impact assessment report
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For the report, we commissioned Professor Brian Lucey, leading economist at Trinity to undertake an evaluation of the economic impacts that CRANN and AMBER have had in the last 10 years and to measure the linkages between academics and business and community. Professor Lucey used the Input-Output approach to analyse our economic and employment impacts in Ireland. His team also empirically measured the linkages between academics based at CRANN and AMBER and business and community, using a field-tested survey instrument. We commissioned Claire O’Connell, science writer, to put together a number of impact case studies, to highlight the reach and significance of our research across a broad range of communities and businesses.

We are delighted that the hard work of our researchers and staff over the last 10+ years is effectively demonstrated in this report through the significant contribution that CRANN and AMBER have made to the economic and societal wellbeing of our local, regional and national communities and through our international reach.

As we look forward to the next decade, we remain committed to making a difference to the social and economic wellbeing of Ireland through the quality of our research and training for graduates and our engagements with businesses and communities both nationally and internationally. We will work to engage with our politicians and policy makers to ensure that the value to Ireland of investing in materials science is evident.

Professor Michael Morris
Director | AMBER

Professor Stefano Sanvito
Director | CRANN
our economic impact

The economic impact assessment for CRANN/AMBER over the 10 year period of 2007–2016 demonstrates a very positive impact for the Irish economy; with a total income of €108 million from 2007 to 2016, CRANN/AMBER generated gross output nationwide of over €505 million.

Table 1.1 shows the economic impact of CRANN/AMBER on the national output over the last 10 years. The output multiplier for a sector refers to the change in total output for the economy as a whole resulting from a unit change in the final demand for that sector. To implement the input-output analysis for CRANN/AMBER, the first thing to do was to construct a disaggregated input-output table, which views CRANN/AMBER as a separate ‘sector’ within the ‘Education Service’ sector as a whole from the National Accounts, based on Central Statistics Office data. The Type I output multiplier for a particular industry is defined to be the total of all outputs from each domestic industry required in order to produce one additional unit of output, while the Type II output multiplier incorporates not only the increase in demand for intermediate inputs but also induced household consumption effects. In other words, the Type I multiplier can be defined as direct and indirect effects, and the Type II multiplier can be defined as direct, indirect and induced effects. As we are concerned with wider economic impact of CRANN/AMBER on the national economy, it is the Type II output multipliers that are presented here.

Table 1.1 Economic impact of CRANN/AMBER in the input-output approach

<table>
<thead>
<tr>
<th>YEAR</th>
<th>INCOME</th>
<th>TYPE II OUTPUT MULTIPLIER</th>
<th>IRISH ECONOMIC IMPACT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>7.05</td>
<td>4.31</td>
<td>30.39</td>
</tr>
<tr>
<td>2008</td>
<td>8.78</td>
<td>4.11</td>
<td>36.09</td>
</tr>
<tr>
<td>2009</td>
<td>15.71</td>
<td>3.51</td>
<td>55.14</td>
</tr>
<tr>
<td>2010</td>
<td>7.28</td>
<td>4.17</td>
<td>30.36</td>
</tr>
<tr>
<td>2010</td>
<td>8.21</td>
<td>5.43</td>
<td>44.58</td>
</tr>
<tr>
<td>2012</td>
<td>9.80</td>
<td>4.66</td>
<td>45.67</td>
</tr>
<tr>
<td>2013</td>
<td>11.08</td>
<td>6.12</td>
<td>67.87</td>
</tr>
<tr>
<td>2014</td>
<td>14.33</td>
<td>4.83</td>
<td>68.21</td>
</tr>
<tr>
<td>2015</td>
<td>12.05</td>
<td>4.93</td>
<td>59.41</td>
</tr>
<tr>
<td>2016</td>
<td>13.43</td>
<td>4.84</td>
<td>68.30</td>
</tr>
<tr>
<td>Total</td>
<td>€107.73</td>
<td>4.69</td>
<td>€505.05</td>
</tr>
</tbody>
</table>

(Current prices, million euro)

Employment impact

Table 1.2 shows the employment impact of CRANN/AMBER on the national labour market over the last 10 years. During the whole period, the Type II employment multiplier for CRANN/AMBER is 12.80, which compares favourably with the employment multipliers for each of the 21 Irish HEIs as reported by Zhang et al., which ranged from 4.45 to 8.84*. The main driver behind our high employment multiplier is that CRANN/AMBER, when compared with each HEI, has raised very significant funding relative to its headcount (larger ratio of income to number of staff). With a total employment of 1116 staff, CRANN/AMBER generated 14,279 jobs nationwide.

Employment refers to the total FTEs of CRANN/AMBER between 2007 and 2016. The Type II employment multiplier is the ratio of direct, indirect and induced employment changes to the direct employment change.

Table 1.2 Employment impact of CRANN/AMBER in the input-output approach

<table>
<thead>
<tr>
<th>YEAR</th>
<th>NUMBER OF EMPLOYEES</th>
<th>TYPE II EMPLOYMENT MULTIPLIER</th>
<th>EMPLOYMENT ON IRISH ECONOMIC IMPACT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>60</td>
<td>8.34</td>
<td>500</td>
</tr>
<tr>
<td>2008</td>
<td>60</td>
<td>6.40</td>
<td>381</td>
</tr>
<tr>
<td>2009</td>
<td>65</td>
<td>4.08</td>
<td>381</td>
</tr>
<tr>
<td>2010</td>
<td>107</td>
<td>12.80</td>
<td>1374</td>
</tr>
<tr>
<td>2011</td>
<td>71</td>
<td>11.48</td>
<td>816</td>
</tr>
<tr>
<td>2012</td>
<td>119</td>
<td>11.74</td>
<td>1387</td>
</tr>
<tr>
<td>2013</td>
<td>131</td>
<td>17.17</td>
<td>2298</td>
</tr>
<tr>
<td>2014</td>
<td>137</td>
<td>10.81</td>
<td>1081</td>
</tr>
<tr>
<td>2015</td>
<td>162</td>
<td>19.65</td>
<td>3183</td>
</tr>
<tr>
<td>2016</td>
<td>184</td>
<td>13.66</td>
<td>2513</td>
</tr>
<tr>
<td>Total</td>
<td>1116</td>
<td>12.80</td>
<td>14279</td>
</tr>
</tbody>
</table>

(Current prices, million euro)

For every 1 euro invested, CRANN/AMBER has helped the Irish economy to grow by 5 euro

Ireland is consistently improving in global scientific rankings, and CRANN and AMBER are significant contributors to these rankings. Since the start of AMBER in 2013, the country has risen in the international materials science rankings (by citation) and in 2016, was ranked 1st in Nanoscience and 3rd in Materials Science and Engineering based on Thomson Reuters Incites data.

CRANN and AMBER have had a measurable impact on the international reputation of Ireland in the area of materials science research. We have published over 2,400 research papers from 2007–2016, generating over 76,000 citations (Table 2.1). Many of our publications were in high impact journals and from 2013–2016 alone, we had 4 papers in Science, 47 in Nature journals, 7 in Biomaterials and 7 in the Journal of Controlled Release. Publications in the latter two emphasize the growth in high quality biomaterials and drug delivery research since AMBER was established.

Table 2.1 Numbers of publications and citations by CRANN/AMBER, 2007–2016

<table>
<thead>
<tr>
<th>Year</th>
<th>NO. PUBLICATIONS</th>
<th>CITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>168</td>
<td>1,874</td>
</tr>
<tr>
<td>2008</td>
<td>183</td>
<td>2,622</td>
</tr>
<tr>
<td>2009</td>
<td>198</td>
<td>3,522</td>
</tr>
<tr>
<td>2010</td>
<td>248</td>
<td>4,685</td>
</tr>
<tr>
<td>2011</td>
<td>256</td>
<td>6,281</td>
</tr>
<tr>
<td>2012</td>
<td>302</td>
<td>7,665</td>
</tr>
<tr>
<td>2013</td>
<td>280</td>
<td>9,527</td>
</tr>
<tr>
<td>2014</td>
<td>286</td>
<td>11,581</td>
</tr>
<tr>
<td>2015</td>
<td>267</td>
<td>13,758</td>
</tr>
<tr>
<td>2016</td>
<td>274</td>
<td>14,855</td>
</tr>
<tr>
<td>Total</td>
<td>2,482</td>
<td>76,304</td>
</tr>
</tbody>
</table>

Our high impact publications have included:

- Professor Jonathan Coleman’s Nature Materials publication (2014) on his novel method for producing industrial quantities of high quality graphene by liquid exfoliation. The research led to the technology being transferred to Thomas Swan Ltd. as a royalty bearing license. The exfoliated graphene product is now available on the market under the trade name Elidar® and there are 8 full time staff currently working on the commercialization of 2D materials within the company.

