory at Birr Castle.

The use of the facility at Birr is significant, not least because it emphasises the continuity of tradition in Irish astronomical exploration. It was here in 1845, of course, that the Earl of Rosse, William Parson, built the Leviathan Telescope, the name that was given to what was then, and would remain for almost half a century, the biggest telescope in the world.

And it is here, at Birr, that Carley sees the potential not only to develop his own work, but to establish Ireland as a pioneering player in astrophysics research.

Led by the likes of Professor Gallagher, there have been on-going efforts to build a Low Frequency Array (LOFAR) radio telescope at Birr, which is crucial to examining how solar eruptions produce light-speed particles and radio bursts. ‘This is state of the art technology’, Carley explains.



‘You’re always remote in astrophysics – there are no direct measurements.’

‘Radio observations are necessary if we want to get at the fundamental physics of one of these solar eruptions.’ [!]

‘It’s a huge network of European radio telescopes combined together to observe the sun and the universe using radio waves.’ It is envisaged that LOFAR will have applications across geophysics, meteorology, and agriculture, but first and foremost it is crucial to the exploration of sun-earth connections and therefore crucial to the type of fundamental research in which Carley has clearly excelled. Indeed, it was to gain experience in radio observations of the sun that he moved to the Paris Observatory. ‘Radio observations are necessary if we want to get at the fundamental physics of one of these solar eruptions. France has some of the foremost solar radio astronomers in the world. My goal is to gain that knowledge here, and bring it to Ireland. This will hopefully establish Ireland as being at the forefront of radio astronomy and astrophysics.’

THE LEVIATHAN TELESCOPE

The Leviathan Telescope, built by the Earl of Rosse, William Parson, in Birr in the mid 1840s and still, at the turn of the 20th century when this photograph opposite was taken, the biggest telescope in the world. It is here, at this historic location, that Dr. Eoin Carley and Professor Peter Gallagher envisage the building of a Low Frequency Array (LOFAR) radio telescope, which they say is crucial to examining how solar eruptions produce light-speed particles and radio bursts.

It is here, too, that the rich tradition of Irish astronomical research has its roots. And a flourishing tradition it remains, attracting both a large number of amateur enthusiasts and a committed cohort of established researchers and post-graduate students. Aaron Kinsella belongs to the latter. Based in the School of Mathematics at Dublin City University, where he is pursuing a Research Master's, Kinsella's particular interest lies in the processes of star formation and the conditions that impact upon them. Kinsella explains:

> Virtually all stars form in cold, relatively dense regions of the interstellar medium known as molecular clouds. These clouds are thought to be turbulent and such turbulence can have a dramatic influence on the formation of stars such as our own sun. As a result of these clouds being so cold, with temperatures of around - 240 degrees Celsius, there are very few electrically charged particles such as electrons or ions present. An implication of this is that we need to model molecular clouds as being made up of gases, or fluids, some of which are electrically charged and the majority of which have no electric charge.

For all that is known, there is much, Kinsella says, that remains beyond the full understanding of the scientific community: 'Molecular clouds are complex, multi-fluid regions in which the different fluids move differently and continually collide with each other producing a vast array of fascinating effects. Not much is known about how energy in such systems is moved around or radiated away.'

Kinsella hopes that his own research, undertaken with Professor Turlough Downes, will 'widen the current understanding of molecular cloud turbulence'.

Like all scientists engaged in Discovery Research, the ambition is to fill gaps in the existing knowledge and reveal new insights. So how will they go about it? 'By systematically studying the properties of the energetics of these clouds', Kinsella answers, 'including more realistic physics than has been done in the literature to date. Studying such systems will lead to a deeper understanding of the physical processes involved in the formation of sun-like stars in our galaxy. This research can also yield better insight into the transfer of energy in multi-fluid systems which could lead to advances in the modelling of systems such as the solar atmosphere, for example.'

Rosse Observatory photographed in the early 20th century (National Library of Ireland)

> 'Discoveries are made in the laboratory and the library, while ideas can arise during walks in the fields. Some will come from directed programmes but so many have their genesis in curiosity-driven research.'

Sir John Cadogan, former Chief Scientist BP, former Director General Research Councils UK, Inaugural President of the Learned Society of Wales, 2014

'I am an environmental archaeologist and, as such, my interest in the past has always gone beyond simply the artefacts and structures to the way people lived, the conditions they created for themselves or had to negotiate, the influence of the environment on their lives and, importantly, how they impacted the environment in which they lived. We sometimes have a view of the past as "ideal" or "better than the present", where everyone lived in harmony with nature. The current fad for paleo diets, for example, is one manifestation! The truth is, of course, much more complex,' says Eileen Reilly of her work in the School of Archaeology at University College Dublin.

Dr. Reilly is currently working on a project entitled 'Dirt, dwellings and culture: reconstructing living conditions in early medieval north-western Europe', based at University College Dublin. 'Essentially my project attempts to understand the conditions in which people lived during the early medieval period – around 600-1100 AD – in north-western Europe. I wanted to try and characterise different attitudes to dirt, cleanliness, waste management, personal hygiene during this time between peoples across this large geographical zone through archaeological, documentary and environmental evidence. Concerns with personal cleanliness, for example, can be traced in writing, art and structural remains back to the Greeks and Romans and even earlier, but how much of this actually translated into everyday life?'

Dr. Reilly's specialist area of study is insects and intestinal parasites – using the habitat information from different insects to examine past living conditions, and the presence of parasites to look at levels of hygiene and exposure to diseases. Analysis of insect remains, wood, plant remains and bone preserved in archaeological soils and in natural deposits like bogs shows that people have been shaping their landscape for thousands of years, cutting down trees, causing erosion into lakes and rivers, causing extinctions of animals, insects and plants. As people created living spaces from organic materials – wood, straw, bracken, heather, reeds, rushes, mosses – they brought into those spaces all the insects associated with these materials and created conditions very suitable for their continued survival.

Dr. Reilly continues: 'I wanted to look inside homes from different parts of Ireland, Britain and across north-western Europe and see the differences and commonalities of behaviour, using insects and intestinal parasites as my "window" into past people's lives. I felt this was a gap in our knowledge and something that I could bring my particular expertise to, expertise built up over 16 years of working in commercial and research archaeology: We can tell how "clean" and "dirty" houses were, how damp, how dry. We can identify where certain types of activities were carried out, such as butchering of animals, or processing of flax stems to make cloth, or tanning of hides to make leather.'

Ultimately, this is research that examines the early urbanisation of Ireland: 'I'm from Dublin, I'm largely an "urban" being and I find cities fascinating from so many perspectives. It's extraordinary to think that Dublin, along with many cities in north-western Europe, is largely a product of only 1000 years of history, a blink of an eye in the long span of human existence. To be urban and exist in towns and cities required a different way of negotiating life, compromising on privacy and living space in

favour of the advantages town life could bring – the ability to rid oneself of the shackles of serfdom, become a skilled craftsperson or tradesperson. The difference between life in towns and life on a rural rath or ringfort must have been stark in terms of the noise, the smells, the sights, the sounds. And yet how people managed their homes, their plots and yards was not dissimilar. Interiors of homes were largely clean and warm, while yards and garden plots were the "messy" spaces. Even here though it appears that moving waste 'out of sight' was important, whether it was piling it up at one location on a boundary or digging a pit to get rid of it or throwing it over the fence into the lake or ditch surrounding your home.'

Ireland is potentially crucial to this developing area of research: 'In order to analyse insects in particular you need excellent preservation, ideally waterlogged preservation – like that seen at Wood Quay in Dublin in the 1970s or Temple Bar in the 1990s. But in Ireland we also have a number of significant rural settlement sites that were also preserved in this way, for example, Deer Park Farms in Co. Antrim and, more recently, Drumclay Crannog in Co. Fermanagh. This gives me the opportunity to compare different types of settlement sites during this period, something not available to researchers elsewhere in Europe.'

Dr. Reilly is clear that her research funding has allowed her to embark on collaborations that would not otherwise have been possible: 'The visibility that working within an academic institution brings is really invaluable. As part of my research I'm working on material from the earliest town-foundations of the city of Antwerp, dating from the 9th and 10th centuries. This research has brought with it collaborations with archaeologists in Belgium, the Netherlands and northern France who are researching early urbanism there. I am also collaborating with colleagues in other schools in UCD, such as Geological Sciences and Medical Sciences, on some interesting side-projects related to disease and health in the early medieval period, a natural follow-on from my core research in many ways. I am also involved in an exciting developing project in South Africa, which will hopefully be looking at the living environments of our early modern human ancestors (ca. 100,000–300,000 years ago) through analysis of occupation floor deposits of cave sites there.'

Within UCD, collaboration with colleagues in the School of Archaeology – and particularly with her mentor Professor Aidan O'Sullivan – on the developing Centre for Experimental Archaeology and Ancient Technologies, has been hugely rewarding: 'What is happening in UCD involved the creation of a facility unique to any archaeology department in the world! My own research is feeding directly into the reconstruction of two early medieval houses there: a round house based on one of the houses from Deer Park Farms, and a typical Dublin house, Pat Wallace's Type-1, three-aisled house excavated at Fishamble Street and elsewhere in Dublin, which would have been the standard "3-bed semi" of its day. Through carrying out experiments within and around these reconstructions – before, during and after building – we hope to come to a better understanding of how people lived at this time, how they sourced materials, how they maintained their houses and managed their living space within and around them.'

Dr. Reilly's ambition is also to expand her work and research network to look at the implications of life during the early medieval period for people's health: 'Investigative techniques such as ancient DNA sequencing of parasites and metagenomics - the study of whole spectra of DNA sequences from soil samples - can potentially identify the actual diseases suffered by people at this time. I'd be keen to extend this to early towns and settlements across north-western Europe and I hope that my collaborations with archaeologists on the continent and here in UCD will provide opportunities to do this.'

'What is happening in UCD involved the creation of a facility unique to any archaeology department in the world! My own research is feeding directly into the reconstruction of two early medieval houses there: a round house based on one of the houses from Deer Park Farms, and a typical Dublin house, Pat Wallace's Type-1, three-aisled house excavated at Fishamble Street and elsewhere in Dublin, which would have been the standard "3-bed semi" of its day.'

[!]

'Two Irish scientists, John Tyndall and Sean Twomey, living a century apart, can be said to be at both ends of the spectrum of what we do and don't know about climate change. In the 1850s John Tyndall set out to answer the question: why is the Earth so warm? The physics of his time suggested it should be a lot colder than it clearly was. Tyndall built a remarkable instrument which enabled him to identify the gases in the atmosphere that trap energy which would otherwise escape to space. These gases keep the Earth warm and are now known as greenhouse gases. At the other end of the scientific spectrum, there is the complexity of clouds. Each cloud droplet is formed around a minute particle, typically less than one millionth of a meter in size. In the 1930s there was a remarkable blossoming of this science in Ireland. Sean Twomey was part of this. He developed the theory of how particulate pollutants influence cloud structures, changing their reflectivity, lifetimes and rainfall characteristic. His breakthrough theory was published in 1977. The Twomey Effect is still frequently referenced in today's scientific literature.'

Frank McGovern, Head of Climate Change Research & Science, Environmental Protection Agency, Ireland

DISCOVERING THE DEEP AND EXPLORING THE UNKNOWN

All photographs for this chapter courtesy of Sabrina Renken

For many academic researchers, the world of work means being tethered to a desk, confined to a laboratory, or hours upon hours endeavouring to plough a productive furrow in comfortably heated libraries. Sabrina Renken is not one of those researchers – at least not all of the time.

In March 2014, the German-born geologist was to be found off the west coast of Ireland on the *Celtic Explorer*, a research cruise-ship that took her along the stretch of the western seaboard before finally resting in Killybegs, Co. Donegal.

She was not alone. This was a collaborative endeavour involving several groups from across the Irish university sector, north and south, as well as international collaborators from Italy (University of Milano-Bicocea) and Switzerland (University of Fribourg). Together, they comprised what was officially known as the West Ireland Coring Program (WICPro) survey.

Each of the academics on board brought with them their own particular research focus. For some, it was the cold water corals that attracted them. For others, the cruise was an opportunity to observe the activity of birds, fish and sea mammals. For Renken, the expedition was primarily about retrieval. Of mud and sand, sediments of which - the so-called core material - could be lifted from the ocean floor and mined for information that just might reveal something new about how climate changed over time. This is research of an entirely exploratory kind and of a type the *RV Celtic Explorer* has been facilitating since it first came into service in 2003. The vessel has proved an enabler of research that would otherwise have been impossible and it has already resulted in numerous new discoveries, bringing to the surface novel deep-sea habitats such as rare volcanic landscapes.

Despite these research breakthroughs, the deep exploration of Irish waters remains, to a large extent, a journey into the unknown, albeit one filled with possibilities.

For Sabrina Renken, however, the voyage of discovery didn't begin when the *RV Celtic Explorer* set sail from Cork harbour in 2014; rather its point of departure was her native Bremen in northern Germany, where she attended university and developed an interest in marine geology that she is now, with Irish Research Council support, progressing into a Ph.D. at Trinity College Dublin. For all that is known about the phenomenon of global warming and its effect on sea levels and on-land weather, there is, Renken says, still much that remains beyond our understanding. So while climate change can be observed in melting ice caps and thermal extension, how exactly the oceans respond to these developments over a protracted period – in terms of ocean circulation, temperature and sea level – has yet to be fully comprehended. This is significant, not least because it emphasises the uncertainties that exist around future climate changes and how they might be predicted, an issue that has acquired a fresh urgency with the collapses of Greenland and Antarctic ice sheets over the last decade.

'It is only through palaeoglaciology that insight on ice sheet dynamism, timing and environmental interactions, from advance to collapse, can be revealed.'