- Professor Graham Cross’s Nature paper (2016) on the self-assembly of graphene ribbons by spontaneous self-healing and peeling from a substrate. This effect holds promise for efficient ways to pattern and assemble graphene, simplifying the production of electronic and other devices in larger volumes.

- Professor Fergal O’Brien’s Biomaterials publication (2016) on the effectiveness of a multi-layered collagen-based biomaterial to direct the body’s own cells to regenerate damaged joints, and successfully treat lesions of the knee in animal studies. This will ultimately benefit patients with damaged knee cartilage.

- Professor Daniel Kelly’s Advanced Healthcare Materials paper (2016) on a process for engineering whole bone organs by innovative 3D bio-printing. The research could ultimately be used to regenerate large defects caused by tumour resections, trauma and infection, as well as inherited bone deformities.

- Professor Ed Lavelle’s publication in Immunology (2016) which provides a new perspective on the design of vaccines. One of the key components in a vaccine is an adjuvant, which serves to enhance our body’s immune response to vaccination. Professor Lavelle and team uncovered the mechanism by which a promising vaccine adjuvant, chitosan, induces an immune response. The discovery provides a roadmap to develop vaccines that trigger ‘cell-mediated immunity’.

- Professor Michael Coey’s publication in Nature Nanotechnology (2016) which could lead to a breakthrough in mass storage of digital data. The team made a new device consisting of a stack of five metal layers, each of them a few nanometers thick, which offers a simpler solution for manufacturing a type of MRAM (Magnetoresistive random-access memory), the main contender for the future of mass storage.

- Professor Stefano Sanvito’s publication in Nature Communications (2016) which demonstrated that in a very high magnetic field an electron with no mass can acquire a mass, the first time anybody ever discovered an object whose mass can be switched on or off by applying an external stimulus. This significant breakthrough in fundamental physics could inspire work in high-energy physics, such as the collision experiments carried out in particle accelerators like CERN.

The Field-Weighted Citation Impact is a measure of how the number of citations an institution has received in a particular discipline relates to the global average. Shown in Table 2.2 is the calculated Field-Weighted Citation for Trinity College (2.00) in comparison to other recognised global leaders in materials science including the top five universities as identified in QS subject rankings (MIT, Stanford, University of California, Berkeley, University of Cambridge and Harvard University). This calculation was based on analysis of Materials Science publications between 2007–2016 using the Elsevier SciVal database. Trinity College Materials science was used as a proxy for AMBER in this analysis as it is the host institution for the Centre and houses approximately 70% of its investigators. As shown, Trinity ranks very favourably with an equivalent citation impact to University of Cambridge, Imperial College London and National University of Singapore.

Table 2.2 Materials Science Field Weighted Citation Impact vs. Number of Citations per publication by Institution including Trinity College Dublin.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Citation Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imperial College London</td>
<td>12.50</td>
</tr>
<tr>
<td>Harvard University</td>
<td>12.50</td>
</tr>
<tr>
<td>University of Cambridge</td>
<td>12.50</td>
</tr>
<tr>
<td>Massachusetts Institute of Technology</td>
<td>12.50</td>
</tr>
<tr>
<td>Imperial College London</td>
<td>12.50</td>
</tr>
<tr>
<td>Stanford University</td>
<td>12.50</td>
</tr>
<tr>
<td>University of California Santa Barbara</td>
<td>12.50</td>
</tr>
<tr>
<td>MIT</td>
<td>12.50</td>
</tr>
<tr>
<td>UC Berkeley</td>
<td>12.50</td>
</tr>
<tr>
<td>Stanford</td>
<td>12.50</td>
</tr>
<tr>
<td>ETH Zurich</td>
<td>12.50</td>
</tr>
<tr>
<td>National College for Materials Science Tsukuba</td>
<td>12.50</td>
</tr>
<tr>
<td>University College London</td>
<td>12.50</td>
</tr>
<tr>
<td>National University of Singapore</td>
<td>12.50</td>
</tr>
</tbody>
</table>

Research citations by CRANN/AMBER compares favourably to the leading Universities in the world for materials science including University of Cambridge, Imperial College London and National University of Singapore.
our engagement with businesses & communities

Methodology
Analysis of the engagement by CRANN and AMBER academics with external organisations was carried out by Professor Brian Lucey and team in Trinity’s Business School to understand the intensity and diversity of our knowledge exchange activities. By knowledge exchange activities, we mean the channels through which academics interact with businesses and the community, including academics’ engagement with private sector, public sector, Technology Transfer Offices within the University, people-based activities e.g. attending conferences and community activities, e.g. visiting schools. We also analysed the types of partners (public and private organisations) with whom our academics worked, the commercialisability of their work, as well as their motivations for engagement and impact on research.

In early December 2016, a survey was sent out to all 56 CRANN/AMBER Investigators who had worked at the Institute over the preceding 10 years. When the survey was closed in February 2017, there were 55 responses in total, of which 42 (75%) were complete. In our analysis below, only the 42 complete responses are considered. This survey was originally designed by Professor Brian Lucey and team in 2014 and used to compare knowledge exchange activities by researchers in commercialisation activities. In all 4 types of commercialisation activities, academics were more closely engaged in knowledge exchange activities (Table 3.1), Problem-solving activities (Table 3.2), Commercialisation activities (Table 3.3) and Community-based activities (Table 3.4). The results show that CRANN/AMBER academics were more closely engaged in knowledge exchange than either Irish or UK academics across 20 of the 26 common exchange activities. In 4 types of commercialisation activities, academics in CRANN/AMBER were far more intensively engaged than other academics from Irish HEIs or the UK. This undoubtedly has been influenced by the SFI Centre remit for motivations for engagement and impact on research.

We have presented the data in 3 sections – Types of Interactions, Types of Partners and Commercialisability of Research and Motivations and Impacts of Interactions.

01_Types of Interactions
Our survey found that CRANN/AMBER academics were involved in a wide range of external interaction activities, from attending conferences and giving invited lectures to joint publications, licencing research and working with public and private sector companies. We have grouped a total of 28 types of knowledge exchange activities into 4 broad categories. People-based activities (Table 3.1), Problem-solving activities (Table 3.2), Commercialisation activities (Table 3.3) and Community-based activities (Table 3.4). The results show that CRANN/AMBER academics were more closely engaged in knowledge exchange than either Irish or UK academics across 20 of the 26 common activities. In all 4 types of commercialisation activities, academics in CRANN/AMBER were far more intensively engaged than other academics from Irish HEIs or the UK. This undoubtedly has been influenced by the SFI Centre remit for engagement by researchers in commercialisation activities.

For example, 45% of CRANN/AMBER academics have taken out a patent compared to 8% of Irish academics and 6% of UK academics.

Examples of CRANN/AMBER patents and licences
- Our collaboration with Merck Millipore on alternative membrane systems for lateral flow diagnostics led to two joint patents. This work will enable new lateral flow assay based products with improved accuracy and sensitivity.
- Thomas Swan & Co. Ltd. took out 2 licences on Professor Jonathan Coleman’s method of exfoliating layered compounds into single-layered 2D sheets e.g. graphene, boron nitride.
- A collaboration between Professor Donagian and Western Digital led to a joint patent on a new optical design for their heat-assisted magnetic recording heads, enabling more efficient data recording.
- Irish SME Bioplastech Ltd. have taken three licences (two patents and know-how) for technology co-developed by Dr. Ramesh Babu and Dr. Kevin O’Connor. These licenses are based on AMBER enabled methods of converting waste plastics into commercial biodegradable polymers.
- Data from a wholly funded project on bioactive collagen-based conduits for peripheral nerve repair, was assigned to Integra LifeSciences, a medical device company specializing in orthopedic, neurosurgery, and reconstructive and general surgery. A patent was subsequently filed by the company with AMBER inventors listed alongside company inventors.
We partner with the best expertise we can find around the globe. As such, we are proud of our association with AMBER. We have found the exchanges to be open, highly intellectual, mutually respectful and of excellent technical and scientific content.