According to Renken, one the most effective ways to make sense of these developments, to improve future predictability and fill gaps in the existing knowledge, is to look at variations in ocean and climate conditions in the past – the very distant past. Renken deals in time-blocs of millennia and her territory of interest is the North Atlantic region, where she believes that a study of the evolution and demise of what was once the British-Irish Ice Sheet can unlock information on the responses of marine-based ice-sheets in a warming world. Quite clearly, this is no straightforward task and marine geoscience of this kind has been traditionally constrained by issues of time, technology and finance. It is a time-demanding and expensive exercise, but one also dependant on good weather to be effective.

When Renken and her fellow crew members set off on their cruise, the weather was anything but good: strong winds and poor visibility made work almost impossible and the *Celtic Explorer*, all sixty-five metres of it, was steered into Bantry Bay for shelter before the first day was complete. This was only a temporary setback for a venture for which preparations had begun months earlier, when all the future crew members were required both to undertake safety training and identify those points along the Irish coast from which they wished to draw their sample.

There is a good reason why Renken selected an area of the Irish shelf known as the Porcupine Bank as the focus of her research work. Situated about 200 kilometres off the west coast of Ireland and with a raised seabed that - at its height - reaches 200 metres below the sea's surface, the Porcupine Bank is 'a block of continental crust that became separated from the rest of the European continent by a failed rift during the opening phase of the North Atlantic, which began about 250 million years ago.'

Owing its name to its discovery by a British survey ship in the late nineteenth century, the *HMS Porcupine*, it is a well-known area of scientific interest and research already undertaken has identified evidence of so-called Heinrich events, the phenomenon by which large icebergs broke from glaciers and crossed the North Atlantic. To put it another way, this climatically sensitive region has a 'proven potential for furnishing palaeoceaonographic records of ice sheet and ocean circulation change.'

In all, Renken identified eight sites to be 'cored' in the Porcupine Bank, four of them in what were regarded as shallow waters that still ran to a depth of 1,000 metres, and four in deep water that plunged to around 3,000 metres. The sites were chosen in the hope that 'optimal thickness and undisturbed layers of the last glacier' could be recovered using an 800 kilogram 'gravity corer' - a long pipe, in effect - which settles into the ocean floor and draws out the sediment.

This is precisely how it worked out. With the researchers on board the *Celtic Explorer* divided into two teams, one working by day, the other by night, Renken found herself operating mostly under the cover of darkness. Up on deck, the core materials were extracted, recorded, labelled and the timings of each stage of the process were documented.

Renken stepped off the cruise ship with 12 'cores' and these have provided the focus for her subsequent laboratory-based research. X-ray technology has been used to 'look inside the cores' and tests have also been run to measure their 'magnetic susceptibility', a valuable way 'to identify ice rafted debris layers or Heinrich Events in marine sediments'. All 12 cores, as it turned out, revealed evidence of 'increased magnetic susceptibilities', while radio carbon dating will help to identify the Heinrich events.

What is striking about all this is the way that technology is being used to yield new information and insights. As Renken remarks: **'**What we hope to see is how the former British-Irish Ice Sheet has impacted on the sea climate of the region and what this will do is give a greater sense of the pace at which change takes place.'

The reference here to 'hope' not only underlines the uncertainty that accompanies all such Discovery Research; it also illustrates how improvements in technology and scientific equipment, while making the processes of research and analysis more efficient, are no guarantors of successful outcomes. Not that any of this fazes or unsettles Renken. Her interest in the exploratory nature of research is undiminished and already she has plans to return to the Porcupine Bank. Indeed, as the official report on the March 2014 West of Ireland Coring Program Survey made clear, this is not only desirable, but crucial to the prospect of any future revelation or insight. Above all else, that report emphasized the importance of practical, on-location, deep ocean research: 'it is only through palaeoglaciology that insight on ice sheet dynamism, timing and environmental interactions, from advance to collapse, can be revealed. Therefore offshore palaeoglaciological research must continue to be a priority.'

'What we hope to see is how the former British-Irish Ice Sheet has impacted on the sea climate of the region and what this will do is give a greater sense of the pace at which change takes place'

THE CELTIC EXPLORER

THE IRISH RESEARCH VESSEL *CELTIC EXPLORER* IS OVER 65 METRES IN LENGTH AND COMES EQUIPPED WITH STATE OF THE ART SCIENTIFIC EQUIPMENT THAT INCLUDES WET, DRY AND CHEMICAL LABORATORIES.

Multi-purpose in its functionality and spacious enough to accommodate over 20 scientists, in addition to crew, the State-owned vessel, run by the Marine Institute, came into service in 2003, since when it has been used for fisheries, acoustic research, oceanographic, hydrographic and geological investigations, as well as buoy/deep water mooring and remotely operated vehicle (ROV) operations. That the *RV Celtic Explorer* has been crucial in facilitating exploratory research in Irish waters is universally acknowledged, yet Dr. Stephen McCarron, a geoscientist based in Maynooth University Department of Geography, whose work on climate change involves analysis of sediment cores from palaeoclimatic archives, gives a lot of credit to the support of the officers and crew on board the vessel. 'They are closely involved with what the scientists are trying to do and will do everything they can to help get results. The *Explorer* is a real team effort.'

If collaboration is crucial, so too, McCarron adds, is good luck: 'Chance plays a huge role in deciding the success or otherwise of any research campaign. And the weather of course.' McCarron knows well the arbitrariness of exploratory research, especially far out at sea when time and the elements impose constraints far beyond the ordinary. Early in 2014, he was part of an international expedition on the *Explorer* which aimed to map the outer limits of the Celtic shelf off the south coast of Ireland. The campaign was part of an on-going Irish-Italian collaboration to locate geological evidence of former ice sheet extents around the island of Ireland. McCarron and his colleagues were looking for evidence of former ice presence far beyond 'accepted' limits, at the outer edge of the Celtic shelf. With 12 days of funding but very poor weather, they ended up with only a short window of 36 hours in which to get to the outer shelf and do their work. The storms of winter 2013/2014 were horrendous and the *RV Celtic Explorer*, for all its tremendous stability, was 'chased off' the shelf by incoming Atlantic storms. 'We ended up running at full speed from 30m high "lumps" of water.' However, what happened in those 36 hours on the outer shelf underscores the roles of both persistence and good fortune in Discovery Research. 'We were very lucky, it was so touch and go whether we could get anything other than (recent) surface gravelly sediment, which tells you little about older ice age events.' Based on the best educated guesses possible, in close collaboration with the *Explorer's* officers and crew and in the face of oncoming storms and their quickly rising seas, it was decided to keep trying to collect longer cores from the ocean floor. Only one core with evidence of ice presence was required to change the models of Celtic Sea glaciation, forever. The campaign ended up recovering three. On Core 60 of the campaign, as the barrel lifted out of the water, McCarron noticed distinctive grey mud hanging from its tip. 'When I saw that, I knew, and the crew quickly learned, that was it. That's what we were looking for. Stiff muddy sediment is like a fingerprint of ice presence. Without ice sitting on the shelf there, you couldn't get that level of consolidation.' Immediately the campaign was transformed into a success story. Subsequent laboratory work bore this out, shells from the cores being radio carbon-dated to the last ice age. For McCarron, the whole episode underlined the risks, uncertainties and potential rewards of Discovery Research. 'We found the footprint of an ice sheet on the edge of the Celtic shelf, which had never been suggested before. If we hadn't recovered these few cores in the few hours of weather window we had available, it's very possible that nobody else would ever have gone and retested the same area. The word would have gone out in the scientific community that we had tried and there was nothing there.'