GERARDO BERTERO – SENIOR DIRECTOR AT WESTERN DIGITAL

CRANN/AMBER academics were significantly more engaged in research which had a commercial interest to business and/or industry than Irish or UK academics – 61% compared to 30% and 37% respectively (Table 3.5).

Since 2011, CRANN/AMBER have worked with over 200 companies across collaborative and contract research, European funded projects and Innovation Partnerships. Our industry engagement is diverse ranging from multinationals including Intel, Nokia, Roche, Abbott, Western Digital to SMEs and spin-outs such as Trinity Green Energy, SelfSense and Eblana Photonics.

03. Motivations and impacts of interactions

Academics were asked to indicate the motivation for interaction with external partners and the degree of importance of each motivation using a 1–5 rating scale, with 5 being “very important” and 1 being “very unimportant”. Table 3.7 shows the mean scores of the 12 motivations. The most important motivations for CRANN/AMBER academics were to secure funding for research assistants and equipment and to test the practical application of their research, while the least important motivation was a source of personal income.

Overall academics felt that there were positive impacts on their research performance and teaching from engaging with external activities (Table 3.8). 67% of CRANN/AMBER academics suggested that their involvement with external organisations led to new research projects.

Table 3.5 Academic knowledge exchange in two sectors

<table>
<thead>
<tr>
<th>% OF RESPONDENTS</th>
<th>CRANN/AMBER</th>
<th>IRELAND</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private sector companies</td>
<td>81.0</td>
<td>57.1</td>
<td>30.8</td>
</tr>
<tr>
<td>Public sector companies</td>
<td>69.0</td>
<td>51.7</td>
<td>34.9</td>
</tr>
</tbody>
</table>

Table 3.6 Commercialisability of research

<table>
<thead>
<tr>
<th>% OF RESPONDENTS</th>
<th>CRANN/AMBER</th>
<th>IRELAND</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>It has been applied in a commercial context</td>
<td>29.3</td>
<td>14.3</td>
<td>19.3</td>
</tr>
<tr>
<td>In a general area of commercial interest to business and/or industry</td>
<td>61.0</td>
<td>30.2</td>
<td>37.4</td>
</tr>
<tr>
<td>It has no relevance for external organisations</td>
<td>4.9</td>
<td>9.5</td>
<td>13.7</td>
</tr>
</tbody>
</table>

Table 3.7 Motivations for academic knowledge exchange

<table>
<thead>
<tr>
<th>MEAN SCORE ON A 1-TO-5 SCALE</th>
<th>CRANN/AMBER</th>
<th>IRELAND</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secure funding for researchers and equipment</td>
<td>4.2</td>
<td>3.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Test the practical application of my research</td>
<td>4.4</td>
<td>4.3</td>
<td>3.4</td>
</tr>
<tr>
<td>Gain insights in the area of my own research</td>
<td>4.3</td>
<td>3.6</td>
<td>2.9</td>
</tr>
<tr>
<td>Keep up to date with research external organisations</td>
<td>3.7</td>
<td>3.6</td>
<td>3.4</td>
</tr>
<tr>
<td>Look for business opportunities linked to my own research</td>
<td>3.7</td>
<td>3.2</td>
<td>2.7</td>
</tr>
<tr>
<td>Create student projects and job placement opportunities</td>
<td>3.5</td>
<td>3.4</td>
<td>3.2</td>
</tr>
<tr>
<td>Secure access to specialise equipment, materials or data</td>
<td>3.6</td>
<td>3.4</td>
<td>3.2</td>
</tr>
<tr>
<td>It is a requirement of my research funding</td>
<td>3.5</td>
<td>3.6</td>
<td>3.2</td>
</tr>
<tr>
<td>Further my institution’s outreach activities</td>
<td>3.3</td>
<td>3.4</td>
<td>3.2</td>
</tr>
<tr>
<td>Secure access to the expertise of the external organisation</td>
<td>3.3</td>
<td>3.4</td>
<td>3.2</td>
</tr>
<tr>
<td>Gain knowledge about practical problems useful for teaching</td>
<td>2.9</td>
<td>3.2</td>
<td>3.1</td>
</tr>
<tr>
<td>Source of personal income</td>
<td>2.5</td>
<td>2.4</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Table 3.8 Impact on research and teaching

<table>
<thead>
<tr>
<th>% OF RESPONDENTS</th>
<th>CRANN/AMBER</th>
<th>IRELAND</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Given me new insights for my work</td>
<td>71.4</td>
<td>63.2</td>
<td>75.5</td>
</tr>
<tr>
<td>Led to new research projects</td>
<td>66.7</td>
<td>42.9</td>
<td>65.8</td>
</tr>
<tr>
<td>Strengthened my reputation in the field</td>
<td>57.1</td>
<td>39.6</td>
<td>69.9</td>
</tr>
<tr>
<td>Led to new contacts in the field</td>
<td>64.8</td>
<td>44.9</td>
<td>72.9</td>
</tr>
<tr>
<td>Very little or no impact on my research</td>
<td>3.5</td>
<td>8.7</td>
<td>10.3</td>
</tr>
</tbody>
</table>

TEACHING

<table>
<thead>
<tr>
<th>% OF RESPONDENTS</th>
<th>CRANN/AMBER</th>
<th>IRELAND</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changed in the way I present the material</td>
<td>38.1</td>
<td>41.2</td>
<td>52.6</td>
</tr>
<tr>
<td>Increase in the employability of my students</td>
<td>28.6</td>
<td>22.4</td>
<td>31.8</td>
</tr>
<tr>
<td>Increase in entrepreneurial skills among my students</td>
<td>16.7</td>
<td>11.2</td>
<td>16.7</td>
</tr>
</tbody>
</table>

NOTE: Ranked in descending order for CRANN/AMBER. Numbers in bold indicate the largest value among the three.
transforming our research into impacts

While we have demonstrated scientific excellence through our outputs – rankings in the world, numbers of publications and citations, attendances at conferences – we are committed to transforming these research outputs into impacts. We have selected a number of case studies across our research activity which demonstrates impact across these key areas:

**Economic**

**International Engagement**

**Health & wellbeing**

**Human Capacity**

**Environmental**

What challenge is your research looking to address?

During a heart attack, muscle tissue in the heart becomes damaged due to loss of blood supply. If the person survives – as more and more do, thanks to clinical interventions – the remaining heart muscle needs to work harder. It becomes inflamed and stiffens, and this can lead to heart failure.

Delivering stem cells to the heart is one way to dampen down inflammation and encourage new muscle to form, but at present, as many as 80% of stem cells injected into heart tissue using saline are lost within 24 hours.

Not only does this mean fewer stem cells are there to do the job, but you have also lost 90% of the €45,000 it took to source and prepare those stem cells.**

How are you using material science to help limit heart damage?

I co-ordinate AMCARE (Advanced Materials for Cardiac Regeneration), a €6.8m EU-funded project to develop new ways to deliver stem cells effectively to heart tissue.

Ultimately we want to source a patient’s own stem cells from adipose (fat) tissue and deliver those stem cells efficiently to the patient’s heart tissue, either through catheter injection or directly on a patch.

Once there are sufficient numbers, the stem cells are poised to ‘sandbag’ inflammation, reduce muscle damage, limit scar formation and promote regeneration.

What implications have arisen from the research?

We have developed new, biomaterials-based delivery systems that can retain up to 60% of functional stem cells at the heart, a vast improvement over the current clinical delivery systems where 90% of stem cells are lost over similar time periods.

The AMCARE project has also designed and prototyped functionally different delivery devices to target stem cells to the heart: three separate catheters and a patch that spreads stem cells directly onto the heart’s surface. These delivery devices have been informed by the needs of clinical and industry partners. The work at AMCARE has led to Irish researcher Wili White working on a separate project at Harvard University to assess how multiple doses of stem cells can be effectively delivered to the heart. AMCARE has also generated seven patent applications to date.**

What is your involvement with the partnership between Nokia Bell Labs and CRANN/AMBER?

“I led the research team directly in Ireland until I moved to the US, and continue to be the senior sponsor of the partnership internationally. I review the strategy and technology and I meet the AMBER team when I am back in Ireland.”

How has the collaboration grown?

“We began the collaboration by funding post-doctoral researchers in CRANN, and that has grown to a four-year strategic partnership with AMBER, which started in February 2016. Today we support seven post-doctoral researchers in AMBER and we have hired AMBER researchers into our team.”

What kinds of challenges does the research look to address?

“In general we are working with AMBER to leverage their world leading expertise in materials science and, in particular, 2D materials. One of the biggest limitations we face is how to cool the lasers we use to transmit information on a network. The standard approach to cooling equipment today consumes a lot of energy and space. We collaborate with Professor John Donegan and Professor Jonathan Coleman on new approaches and materials to efficiently transmit information and cool lasers. We also want to develop long-life batteries for small base stations (called small cells), and we are exploring the energy-storage properties of two-dimensional materials with Professor Coleman and Professor Valeria Nicolosi.”

How is the work progressing?

“It is going extremely well. Nokia Bell Labs is a research organisation, and we tend to form long-term partnerships with universities. We set phased targets and the collaboration with AMBER has hit those targets. We are publishing in the highest impact journals (including ACS Nano in 2016) where world experts review the research.”

What kind of impact has the partnership been making beyond the directly supported research?

“As a result of working with AMBER researchers, we become aware of other projects they have ongoing. In the case of Professor Jonathan Coleman, we saw he was developing ‘G-putty’ by combining a polymer with graphene to make a conductive and pliable material. Our team in Dublin has expertise in packing electronics, so through a material transfer agreement with Professor Coleman we took the G-putty, built prototypes around it and put it into wearable form factor.

On a more general note, the strategic partnership between Nokia Bell Labs and AMBER is one of only around 20 strategic partnerships we have with university research institutes globally, but it is the one that our President Marcus Weldon cites as an exemplar of excellent industry and university collaboration. I think for AMBER, for Trinity College Dublin, for Science Foundation Ireland and for Ireland in general, that is a great sign of support and trust in AMBER.”

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**AMBER is currently considered as an exemplar academic collaborator across Bells Labs globally and for good reason. They stand out for their ability to engage with industry while delivering world leading scientific research. In my opinion they are a dream partner and acting as the executive sponsor I plan on growing this collaboration substantially.”**

DOMHNAILL HERNON – HEAD OF INNOVATION INCUBATION AND EXPERIMENTS IN ARTS AND TECHNOLOGY, NOKIA BELL LABS
You are both interested in tissue regeneration research, can you explain?

Professor O’Brien: “We are developing new materials that help the body to heal, or that replace damaged tissues. At the moment if bone or cartilage is damaged by trauma or disease, you may need a graft to repair it. Our approach has been instead to come up with materials that you can implant onto the defect, and that will act as a scaffold to encourage the bone or cartilage to repair itself.”

Professor Kelly: “Work on our lab is looking to address larger areas of damage in the body. We are developing new ways to grow complex structures of cells and tissues outside the body such that they can then be used to replace, say, a damaged knee or hip joint.”

How has the research progressed?

Professor O’Brien: “We have developed a material using the natural components of bone — collagen and hydroxyapatite — that stimulates bone tissue to repair itself. That has gone through clinical trials and is now approved for use in humans. We have also developed a corresponding material to encourage collagen to grow, and one of the highest profile applications to date was in a horse called Beyonce who had damaged knees. Our multi-layered material was implanted into the joints following surgery, where it encouraged new bone and cartilage to grow, and Beyonce returned to competitive showjumping.”

Professor Kelly: “All the post-doctoral researchers who have worked in my lab have gone on to secure faculty positions, and half of the PhD students went on to posts in industry. Myself and Fergal are to host the World Congress of Biomechanics in Dublin in 2018, which is a mark of how well respected Ireland is now in this space.”

How has your research built expertise in the field?

Professor O’Brien: “Of the ‘alumni’ from my lab, 15 are now in faculty positions around the world. And, importantly, one of the post-docs Dr. John Gleeson was the founding CEO of the spin-out company SurgaColl, providing an expert link between the research and the commercialisation.”

What’s next for the research?

Professor O’Brien: “We are continuing to develop and test further generations of implantable materials that can act as functional delivery systems for other agents such as genes.”

Professor Kelly: “We are working towards a biological alternative to a total hip and knee replacement, that is our ultimate goal.”

Why was Merck Millipore initially keen to work with AMBER?

Michael O’Donohoe: “We started engaging with AMBER in 2011. At the time we wanted to gain a deeper understanding of our processes, by characterising them, with a view to optimizing process performance. It made sense to work with AMBER, as the Centre had both the equipment and the expertise in materials science to help us to do that.”

How has the partnership grown?

Mick Morris: “It has developed over the years. Cork is a centre of excellence for membrane manufacturing in Merck, and we started collaborating with AMBER on membrane projects. Then we moved into chromatography media, and more recently we have started discussions with AMBER on future projects in our Biotools analytical devices manufacturing operation. Overall the collaboration has developed eight joint research projects led by Professor Mick Morris, Dr. Ramesh Babu and Dr. Aran Rafferty.”

What kinds of projects has the partnership encouraged?

Mick Morris: “One area of collaboration is on polymer membranes, which are used for filtration or as a platform for diagnostic devices. My group in AMBER has had a successful joint project with Merck to further develop membrane technology of the type used in home-based or point-of-care kits to diagnose medical conditions. Two licenses are now in negotiation, arising from this project.”

The collaboration with AMBER has given Merck Cork access to state of the art analytical infrastructure that has enabled a deeper fundamental characterization understanding of our products which in turn has allowed us to implement additional manufacturing controls to improve product quality.”

Michael O’Donohoe — CCB PROCESS & TECHNOLOGY LEAD, MERCK MILLIPORE

What has AMBER gained from the partnership with Merck?

Mick Morris: “Merck is now AMBER’s largest industry contributor, and the partnership has given us the opportunity to leverage funding from Science Foundation Ireland. We have had six post-docs and three graduate students from AMBER working on the collaborative projects, and their training with Merck in the Cork and Boston facilities has brought expertise back into the research environment in AMBER.”

Alongside the technical expertise, working with Merck has also enabled scientists in AMBER to take fundamental materials research and translate it with Merck towards the commercialisation of products. AMBER scientists have thus built up their expertise in how to scale up and commercialise research.”

What are the benefits to Merck of engaging with AMBER?

Michael O’Donohoe: “Working with AMBER has helped us to better characterise our proprietary processes. That in turn helps us to continue to meet customer needs and to further enhance process yield, efficiency and quality. We have also seen an impact on specific products, including a new membrane reaching full production trials. And, very importantly, AMBER is enabling us to build a technical talent pipeline. Merck has hired a number of AMBER researchers through the course of the collaboration with two former AMBER researchers joining Merck as permanent colleagues.”

AMBER and Merck won the SFI Industry Partnership Award in 2016. What does SFI’s support mean?

Michael O’Donohoe: “SFI support is crucial for many of the collaborations we have with AMBER, and I think this is something that stands out in Ireland. Merck has also benefited from the SFI Fellowship program with two SFI fellows working on projects in Merck. It makes sense to collaborate where State support is available, and it shows that the State sees the benefit of such industry partnerships.”
Trinity Green Energies is an innovation partner with AMBER. How does that work?

“Within AMBER we employ three post-doctoral researchers. The company pays for 30% of the project, and through that we get access to the facilities, analysis techniques and equipment at AMBER.”

What are the benefits for a small company of partnering with AMBER, in your experience?

“As well as having access to the expertise and equipment at AMBER, by linking in to the wider network of AMBER partners we have been able to recruit key staff into the company. The partnership also gives our investors the opportunities to talk to experts in the Centre, and something I think is particularly useful is being able to connect with experts in AMBER and Trinity on commercialisation and intellectual property. This area can be challenging for academics or small companies, so having access to this expertise is a big advantage for Trinity Green Energies.”

How is the carbon-capture work progressing?

“We have validated our chemical compounds in the lab, and we are now working on a prototype that can be deployed in ‘real’ environments to capture carbon dioxide. We hope this will soon result in a demonstration model that capture a tonne of carbon dioxide from the ambient environment.”