'We found the footprint of an ice sheet on the edge of the Celtic shelf, which had never been suggested before. If we hadn't recovered these few cores in the few hours of weather window we had available, it's very possible that nobody else would ever have gone and retested the same area. The word would have gone out in the scientific community that we had tried and there was nothing there.'

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'Fundamental research is crucial to undertake because it generates new discoveries and provides the basic knowledge for applied and policy-led research and interventions. Any funding system that does not fully support such research is severely limiting its ability to push scientific boundaries, to produce new applications, and to be at the cutting-edge of international scholarship.'

Professor Rob Kitchin, European Research Council Advanced Investigator in the National Institute of Regional and Spatial Analysis at Maynooth University, and the 2013 recipient of the Royal Irish Academy's Gold Medal for the Social Sciences

UNEXPECTED INSIGHTS INTO A CONTINENT

It's hard to believe that the European Social Survey (ESS) only began in the early years of this century. So widely is it referenced in academic literature and so frequently does it feed into mainstream media, the inclination is to consider that it has always been an integral feature of the Ireland's engagement with European institutions. It hasn't of course, yet the impact of the ESS on the whole discipline of social sciences has been little short of transformational – and in ways that could not have been envisaged when the enterprise began. The ESS has proved an exercise in basic research that has yielded a bedrock of information that scholars working across a range of subject areas - from environmental studies to those concerned with social policy as it relates to issues of health, age, gender and geography - have been able to creatively build upon and develop, to reveal new, and sometimes surprising, insights. In other words, the ESS has facilitated research and stimulated inquiries that might otherwise not have happened, or, indeed, could not have happened.

'There were lots of individual country datasets, but in terms of being able to compare sets of people within countries and across time, that was missing. This was one of the big gaps in the infrastructure.'

As to the original and intended value of the surveys, Dr. Finbarr Brereton of University College Dublin (UCD) who, alongside his colleague Professor Peter Clinch, serves as Ireland's National Coordinator for Round 7 of the ESS, stresses the importance of its international comparability. 'That was missing in the social sciences', he says. 'There were lots of individual country datasets, but in terms of being able to compare sets of people within countries and across time, that was missing. This was one of the big gaps in the infrastructure. '

The driving force behind Ireland's involvement in the ESS was Professor Richard Sinnott, the now retired UCD political scientist whose fingerprints are to be found upon many of the major initiatives that have helped progress Irish political and behavioural social sciences, not least the on-going, twice-yearly documenting of Irish people's attitudes to European Integration. Given this background, it's easy to see why the idea of a European social survey appealed to Sinnott.

What it set out to do – and what it has undoubtedly delivered – is the production of important new, fundamental knowledge that allows for proper comparisons between countries across a Europe that is remarkable for its diversity - of people, languages, attitudes, beliefs, opinions and experiences.

At the core of the ESS since its inception are a series of questionnaires pertaining to major themes such as politics, subjective well-being, media, social trust and human values. For the most part, the questions used in each round of the survey, beginning in 2001 and carried out at

approximately two-year intervals thereafter, have remained the same and this has been crucial to the tracking of responses over time. But flexibility is also provided for. 'If questions aren't used, they're dropped', says Brereton. Then there is the allowance for new realities, with Brereton pointing out that questions that might have been appropriate for the media module in 2002 would have been entirely redundant a decade later given the explosion of online and social media that occurred in the intervening years.

Complementing this core - and recurring - set of themes are a series of rotating modules which reflect shifting topics of concern that must, by necessity, be of relevance across Europe. Ideas as to what should be surveyed are proposed by teams of academics and those that have been chosen heretofore have addressed such matters as healthcare, working lives, democracy and immigration.

Underpinning all of this work are rigorous methodologies and principles of easy, free and open access; indeed, the only stipulation concerning usage is that it is not for commercial purposes. Transparency and thoroughness are guiding rules throughout the process: in terms of sampling and field work, every variable is documented and published, from the day of the week the survey was carried out to the differences in the weather on survey days in each of the countries covered. A similar concern with methodological rigour is also evident in the great care taken to ensure that questions translate accurately across the spectrum of languages used to cater for such a diverse cohort of respondents. This is a far from straightforward matter. There are, for instance, difficulties translating 'well-being' into Russian, which is particularly problematic in framing a questionnaire whose very aim is to measure personal and social well-being. Furthermore, for the module on immigration, first carried out in Round 1, Brereton points out that 'ethnic minority' is mainly understood as a synonym of Roma in languages in Central East European countries, but of course the purpose of the survey is gather information on all migrant experience, not just the Roma people.

Navigating these linguistic minefields is just one part of the practical challenge involved in designing surveys, the wide availability of which, Brereton insists, has proved ground-breaking in terms of academic research and public knowledge.

The series of surveys already carried out have, he says, 'allowed innovations in research that couldn't have occurred without it'. Notable examples include the work of Irish academics Dr. Helen Russell of the Economic and Social Research Institute, whose work has centred on the relationship between family, work and well-being; and Dr. Edel Walsh of University College Cork, who has attracted widespread media attention for her reports on the quality of life of older people and those in rural Ireland.

And then there is Brereton himself, who, alongside colleagues Peter Clinch and Tine Ningal, has made novel use of the ESS to explore the influence of environmental issues on subjective well-being. Specifically, what they, as part of an international consortium, have done is to take the series of European surveys on life satisfaction, available across twenty-three countries, and link them with regional data on sulphur dioxide (SO_2) concentrations that were collected from a network of monitoring stations across Europe and accessible through a public air quality database system known as Airbase.

> 'The surveys have allowed innovations in research that couldn't have occurred without it.'

The results are at once revealing and significant. For the most part, Europeans reported high levels of life satisfaction, though variations could be observed both across countries and between regions within countries. By linking this ESS data with that available for SO_2 levels, Brereton and his colleagues were able to demonstrate a significant correlation between air quality and life satisfaction. In short, they showed that Norway and Denmark, the countries which had the lowest SO_2 concentrations, were also those with the highest levels of life satisfaction. Moreover, they were able to show a clear connection between increases in SO_2 levels and decreases in life satisfaction.

Such findings, unreachable without reference to the survey's core research, present obvious, clear-cut challenges to policy-makers. Yet, according to Brereton, the next key phase in the development of the ESS will be the push to ensure its greater use in the formation of public policy and presentations to this effect have already been made in the European Parliament. If this is to be achieved, however, it will be crucial that the retreat from participation among certain countries, a consequence of the international financial crisis, can be reversed. The problem is real: where, at its peak, participation in the ESS spread to thirty-one countries, it has shrunk to twenty-three countries for certain crisis-era modules.

Ireland has never been inclined to withdraw – and with good reason. It's not just that the ESS enjoys the prestigious status of a European Research Infrastructure Consortium (an ERIC) to which Ireland is a signatory or even that it won the Descartes Prize, awarded by the European Commission for 'excellence in scientific research' in 2005, the first social science project to win this prize. It's also that with almost 80,000 registered users of the data worldwide, Ireland, whose participation is funded by the Irish Research Council, is one of the highest per capita consumers of survey content. This pattern of heavy usage is unlikely to change anytime soon. If anything, indeed, demand is set only to increase. A defining feature of the ESS is that it offers a 'time series' the effect of which, Finbarr Brereton emphasis, is that 'the more you stay involved, the more valuable it becomes'.

That future value is at once clear and uncertain. For if past experience is any guide, it is that core research undertaken by ESS will, most likely through linkages with other datasets, open new fields of inquiry and throw up fresh and unplanned insights.

> What it set out to do – and what it has undoubtedly delivered – is the production of important new, fundamental knowledge that allows for proper comparisons between countries across a Europe that is remarkable for its diversity – of people, languages, attitudes, beliefs, opinions and experiences.

'The essence of basic frontier research is that you don't know what way it is going to go. But if we don't fund it, where are the breakthroughs going to come from? There's a huge unmet need in cancers and pathologies like Alzheimer's and the only way to make progress is to understand the disease at a fundamental level. That involves basic research … Let's say we do make a fundamental discovery and we don't commercialise and someone else does, that would be terrible. It's like in football – you would be stupid to have a whole load of backs on your team, you need wingers and forwards as well.'

Professor Luke O'Neill, School of Biochemistry & Immunology, Trinity College, Dublin, 2012

DISCOVERING A KEY PIECE OF THE JIGSAW - THE POWER OF FUNDAMENTAL SCIENCE

‘From an early age I have been fascinated with science because of the high impact that it has on our daily life. I would like to contribute to society by using science to ameliorate human suffering and to improve the quality of human life. I chose to pursue this interest by studying Biotechnology at NUIG, because this course comprises the application of biology for the benefit of humanity and the environment. I also think I have always been lucky to have passionate science teachers who have inspired me and let my passion for science and research to develop,’ says Izabela Koryga, a doctoral student at the School of Natural Sciences at the Apoptosis Research Centre, National University of Ireland, Galway (NUIG).

Ms. Koryga completed her second-level education in Poland and then successfully completed the NUIG Access Programme in Co. Longford that enabled her to progress into higher education. She graduated from NUIG with first class honours in Biotechnology and was awarded the Biotechnology Prize Medal for academic excellence as well as a host of other awards and research grants.

It was at NUIG that Ms. Koryga found the particular niche within scientific research that now dominates her work: ‘During my undergraduate studies I took a module given by Dr. Adrienne Gorman which focused on the process of cell death. I became fascinated by the idea of manipulating this process to ameliorate human suffering. The cell death field is growing very quickly. Every year new discoveries are made which have direct implications for patients suffering from a broad range of diseases such as cancer and degenerative diseases.’

‘We believe that detailed investigation of these cellular phenomena can bring advances in our understanding of the cell death process and its regulation.’

Having been fascinated by Dr. Gorman’s undergraduate lectures, Ms. Koryga approached her to enquire about research positions in her laboratory. This led, in turn, to the development of an Irish Research Council-funded Ph.D project entitled ‘Identification of a Novel Cell Death-Inducing Complex Assembled in Response to Stress’: ‘The aim of my project is to characterise a novel cell death inducing protein complex, called the Stressosome. This protein complex was recently discovered in the Apoptosis Research Centre to which our laboratory belongs and represents an exciting development in the field of cell death. The importance of this discovery was highlighted by its publication in the highly renowned scientific journal *Autophagy* in 2014. This protein complex forms in cells that are unable to die by normal means due to the absence of one crucial cell death protein. Such cellular conditions are commonly found in cancer cells which can inactivate pro-death proteins to escape cell death and continue to grow, eventually leading to death of the patient.’

Ms. Koryga continues: ‘The formation of the Stressosome activates an alternative and slower mode of death, and relies on the activation of a

well-established pro-survival cellular pathway called autophagy. The Stressosome therefore unmasks the alternative role for autophagy in facilitating cell death. With this research we are trying to identify the proteins which make up the Stressosome and identify their role in the formation of the complex as well as in activating cell death. We are also examining the alternative mode of cell death that is activated by the Stressosome and trying to understand its importance in the context of life and death decisions in cancer cells. We believe that detailed investigation of these cellular phenomena can bring advances in our understanding of the cell death process and its regulation. Such studies may highlight novel targets that are important in cancer and allow us to determine the therapeutic potential of Stressosome signalling.'

This project is part of a wider body of work being undertaken in NUIG on mechanisms of cell death and survival. Another Ph.D student in the group, Karolina Pakos-Zebrucka, is investigating the cell signalling that leads to formation of this protein complex. Indeed, as her doctoral work has progressed, Ms. Koryga has come to appreciate more fully the importance of collaborative research processes: 'I now see that important discoveries are very often a combined, sustained effort between different laboratories. I think that close collaborations with other scientists and the constant growth of the social scientific network are equally important to success as the hard work in the lab. In NUIG we are working closely with other labs that are part of Apoptosis Research Centre at NUIG, especially with the lab of Prof. Afshin Samali who is co-supervising my project. But also we have developed close collaborations with the lab of Prof. Peter Vandenabeele from Ghent University in Belgium who is also investigating cell death processes.'

Ms. Koryga's work is on-going and she is optimistic for its future: 'I have not discovered anything surprising yet, but what I find very intriguing are the recent discoveries from the cell death field that expose a close signalling network between different cell death processes and the well-established pro-survival process of autophagy. I am excited by the fact that my project directly addresses this gap in our knowledge and I believe that it has great potential. Elucidating the components of the Stressosome protein complex and its signalling regulators will enable us to target them therapeutically. This gives my project direct therapeutic relevance and I am very excited to see how we can turn the discoveries we make in the lab in to therapies in the clinic. My project has direct implications for resistant cancers such as ovarian cancer, metastatic melanoma and lymphomas where the normal cell death process is disrupted and cancer cells continue to grow. Pushing cancer towards Stressosome formation is another means that we have of combatting cancer.'

This is work which Ms. Koryga hopes to continue for the foreseeable future: 'I would like to continue working on cell death signalling after obtaining a Ph.D degree. I think that this field has great potential for further treatment of a range of diseases including cancer. I believe that better understanding of the signalling pathways that govern cell death processes will enable us to create more tailored therapies for treating cancer and degenerative diseases.'

'I am excited by the fact that my project directly addresses this gap in our knowledge and I believe that it has great potential.'