Why did Thomas Swan choose to work with AMBER?

“I think the main attraction for working at AMBER and TCD was the opportunity to work with Professor Johnny Coleman. His output is impressive, and he has this ability to do really clever science and demonstrate real applications, particularly in the field of electronic devices.”

What arose from the collaboration?

“Professor Coleman showed at a lab scale that there was a potential way of making graphene from graphite. Thomas Swan has taken that concept and done further process engineering to build out to a scalable route to manufacturing graphene. This is one of the few routes to give pristine graphene platelets with little oxidation and few defects. That means their electrical conductivity and thermal conductivity are maintained. We can now make 20 tonnes per year of pristine graphene platelets using this scaled-up manufacturing route.”

What aspects of the collaboration stood out?

“A big factor in making the collaboration successful was having a Thomas Swan employee embedded in the team in Trinity. It meant for two or three years you have a person in lab who is well linked back to the industrial needs of the company and who provides a communication channel. The other staff members at TCD were also key, and the project management and licensing discussions ran very smoothly.”

How will Thomas Swan take the technology further?

“We are continuing to invest in a graphene and 2D-materials business, and because of the technology that was developed at AMBER we can offer a stable, reliable supply platform from which our customers can build their own products.”

How does the carbon-capture technology work?

“You are a campus company in Trinity, founded in 2014 to develop materials that can capture carbon dioxide. Carbon dioxide levels are rising in the Earth’s atmosphere and we want to use porous materials to remove carbon dioxide from the ambient atmosphere in an energy-efficient manner. Once we have captured the carbon dioxide, we want to turn it into harmless waste, to use it in greenhouses to help grow plants or to capture into fuel.”

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“How does AMBER’s grant helped us? The key is that the iron is encapsulated in a material called whey, which is a protein naturally derived from milk. These protein micropheres are designed to release iron in the small intestine where the body can absorb iron effectively using the metal transporter DMT-1. This is the optimal fate for iron absorption in the intestine, and clinical trials show that the whey-based delivery increases the bioavailability of the iron in the supplement, meaning you can take a lower dose and it is gentler on the stomach and intestine.”

How did your expertise support Solvotrin?

“Professor Healy: “My group started working on iron delivery with Solvotrin when they had a prototype formulation for the supplement, and our research helped to optimise the formulation and manufacturing processes, particularly around whey microparticle encapsulation. This helped Solvotrin to scale up the manufacturing of Active Iron while also maintaining the consistency of the product.”

Where is Active Iron now?

“Professor Healy: “On the shelves! Active Iron launched in 2016 and is available in Boots.”

Are you still working with Solvotrin?

“Professor Healy: “Yes, we are looking at other formulations for iron delivery”

How has working with AMBER had an impact on Solvotrin?

“Mark Ledwidge: “Working with AMBER, Professor Healy and our TCD colleagues has made a huge difference to the success of Solvotrin. Amber was not only a fantastic resource for the scale up and development of Active Iron, but also is a great scientific partner in a world class institution for our ongoing work.”

How does work it?

“Professor Healy: “The key is that the iron is encapsulated in a material called whey, which is a protein naturally derived from milk. These protein micropheres are designed to release iron in the small intestine where the body can absorb iron effectively using the metal transporter DMT-1. This is the optimal fate for iron absorption in the intestine, and clinical trials show that the whey-based delivery increases the bioavailability of the iron in the supplement, meaning you can take a lower dose and it is gentler on the stomach and intestine.”
The development of innovative programmes and resources which stimulate interest amongst school students in STEM (Science, Technology, Engineering and Mathematics) has been a critical part of CRANN and AMBER in the last decade. In addition to inspiring school students to study STEM at third level, we have worked with audiences across many life stages, not just school-age, so that Ireland's general public will recognise that nano and materials science are enabling everyday technologies and driving future innovations.

Our programmes and resources outlined below particularly demonstrate impact across 3 pillars within SFI's impact framework:

**Societal**
Public debate, interest and engagement has been stimulated or informed by research, increased number of young people taking up STEM at 3rd level.

**Policy & Public Services**
School programmes, improvements in delivering science teaching.

**Human Capacity**
Increased uptake of STEM subjects at secondary and university level.

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**2016**

Science LIVE provided interactive online, guided tours of AMBER to primary school classes. 30-40 minute Skype calls facilitated by young researchers brought electron microscopes and the scientists who work with them to classes all over Ireland.

**TEACHER’S COMMENTS:**
"Thanks for the support. Finally, we are seeing tangible interaction with 3rd level institutions that are engaging with primary sector, in a practical and meaningful way."

"I teach 30 5th and 6th class pupils and they thoroughly enjoyed participating in this programme. There was great excitement whenever the microscopes were taken out. Some of the pupils demonstrated their new skills to their parents when they came into our classroom for Open Day. Everyone was very impressed, including the younger pupils who looked on with envy."

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**2015**

EngAGE with Science – This intergenerational learning programme brought together 5th class school students with older learners from St Andrew’s Resource Centre on Pearse Street.

**PARTICIPANTS’ COMMENTS**
"I’ve told my friend about it and lent her the pack, she was very interested." — older female participant.

"I was telling my mam and she didn’t have a clue what nanoscience was about.” — 5th class student.

"It was amazing to look at the microscope images and see a butterfly and a spider at that intensity, I will take that with me for the rest of my life. I’m even telling my 7-year old grandson about it and he’s very interested in science.” — older female participant.

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**2014**

AMBER ran our first 5-day Continuous Professional Development course for primary school teachers. “Magical Materials – nano and materials science in the classroom. The course is Department of Education approved and enables primary school teachers to experience how a world-class research centre operates and bring this excitement through practical learnings back to the classroom.

**TEACHER’S COMMENTS:**
"Mind blowing insight into the world of materials. I’m going away with ideas on how to teach science in the classroom next year.” — Catherine Brodie, Belgrove Senior Girls School, Dublin 3 (July 2014).

"I gave up science after junior cert because it was textbook based and I found it boring. I feel totally inspired now, I feel more equipped to talk about careers in science. I also feel confident about the way I had been teaching scientific thinking and approaches, and now I feel that I have more understanding of the concepts and content. Things I will bring back to my classroom: anecdotes about visiting the various labs and speaking to scientists, scientific journals, making slides and using a microscope, using an iphone as a microscope, design and make ideas, all of Shane’s games and ideas, can’t wait to use the NanoWOW pack.”

— Sorcha Brennan, Glasnevin Educate Together NS (July 2014).

"The excitement of modern cutting edge scientific discovery is cleverly linked to a range of curricular areas. Using a broad range of presenters, various ICT resources, experimentation and cooperative learning, the course is delivered in a very structured, well-paced and stimulating manner.”

— Department of Education inspector (Sept 2014).
AMBER launched NanoWOW in 2013, a resource pack with teachers’ notes, lesson plans, curriculum links, PowerPoint presentations, video links, hands-on activities to enable primary school teachers to bring the excitement of nanoscience to senior cycle primary students. Since then NanoWOW has been requested by over 500 schools throughout Ireland and by teachers internationally including Canada, Sweden, Slovakia, Switzerland, Finland and Germany.

**TEACHER’S COMMENTS**

*An excellent resource. Very well laid out. Appropriate. Unique. By far the best resource provided to me as a class teacher in my 10 years of teaching.* — Pat Buckley, Ayls N.S., Tipperary (Dec. 2013).

“They all look forward to science class – once a week and regularly ask what are we doing next week. Even their parents are talking about it! Fits in well with the Primary School curriculum. Pupils are motivated to learn and it renews their interest in science. Great to see them enjoying the subject so much. Would like to congratulate you on producing a wonderful up-to-date resource that really caught the interest of the children.” — Alex Wilson, Whitechurch NS, Dublin 16 (Nov. 2013).

“It is a new area of study. It explores new and exciting ideas. It shows children that science can be so creative and useful. It has the potential to awaken in them the spirit of enquiry and possibility. I think it can engage them in ways that have resonance with the world they inhabit.” — Mary Egan, St. Mary’s Central N.S., Thurles, Tipperary (Aug. 2014).

2013

2012

CRANN curated Magical Materials, a six-week exhibition with Science Gallery which was their 2nd most popular ever exhibition with over 44,000 visitors. The exhibition featured over 80 innovative displays and gave visitors a chance to see first-hand how research into nanoscience is adding new functionality to existing electronics and medical devices.