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'In this time of severe budget constraints, Americans need to know that today's basic research is the engine that powers tomorrow's therapeutic discoveries. They need to know that basic research is the type of science that the private sector, which requires rapid returns on investment, cannot afford to fund. They need to know that, because it is impossible to predict whence the next treatment may emerge, the nation must support a broad portfolio of basic research. '

Dr. Francis S. Collins, Leader of the Human Genome Project and U.S. Director of the National Institutes of Health, 2012

LOOKING BEYOND THE USUAL SUSPECTS

Scanning electron micrograph of *Campylobacter ureolyticus*. Credit: Dr. Brigid Lucey. This image graced the cover of the 15 May, 2014 issue of the Journal "Virulence' (Volume 5, Issue 4)

‘We know that there are many more pathogens to be found and we believe that we may have the means to find them. We have among our group farmers, veterinarians, medical scientists, bioinformaticians, medical consultants, and some excellent students, both at under- and post-graduate levels. We need to keep an open mind on the possibilities within our research, and to try to know which questions to ask at key times. The diversity of the research team enables us to look at our research questions from many different angles. It also gives us a level of expertise that you would not otherwise realize existed’, explains Dr. Brigid Lucey of a unique research project which has been underway in Cork since 2008.

The research looks afresh at the causes of human acute gastroenteritis, a distressing condition that causes diarrhea and vomiting, and is extremely serious in vulnerable patients. Dr. Lucey – along with Dr. Roy Sleator – directs this research at the Department of Biological Sciences at Cork Institute of Technology, in concert with a range of partners, including Cork University Hospital.

Dr. Sleator sets out the thinking behind the project: ‘When we have a suspected infection, the basis for diagnosing the cause is usually to think about what the usual culprits might be and then to look specifically for those agents. This has led to the creation of systems designed to detect the most likely disease-causing microbes. What we have tried to do is to move beyond those long established systems, in response to the fact that the existing systems often fail to detect the cause of gastroenteritis.’

The research group in Cork began to look at the feasibility of using a new system in their clinical laboratory that promised simultaneously to detect salmonella campylobacter, shigella and verotoxigenic *E. coli* – the four most common bacterial causes of gastroenteritis. The new approach brought a significant development, as Dr. Lucey notes: ‘One of the results of our research work in Cork was that we had more confirmed campylobacter positives than we could identify definitely as being any of the known species. Already, campylobacter accounted for the majority of bacterial cases of gastroenteritis worldwide. Our research led to finding that one-quarter of the acutely ill patients who had a campylobacter had what became known as *Campylobacter ureolyticus*. The patients who were found to have this microbe, but no other causative agent, tended to be either elderly or immunocompromised (for example, HIV-positive).’

‘Many investigations later, it transpired that we actually had a new campylobacter on our hands. Our group had the naming of the new microbe; we named it Campylobacter corcagiensis, after Cork, its county of origin. This was a thrilling discovery for us. It’s not something we had anticipated having the honour of doing.’

The next step in the research process brought further developments: 'The detection of *Campylobacter ureolyticus* in patients with gastroenteritis led to the need to develop a culture medium that would allow us to grow the organism from human faeces. This approach to microbiology is exactly the opposite strategy from that used until now, whereby investigations always began with first growing the organism as a culture. The challenge in our case was to have the means to grow our rather exacting organism of choice while suppressing the growth of any competing microbes.'

Meeting this challenge brought more innovation. One of the research team developed a new medium, which allowed the first-ever isolations to be made for this organism in cases of gastroenteritis. Dr. Sleator continues: 'In fact, the first successful isolation of a wild-type strain from human faeces was made by one of our students during his final undergraduate year research project. Then, one of our Ph.D. students, Monika Koziel, searched environmental reservoirs for the new pathogen. She actually chose to look in-depth at cattle rather than poultry and found the organism in cow's milk.' Dr. Koziel then decided to check whether primates also harboured the organism, and, using the research team's newly developed medium, went on to grow an organism that resembled *Campylobacter ureolyticus* from the faeces of sick lion-tailed macaques. Initially, the ureolyticus-specific genes that she anticipated as being in these colonies were not found, however. This led the team to explore a new approach.

Dr. Lucey describes what happened next: 'Many investigations later, it transpired that we actually had a new campylobacter on our hands. Our group had the naming of the new microbe; we named it *Campylobacter corcagiensis*, after Cork, its county of origin. This was a thrilling discovery for us. It's not something we had anticipated having the honour of doing.' The research team in Cork had embarked on this research with no sense that they would end up making such a discovery: 'What has happened here is way beyond what we could have anticipated. What we had initially set out to do was to solve a mystery around gastroenteritis – we can't say that we have solved the mystery but we have solved some parts of it. And this makes us want to solve more of it.'

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Dr. Brigid Lucey and Dr. Roy Sleator wish to acknowledge their team members Ms Aisling O'Doherty, Medical Scientist, and Dr. Daniel Corcoran, Consultant Microbiologist; their gratitude also to Mr Brendan O'Reilly and all the staff at the Microbiology Dept. of Cork University Hospital.

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A vibrant base of fundamental, blue-skies research on gut microbiome is essential to understand how this bacterial community influences the health of the human or animal host. Exploratory research of this nature leads to serendipitous discoveries, such as new therapeutics, diagnostics or functional food ingredients, compliments more downstream research programmes needed to bring these discoveries to the market place, and helps to germinate hi-tech start-up companies, such as Alimentary Health Ltd.’

Dr. Sally Cudmore, APC Microbiome Institute, UCC

WHY AND HOW DOES THIS WORK?

PROVIDING A ROBUST SCIENTIFIC BASIS FOR PROBIOTIC FOODS

The human intestine is home to an almost inconceivably large number of microorganisms called the human gut microbiota. These can be pictured as an organ placed within a host organism. Overall, the microorganisms present in the intestine are believed to possess many positive functions on human health. Bifidobacteria are commonly found in the gastro-intestinal tracts of humans and most animal and insects. And yet, despite the generally accepted importance of bifidobacteria as positive components of human gastro-intestinal tracts microflora and their use in health-promoting foods (probiotics), there is a paucity of data about the molecular mechanisms that explain their probiotic features.

A project being undertaken by Dr. Francesca Turroni, under the direction of Prof. Douwe van Sinderen at the Department of Microbiology and Alimentary Pharmabiotic Centre, University College Cork (UCC), is engaged in ground-breaking research in the area: 'My project is aimed at increasing our knowledge on the molecular background pertaining to the interaction between intestinal commensals such as bifidobacteria and its host, which is an under-explored area as compared to other bacterial groups, including pathogens. Within the human gut microbiota, bifidobacteria represent the first most numerous microbial groups encountered in the colon of infants, considerably outnumbering other bacterial groups.'

> 'Despite extensive research on bifidobacteria, little is known about the molecular details that explain the impact or dependency of this particular group of probiotic gut commensals on other members of the human gut microbiota, or on their host.'

Dr. Turroni's motivation for undertaking the research included the idea of looking at the scientific evidence that might underpin the value of probiotic foods: 'In recent years significant efforts have been directed to investigate and understand the mechanisms of action of probiotic bacteria (i.e. microorganisms with positive effects on human heath), such as bifidobacteria. The idea is to validate and exploit their use in (novel) functional foods. Despite extensive research on bifidobacteria, little is known about the molecular details that explain the impact or dependency of this particular group of probiotic gut commensals on other members of the human gut microbiota, or on their host. A clear identification of their biological functionalities in the gut is necessary in order to provide a robust scientific basis for probiotic foods.'