2011

CRANN launched Nano in My Life – a new innovative resource pack for secondary science teachers to introduce transition year students to nanoscience. The pack consists of 7 modules, each containing teachers’ notes, PowerPoint presentations, lab and classroom activities e.g. Nano and Health; Nano and IT; Nano and the Environment.

**TEACHER’S COMMENTS**

“They can see the future in science and possibly job opportunities. One of my students has just started Nanoscience in Trinity.” — Diane Condon, Teacher Ardscoil Ris, Limerick (Nov. 2013).

“CRANN... have produced a truly brilliant resource – ideally suited to Transition Year science students. The modules are conceived extremely well, the learning outcomes are clear; concise and attainable, the activities are interactive and relevant, the videos are brilliant produced and perfectly suited to the target audience…” — Humphrey Jones, Science Teacher, St Columba’s College (2011).

2010

CRANN worked with Trinity’s Schools of Physics and Chemistry to launch and market an updated undergraduate degree programme – N-PCAM (Nanoscience – Physics and Chemistry of Advanced Materials). The demand for this course has increased significantly over the last 7 years – in 2010, the entry requirement was 410 points compared to 595 in 2016 with four times as many applicants as there were in 2010.

“I'd like to thank CRANN and especially those in charge of education and outreach since before the launch of the N-PCAM degree in helping the nanoscience brand of CRANN rub off so successfully onto students' perceptions of the N-PCAM degree course that TCD offers… Clearly, it has been CRANN that has effectively established the "Nanoscience" brand in Ireland and associated it with the N-PCAM degree course.” — N-PCAM Course Director, 2013.

In 2010, CRANN also opened up a structured Transition Year (TY) programme, providing 30 places each year over 2 weeks to students throughout the country. Since then, over 200 students have had the chance to spend time in CRANN’s labs and meet researchers and industry collaborators.

**TEACHER’S COMMENTS**

“In my opinion this week has been a fantastic experience. I really learnt a lot about nanoscience, a subject not very well covered in secondary schools. It has opened up my mind to how broad science is and how many possible career paths there are.” — Kate Grealish, Colaiste Iognaid, Galway (Nov. 2014).

“Thank you so much for the wonderful week I experienced in CRANN. The experience was very informative and definitely opened my eyes to the possibility of doing an N-PCAM course in the coming years.” — Fionán D’Onorgua, St Brendan’s College, Killarney (Oct. 2012).

2009

Ireland’s first Nanoweek, a national awareness week around nanotechnology and its impacts for Ireland, was coordinated by NanoNet Ireland, a consortium of industry, academia and government stakeholders. The week featured an academic conference, public talks and schools’ events. Nanoweek was held yearly until 2015.
Over the last decade, our PhDs and postdoctoral researchers have been successful in attaining fulfilling and challenging positions across a range of employment sectors, from academia to industry to public service. Since AMBER commenced, 28% of employment sectors, from academia to industry to public service. Since AMBER commenced, 28%

...
After I was awarded my PhD, I took up a postdoctoral position in Germany and, later, another in Sweden. During this time, I investigated how organic materials interact with surfaces, working alongside some of the leaders of this field. In October 2016, I returned to Trinity’s School of Physics and CRANN with an SFI Starting Investigator Research Grant. Over the next few years, I plan to address the structural and electronic effects of inserting different molecules (intercalants) between the layers of two-dimensional (2D) solids.

My PhD topic was about the reversible modification of magnetic properties in thin films using electric fields. In short, you could change the data stored in a memory element without having to flow a charge current, so one can develop quite low power memory.

When I left CRANN in 2010, I moved to the Paul Scherrer Institute in Villigen, Switzerland and then moved to Dresden, Germany in 2011 where I work as a post-doc. We work on developing nanometer-sized magnets for both digital memory and wireless telecommunications. Because of the facilities available, we are in a unique position to investigate new magnetic materials for the purposes of faster wireless communications, up to several hundreds of GHz! This has led to extremely successful collaborations with several research groups. My career highlight to date is our recently accepted TRANSPIRE project, a 4 year, €4.4 million, collaboration which I co-authored alongside groups in Dresden, AMBER, Switzerland and Norway. It was accepted under the highly competitive FET-Open call of the EU Horizon 2020 programme.

Due to the fact that I was a PhD student when CRANN initially opened, I gained valuable experience in the actual setting up of lab space, as well as the administrative and technical organisation of a research centre. As well as the inter-disciplinary nature of CRANN, this experience allowed me to better forge scientific collaborations, gave focused leadership and dealt with the administrative tasks that I encounter in my current position.

Karen Young
PhD completed in 2012 under the supervision of Professor Jonathan Coleman, Trinity’s School of Physics and CRANN. 

Now a secondary school physics teacher with DePuy Synthes

My research was centred on the development of super strong lightweight composite materials made by combining nanomaterials such as graphene and carbon nanotubes with plastics.

I am currently a secondary school teacher in Loreto College Foxrock and teach Physics, Applied Maths and Science. Over the past two years, I have also written the "Leaping Certificate Physics Experiment Book", which was published last year. Prior to this, I taught in London for two years. While completing my PhD, I also lectured in the Trinity Access Programme for three years. Here, I taught Physics and Maths to students who wished to gain access to University. It was a very rewarding experience and this helped me to make my decision to become a tailor. I also do some part time lecturing in UCD for students who are studying to be science teachers.

My experience working as a research scientist has helped me to develop a set of skills which I use on a daily basis in my classroom. My experience involved designing and executing experiments, analysing data, publishing in peer reviewed journals, collaboration with other research groups and communicating these findings at international conferences. I feel that I can impart all of this knowledge in the classroom, helping students to understand how to design experiments themselves and how best to communicate their findings. I believe that my experience working as a scientist has helped me to enhance the learning experiences of my students.

Tom Fitzgerald
PhD completed in 2008 at Dublin City University.

Now a senior materials engineer with DePuy Synthes

My PhD research was in collaboration with an industrial partner looking at the self-assembly of block copolymers (structured units) to form highly ordered structures on the nanoscale. These structures were used as templates to produce nanosized features (wires and dots) as an alternative to existing photolithography techniques, the standard process used to make computer chips.

I am currently part of the Materials and Surface Technology group at DePuy Synthes. My role involves working on targeted projects evaluating new technologies as well as supporting issues that require additional support CRANN/AMBER. I have been involved in several successful projects with CRANN/AMBER. A project at Merck led to a joint patent application with CRANN/AMBER.

During my time at CRANN/AMBER I held roles as a Researcher-in-Residence for Intel Ireland and in R&D at Merck – both these roles included collaborative projects with CRANN/AMBER. A project at Merck led to a joint patent application with CRANN/AMBER.

Now a secondary materials expert with Intel Components Research

I joined Intel Ireland just after my PhD and started working as Intel’s researcher in residence in CRANN. I joined Intel Components Research division in Oregon, USA as a magnetic materials expert in 2013 and have been responsible for designing a variety of new materials for future technologies.

Working and studying in CRANN enabled me to develop a variety of skills including materials deposition and characterization, device fabrication and testing. The collaboration between CRANN PIs and industry certainly opened the opportunity for me to reach where I am today.

Karen Young
PhD completed in 2012 under the supervision of Professor Jonathan Coleman, Trinity’s School of Physics and CRANN.
our international engagement

Our academics collaborate widely internationally through a variety of research funding mechanisms from one-to-one PI collaborations to European funded programmes and beyond.

European funding

The level of funding secured from European programmes by CRANN and AMBER has increased significantly each year.

From 2007–2013, CRANN PIs were awarded three ERC Starting Investigator awards and were participating in 22 EU projects, valued at €17m.

Since AMBER was established in 2013, the Centre has brought in over €28m in European funding – over €14m from European Research Council (ERC) awards, over €11m from Collaborative projects and €1.8m from Marie Skłodowska Curie awards.

Our ERC awards have generated 47.3 jobs and our Marie Curie awards have enabled 16 Fellowship posts. Our European collaborative projects have enabled us to work with 25 different countries.

From 2013–2016 alone, 56% of AMBER publications have had authors based outside Ireland.

Our ERC awards have been awarded more ERC funding than any other research centre in Ireland and Professor Valeria Nicolosi is Europe’s only 5 time ERC awardee.
Our ERC Awards

The main goal of the ERC is to encourage high quality research in Europe through competitive funding. AMBER investigators have won 11 awards since the Centre was launched, which has provided €7.3 Full Time Equivalent posts (FTEs), 21 Postdoctoral researchers, 23 PhD students, 2 Process Engineers and 13 Administrative staff.

Professor Nicolosi’s 5th ERC award was awarded pre-AMBER in 2017.

Professor John Boland

**Award Type:** Advanced

**Research Topic:** Aims to develop intelligent materials with properties that evolve in response to external stimuli and to create novel easy-to-fabricate devices capable of memory and self-learning.

Jobs Created (FTEs)*: 9.5

Professor Daniel Kelly

**Award Type:** Consolidator

**Research Topic:** Envisions a future where 3D bioprinting systems located in hospitals will provide ‘off-the-shelf’, patient-specific biological implants to treat diseases such as osteoarthritis. This project will use 3D bioprinting to generate anatomically accurate, biomimetic constructs that can be used to regenerate both the cartilage and bone in a diseased joint.

Jobs Created (FTEs)*: 3

Professor Forgal O’Brien

**Award Type:** Proof of Concept

**Research Topic:** Adult articular cartilage has a limited capacity for repair so when damaged it can lead to joint degeneration and ultimately osteoarthritis. This project aims to deliver microRNAs (miRNAs) to stem cells using nanomaterials. The idea of using miRNAs as therapeutics is appealing as they can influence expression or silencing of multiples of genes so is potentially more effective than delivering single genes alone.

Jobs Created (FTEs)*: 1.1

Professor Jonathan Coleman

**Award Type:** Advanced

**Research Topic:** Aims to develop methods to transform large volume suspensions of exfoliated nanosheets into bespoke 2D inks. The ink will be used to print patterned or large area 2D nanosheet networks with controlled structure, allowing us to tune the electrical properties of the network during printing.

Jobs Created (FTEs)*: 7.5

Dr. Micheál Scanlon

**Award Type:** Starting

**Research Topic:** Innovations in solar energy conversion are required to meet humanity’s growing energy demand, while reducing reliance on fossil fuels. Solar energy conversion devices are typically made from inorganic materials and involve high processing costs, occasionally the use of toxic materials and an inability to generate a large and significant source of energy due to manufacturing limitations. This project aims to develop “soft” novel materials self-assembled at liquid-liquid interfaces capable of achieving solar energy conversion without solid electrodes.

Jobs Created (FTEs)*: 5

Professor Aidan McDonald

**Award Type:** Starting

**Research Topic:** The chemical, pharmaceutical, and materials industries rely heavily upon chemicals from oil and natural gas feedstocks that require considerable functionalisation prior to use. This project will take a Nature-inspired approach to design and prepare powerful oxidation catalysts, a potentially sustainable, cheap, and green route to these high-commodity chemicals.

Jobs Created (FTEs)*: 5

Professor Valeria Nicolosi

**Award Type:** Proof of Concept

**Research Topic:** Aims to determine the technical and economic feasibility of using readily scalable technologies for the development of inexpensive and high performance ultra-thin, flexible films of 2D nanosheets for supercapacitors manufacturing for the aerospace and automotive industry.

Jobs Created (FTEs)*: 1.1

Professor Valeria Nicolosi

**Award Type:** Consolidator

**Research Topic:** This project aims to develop micro-energy devices, both supercapacitors and batteries.

Jobs Created (FTEs)*: 5

Professor Fergal O’Brien

**Award Type:** Proof of Concept

**Research Topic:** Aims to determine the technical and economic viability of scaling-up ultra-thin, ink-jet printed films based on liquid-phase exfoliated single atomic layers of a range of nanomaterials. These 2D materials have immediate and far-reaching potential in several high-impact technological applications such as microelectronics, composites and energy harvesting and storage.

Jobs Created (FTEs)*: 1.1

Professor Daniel Kelly

**Award Type:** Consolidator

**Research Topic:** Addresses the question of how novel, bio-inspired metallo-supramolecular systems can be prepared and exploited for sustainable energy applications. The efficient conversion of light into chemical energy would be one of the greatest scientific achievements with unprecedented impact for future generations.

Jobs Created (FTEs)*: 6

Professor Wolfgang Schmitt

**Award Type:** Consolidator

**Research Topic:** Envisions a future where 3D bioprinting systems located in hospitals will provide ‘off-the-shelf’, patient-specific biological implants to treat diseases such as osteoarthritis. This project aims to deliver microRNAs (miRNAs) to stem cells using nanomaterials. The idea of using miRNAs as therapeutics is appealing as they can influence expression or silencing of multiples of genes so is potentially more effective than delivering single genes alone.

Jobs Created (FTEs)*: 5

Professor John Boland

**Award Type:** Advanced

**Research Topic:** Aims to develop intelligent materials with properties that evolve in response to external stimuli and to create novel easy-to-fabricate devices capable of memory and self-learning.

Jobs Created (FTEs)*: 9.5

Professor Daniel Kelly

**Award Type:** Consolidator

**Research Topic:** Envisions a future where 3D bioprinting systems located in hospitals will provide ‘off-the-shelf’, patient-specific biological implants to treat diseases such as osteoarthritis. This project aims to deliver microRNAs (miRNAs) to stem cells using nanomaterials. The idea of using miRNAs as therapeutics is appealing as they can influence expression or silencing of multiples of genes so is potentially more effective than delivering single genes alone.

Jobs Created (FTEs)*: 6

Professor Forgal O’Brien

**Award Type:** Proof of Concept

**Research Topic:** Adult articular cartilage has a limited capacity for repair so when damaged it can lead to joint degeneration and ultimately osteoarthritis. This project aims to deliver microRNAs (miRNAs) to stem cells using nanomaterials. The idea of using miRNAs as therapeutics is appealing as they can influence expression or silencing of multiples of genes so is potentially more effective than delivering single genes alone.

Jobs Created (FTEs)*: 1.1

Professor Jonathan Coleman

**Award Type:** Advanced

**Research Topic:** Aims to develop methods to transform large volume suspensions of exfoliated nanosheets into bespoke 2D inks. The ink will be used to print patterned or large area 2D nanosheet networks with controlled structure, allowing us to tune the electrical properties of the network during printing.

Jobs Created (FTEs)*: 7.5

Dr. Micheál Scanlon

**Award Type:** Starting

**Research Topic:** Innovations in solar energy conversion are required to meet humanity’s growing energy demand, while reducing reliance on fossil fuels. Solar energy conversion devices are typically made from inorganic materials and involve high processing costs, occasionally the use of toxic materials and an inability to generate a large and significant source of energy due to manufacturing limitations. This project aims to develop “soft” novel materials self-assembled at liquid-liquid interfaces capable of achieving solar energy conversion without solid electrodes.

Jobs Created (FTEs)*: 5

Professor Aidan McDonald

**Award Type:** Starting

**Research Topic:** The chemical, pharmaceutical, and materials industries rely heavily upon chemicals from oil and natural gas feedstocks that require considerable functionalisation prior to use. This project will take a Nature-inspired approach to design and prepare powerful oxidation catalysts, a potentially sustainable, cheap, and green route to these high-commodity chemicals.

Jobs Created (FTEs)*: 5

*Includes PhDs, post-docs, technical and administrative posts.
Collaborative Projects:

**The Graphene Flagship**

The Graphene Flagship was launched by the European Union in 2013. With a budget of €1 billion it represents a new form of joint, coordinated research initiative on an unprecedented scale. The overall goal of the Graphene Flagship is to take graphene from academic laboratories into European society, facilitating economic growth and creating new jobs, in the space of ten years. It is a combined academic-industrial consortium consisting of more than 150 partners in over 20 European countries. Professors Jonathan Coleman and Georg Duesberg from AMBER are both part of the consortium. Funding provided to both by the Flagship has totalled €1,320,043 (to end March 2017), employing 2 postgraduate students and 1 research fellow. This will expand to 5 postgraduate students, 2 research fellows and 1 technical support, with a further €180k in funding due in 2018.