The project results to date suggest that there is an interactive relationship between host and components of the intestinal microbiota. Overall, the generated knowledge has increased the understanding of the ecological role and associated physiological activities of bifidobacteria in the mammalian gut. The project has also changed the manner in which Dr. Turroni has approached her research: 'Since starting this postdoctoral work, I have become persuaded that it is not anymore possible to perform research in a specific field, but that it is needed to broaden our view. Human beings and bacteria have co-evolved and cannot be studied as two separate organisms. I am firmly convinced that in the near future microbiology and medicine will not be two separate disciplines anymore and the understanding of the close links between them will be crucial for the development of new therapeutic interventions for currently untreatable diseases.'

Crucial to this process has been the development of links between the research project in UCC and other research projects across the world: 'In the last few years I have initiated and sustained strategic collaborations; the most important is with Prof. David Sela, of the University of Massachusetts in America. Prof. Sela's research group investigates the genomics and ecology of commensal microorganisms and is working on the characterization of the mechanistic linkages with health emanating from host-microbial interactions.'

Presentations at international conferences have also facilitated engagement with other young scientists working on the gut microbiota and bifidobacteria from research institutes or academia across world: 'My research allowed me to attend various international conferences covering different areas of microbiology, such as the ASM General Meeting in San Francisco in May 2012. This conference gave me the opportunity to get a very wide scientific view of what is the current state of knowledge not only in my research topic but also in related fields.'

Dr. Turroni, who had previously been based at the University of Parma in Italy where she had undertaken doctoral and postdoctoral work, has been engaged in research in Cork since 2011 and is clear about the benefits of coming to UCC:

I selected this laboratory because it is at the forefront of research in the field of bifidobacterial molecular biology and functional genomics. I'm very grateful to have received an Irish Research Council Empower Postdoctoral Fellowship. It has been a wonderful opportunity for my research and my academic career. In fact, it allowed me to continue to perform research in microbiology, in the same field where I have been working since the beginning of my Ph.D. 8 years ago. This project offered me the possibility to acquire a range of new competencies and skills that have very significantly increased my scientific capabilities in the field of health-promoting bacteria and human gut bacteria. I have also been able to pass on what I have learned to others through the supervision and direction of research performed by undergraduate, postgraduate and visiting students. This has, without a shadow of a doubt, been a fantastic career-opportunity, which will be crucial for me in order to proceed with a scientific career in either an academic environment or in a commercial setting.

'I am firmly convinced that in the near future microbiology and medicine will not be two separate disciplines anymore and the understanding of the close links between them will be crucial for the development of new therapeutic interventions for currently untreatable diseases.'

BELIEVING IN YOUR IDEA - FROM WI-FI TO THE INTERNET OF THINGS

'In the early days of computing in the 1970s, we couldn't imagine taking the performance of a room full of computers and squeezing them into a watch attached to our wrist. In the early days of the internet in the 1990s, we couldn't imagine having a world of digitized data accessible nearly instantly from a phone in the palm of our hands. But the combination of fundamental and applied research enabled these revolutions to happen. Today, we can only vaguely imagine the transformation that will result from all things being smart and connected to the Internet.

But this Internet of Things (IoT) revolution is coming. And as happened with computing and the internet, it is through those engaged in fundamental and applied research that we will expand our imagination and our realization of the revolution that will be IoT.'

Philip Moynagh, Vice President, Intel – The Internet of Things (IoT)

Some time ago, when asked by a university magazine about what it was that drove him and his work, Mark Davis offered a response that was as short as it was revealing. 'A puzzle', he answered, 'especially where I don't even know the right question to ask.'

This is a philosophy that has underpinned much of the very best of Discovery Research across a broad spectrum of disciplines. It also emphasises the spirit of open inquiry, of adventurous exploration that has shaped the trajectory of much of Davis's impressive career, which has straddled the worlds of academia and industry. It was, after all, in response to a 'puzzle' that Davis, the Director at Dublin Institute of Technology's Communications Network Research Institute (CNRI), embarked on a research path that would end up a decade later, as much by accident as design, in the creation of a successful company employing ten people and with plans for future expansion.

In the early 2000s, after spells working in the Netherlands, the UK and at home in Ireland, Davis joined the then recently established CNRI, which had been founded in 2001 on the strength of the vision of the now deceased Trinity College Dublin statistician, Professor John Lewis, and a start-up grant from Science Foundation Ireland (SFI), the ambition being to find and apply mathematical techniques to, amongst other things, analyse traffic flows on communications networks.

The environment clearly suited Davis. No sooner was he in the door of the CNRI than he became involved with a project that entailed what he later says was 'probably the first use of Wi-Fi in Ireland'. Building on a prior collaboration with Eircom and with funding support from Enterprise Ireland, Davis and his colleagues established a Wi-Fi link between their research building on Dublin's Herbert Street and DIT's campus on Kevin Street, a distance of 1.5 km. This was an experiment that looked to examine the feasibility of combining the technologies of Wi-Fi and Voice over IP (VoIP) telephony.

What they found was not what they expected. Based on a simple analysis of the capacity for fixed wireless calls, a link such as this should have been able to accommodate 20 to 30 calls simultaneously, yet the reality was that it was only accommodating about 3 or 4.

Hence the puzzle: what happened to cause the performance anomaly and where did all the bandwidth go? Making sense of this conundrum became the unexpected focus of Davis's research endeavours in the years that followed. After three years of further research, supported through funding from Enterprise Ireland, his efforts - and those of his colleagues - were rewarded. Their achievement was to develop a mathematical framework that modelled the way in which bandwidth was shared out among users of a Wi-Fi network, thereby enabling a network operator to monitor and effectively control how the bandwidth is used. In practical terms, it enables the operator to allocate, for instance, more bandwidth to support bandwidth heavy services such as video streaming or, alternatively, to enable priority treatment to premium customers.

The timing of this discovery, given the upsurge of interest in Wi-Fi in the mid 2000s, appeared perfect. And so a patent was secured for the technology and Davis and his team set about attempting to commercialise their research. They headed west to California - and not just the once - to introduce their technology to all of the major players in the global technology field. Pick a big name, they met them: Apple, Aruba Networks, Cisco Systems, Microsoft, Netgear and others. The responses were uniformly positive, but the uptake was poor. Why? All agreed the technology was great, but all asked the same question: 'Where's the demand?'

This was 2008 and, reflecting on it now, Davis acknowledges that while the lack of commercial buy-in was a set-back, it was never a crippling one. 'I never lost heart', he says. 'I could see the potential in it. The people I was talking to were commercially focussed, but working in communications is about being ahead of the curve … You have to believe in your technology.' In this case, the belief was justified, but the work carried out at the CNRI only found a viable commercial application once industry innovation caught up with the research.

Demand for Wi-Fi was indeed on the rise, but the single most important development was the introduction of the smartphone. It was, Davis admits, 'a complete and utter game-changer'. The sheer pervasiveness of the technology meant that the amount of data on wireless networks 'went through the roof'. There was an explosion in Wi-Fi use and doubts previously expressed by the Californian tech giants seemed suddenly redundant. Where once the question was 'where's the demand', now the challenge was how to satisfy all the demand that existed.

Davis dusted down the technology, fine-tuned it further, and set about the process of commercialisation. He did it with the help of entrepreneur Mark Burke, to whom he was introduced through DIT's Hothouse incubation office. Burke was both excited by the work going on at the CNRI and fully aware of its commercial possibilities. Together, Davis and Burke founded a start-up company, OptiWi-Fi, which was incorporated in 2011 with the aim of delivering 'next-generation monitoring and self-optimisation solutions to Wi-Fi providers, Mobile Network Operators and Wi-Fi equipment manufacturers'.

Chances are that even if you've never heard of them, you may well have availed of their technology. Millions already have, mostly in the UK where it is to be found in use on the streets and in retail outlets in Birmingham, Glasgow and London, as well as at various sporting venues. This expansion was greatly aided by being selected, in 2012, to join the prestigious Wayra Academy, a global initiative of Telefonica - O2's parent company - to support early-stage technology start-ups. The Academy attracted 335 applicants and OptiWi-Fi, in being only one of ten chosen, was supported with a €50,000 investment in the company.

Since then, the story of the company has been one of trials and roll-out. The first trial of OptiWi-Fi technology took place in Twickenham during the England vs Italy RBS 6 Nations rugby international of March 2013, when it was installed at a number of points – mainly corporate boxes and bars – around the stadium. It went well, which is to say it successfully pinpointed problems associated with the clogging up of Wi-Fi in stadium full to its 80,000 spectator capacity.

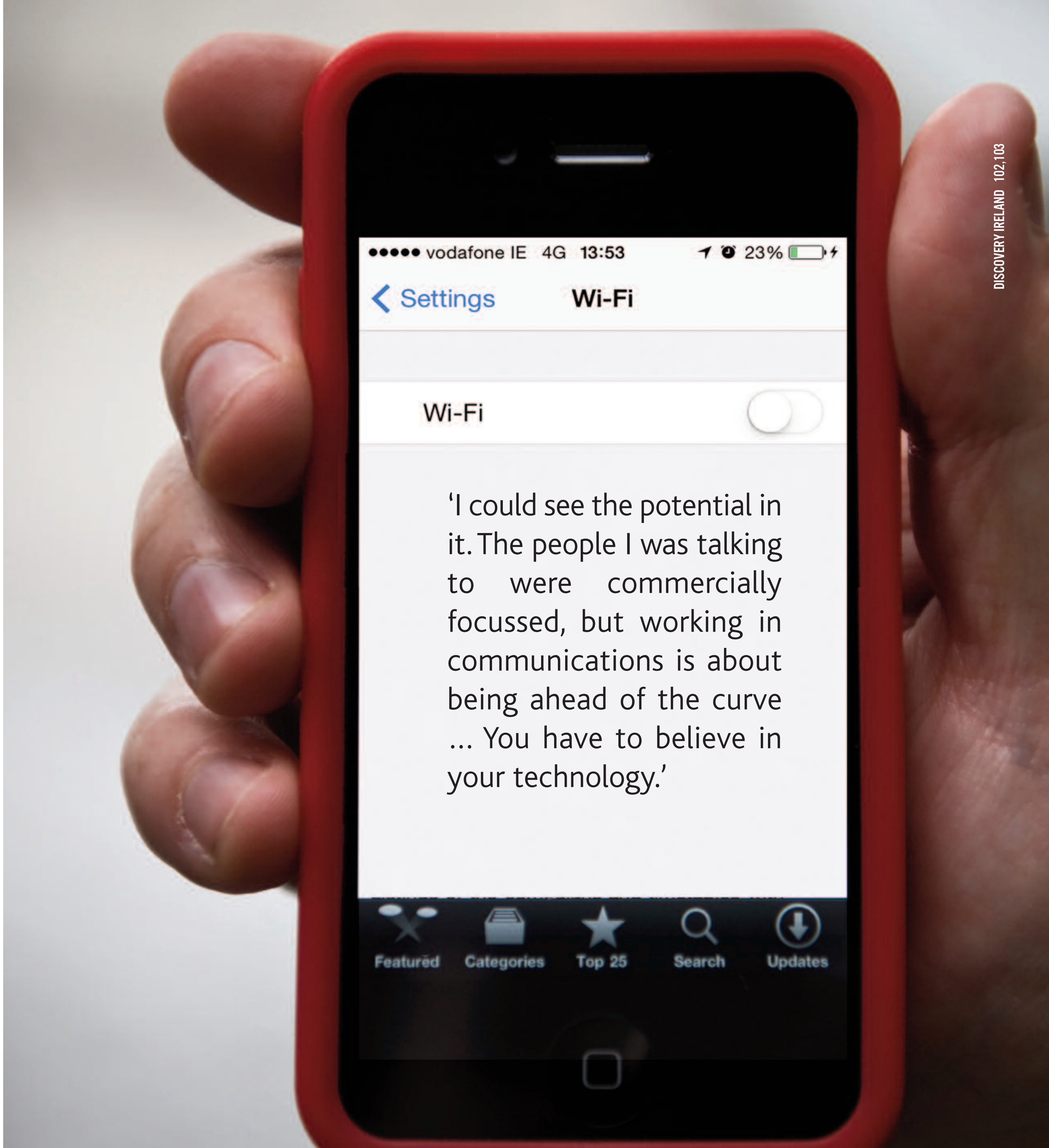
The technology has been doing the same along London's fashionable Oxford Street, where it has been installed aside the Wi-Fi radios that are affixed on lampposts along the street, enabling the performance of the various Wi-Fi hotspots to be viewed, assessed and better managed. Indeed, the success of that Oxford Street initiative has resulted in the further deployment of OptiWi-Fi technology within the O2 retail store network across the UK.

The pace of this progress has bred not even a scintilla of complacency. Quite the opposite: Davis is conscious that where technology is concerned nothing stays the same for long. Change is not only inevitable, it is constant and Davis's focus has remained fixed on the future and on staying 'ahead of the curve'. Already he has developed a tool for measuring and optimizing the quality of VoIP calls, which has spawned a new company, Vopti, which aims to commercialise the technology.

And while it is still 'early days' for this new company, it is clear that the 'puzzles' to which Davis is so drawn will, into the future, only become more elaborate and complex. 'The next really big thing is the Internet of Things', Davis says. 'By 2020 there will be about 50 billion devices connected to the internet, everything from your car, to your oven, to your lights and heating system, in fact anything that has a control system. These devices will be bedded into the fabric of your life; everything will have a chip that will relay information on your life.'

The Internet of Things is fast becoming reality and with it the requirement for greater wireless connectivity is set to grow and grow. The implications of this for Mark Davis and his CNRI team are hugely significant and it can be assumed that the next time they knock on doors with their technology, there will be nobody asking 'Where's the demand?'

> 'By 2020 there will be about 50 billion devices connected to the internet, everything from your car, to your oven, to your lights and heating system, in fact anything that has a control system.'



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