**TRANSPIRE**

In 2016, an AMBER led consortium was awarded €4.4 million under the European-funded “Future and Emerging Technologies – Open” (FET Open) programme. They are the first group in Ireland to coordinate such a project, from the most competitive science funding programme in the EU. FET Open funds visionary research and innovation for radically new future technologies, at an early stage, when there are few researchers working in a field. AMBER’s share of the €4.4m was €1.7m. The funding was awarded to the TRANSPIRE project, which is led by Professor Plamen Stamenov, AMBER and involves collaborators in Germany, Norway and Switzerland. TRANSPIRE (Terahertz RAdio communication using high aNisotropic SPIn torque RESonators) will develop a new class of magnetic materials which should enable new and exciting terahertz (1000 gigahertz) technologies, which could underpin the next wave of the Big Data revolution. Personal and substance security screening, medical spectrometry and imaging, geophysical and atmospheric research and the Internet of Things will all benefit from ultra-fast data transfer.

**Royal Society University Research Fellowships**

The Royal Society Research Fellowship scheme is for outstanding early career scientists across life and physical sciences in the UK and Ireland. Just 45 fellowships were awarded in 2016. Successful candidates in Ireland are funded by Science Foundation Ireland. Professor Aidan McDonald, AMBER and Trinity’s School of Chemistry, was awarded a fellowship in 2016, valued at €735,000, which will enable him to progress his work on understanding metal-containing enzymes that play a pivotal role in human health. This fellowship adds to Aidan’s ERC starting grant, awarded in 2015.

**Dr. Richard Hobbs** was awarded a Royal Society Fellowship in 2016 that will provide him with €560,000 over 5 years allowing him to start his independent research career in the areas of nanofabrication and nanochemistry.

**Marie Curie**

Dr. Cathal Kearney, originally a Dublin native, completed a PhD (Massachusetts Institute of Technology, Boston) and Postdoc (Harvard University, Boston) in the USA before returning to RCSI and AMBER as a Senior Research Fellow in 2014. In 2015, he was awarded a Marie Curie Reintegration Fellowship, which has enabled him to combine techniques learnt in the USA for delivering drugs locally within the body at precise times with expertise at RCSI on collagen-based biomaterials. These collagen-based biomaterials can be used to provide a “scaffold” for cells to grow new tissue on and, functionally these scaffolds with carefully timed drug delivery allows doctors and researchers to orchestrate cell behaviour(s). These novel medical devices are initially being developed to heal diabetic wounds but the research should be applicable to growing many different tissues. The Marie Curie fellowship has enabled him to attend international conferences in the UK and the US, and, as part of the Marie Curie he acquired additional short term travel fellowship funding (European Foundation for the Study of Diabetes) to undertake research at Tufts University (Boston, USA), where he learnt to work with patient-derived stem cells. The ultimate success of the Marie Curie for Dr. Kearney is that it led to him acquiring a permanent Lecturer position at RCSI, which begins at the conclusion of the fellowship in April 2017.

**Non-European funding**

**AMBER has a small but growing engagement with institutions and funding agencies outside of the European Union, currently comprising 5% of our total funding.**

**US Ireland R&D Partnership Programme**

Professor Daniel Kelly from AMBER was part of a €1 million project funded from 2013-2016 under this programme which is facilitated by the National Science Foundation (NSF) and National Institutes of Health (NIH) in the US and Science Foundation Ireland. The project aimed to develop a biomaterial to repair damaged ligaments, with a particular focus on regenerating the complex interface between the ligament and bone. The project brought together 5 different research groups (Professors Tammy Haut Donahue and Ketul Popat, Colorado State University; Professors Nicholas Dunne and Helen McCarthy Queen’s University Belfast; Professor Daniel Kelly, Trinity College Dublin), and to date has resulted in 4 collaborative journal papers. Professor Kelly’s lab received €250,000.

AMBER received a Centre-to-Centre Award under the US-Ireland Research and Development Partnership programme in 2016. AMBER will collaborate with the NSF Engineering Research Centre, Translational Applications of Nanoscale Multiferroic Systems (RANMS), and the Centre for Nanostructured Media (CNM) at Queen’s University Belfast (QUB) on the project, Ultra-Low Energy Electric Field Control of Nonvolatile Magnetoelastic Memory Devices. This collaboration aims to develop materials which can be used to manufacture high performance memory cells. Science Foundation Ireland is investing €800,000 into this collaboration over the course of 36 months.

**National Institutes of Health (NIH)**

Professor Anne Marie Healy AMBER, and Head of the School of Pharmacy and Pharmaceutical Sciences at Trinity is a collaborator in NIH-funded programmes worth €8.8million. NIH is one of the world’s foremost medical research centres based in the United States. Anammarie was awarded €600,000 in research funding in 2016 to develop an innovative new dry powder inhaler for the treatment of lung disease. It could help millions of patients with cystic fibrosis, asthma and chronic obstructive pulmonary disease (COPD).

**International Networking**

As the only 5 time European Research Council (ERC) awardee in Europe, Professor Valeria Nicolosi has had numerous high profile engagements politically in Europe. In November 2016, Professor Valeria Nicolosi presented her work to the European Parliament Committee on Industry, Research, Telecoms and Energy in Brussels. Prior to that she spoke to the general Parliament.

From left to right: The European Commission Vice-President, Jyrki Katainen, responsible for Jobs, Growth, Investment and Competitiveness (May 2015); Professor Valeria Nicolosi with Professor Jean Pierre Bourgignon, ERC President; Professor Mick Morris in discussion with NSF Director France Cordova and Professor Mark Ferguson, Director General of SFI.
concluding remarks

The measure of a centre is that its impact is ‘more than the sum of its parts’. There is no doubt that this has been achieved through the foundation of CRANN and its successor AMBER. Through centre funding we have created a strong core team to support our researchers, established world-class infrastructure to compete with internationally leading centres, attracted world class junior and established researchers, elevated the ability to compete for funding nationally and internationally as well as enhancing the scientific reputation of the country. Importantly, we have made major economic contributions to the country through innovation led research programmes. These include creating spin-out companies, enabling SME growth, carrying out highly successful medium and long-term collaborative research programmes with multinationals based here and abroad. Moreover, the centre has made a considerable economic contribution to the country in terms of employment and investment.

The last 10 years has seen a remarkable development in Ireland’s reputation as a global leader for materials science research. CRANN followed by AMBER have been at the focal point of this progression. Today, the AMBER centre is a true national centre, spanning 6 Universities, engaging in collaborative research with 36 companies and international engagements across 25 countries. The investment in state of the art infrastructure coupled to the international reputation of our researchers has underpinned this success allowing the Centre to compete for research investment with global leaders such as Cambridge and Stanford Universities. Throughout this report we have provided examples of how CRANN and AMBER have impacted the Irish economy and broader society through for example our research across health, ICT and the environment. Our analysis has indicated that our PIs have a higher than average level of participation in commercialisation (through taking out patents and licensing research outputs) and industry collaboration activities as well as people based activities such as giving invited lectures, compared to previously published data on Irish and UK academics.

Our research program spans multiple areas of societal impact from developing materials for improved treatment of cardiac disease and diabetes to novel materials for carbon dioxide capture and storage. Many of our engagements with foreign based multinationals companies have led to an expanded local mandate for R&D activities bringing with it increased investment and high value jobs. Finally over the past 10 years we have been active in the education and training of the next generation of scientists through our primary and secondary school programs and through supporting the careers of our postgraduate and postdoctoral researchers.

As we look forward to the next decade, our ambition is to grow by building on what has been a remarkably successful foundation. We are at an exciting time in our research program where we see the translation of some of our early stage research towards pre-commercialisation and clinical trials where we are poised to make increased economic and societal impacts. We will continue to foster new talent to enable the next generation of Irish researchers and provide a pipeline of highly skilled researchers for academia and industry. We will continue to work with partner companies to develop a research led economy that will anchor, grow and attract companies and we will continue to use our research to innovate new technologies and products. We are well positioned to become internationally respected thought leaders in materials science and use our expertise to address societally important Grand Challenges. Finally, we will engage with our stakeholders, business and policy makers to develop AMBER into the leading, industry informed, materials research centre internationally.
industry testimonials

**Ascenix Biotechnologies**

"My interaction with AMBER has been a valuable partner in the execution of the Glanbia R&D strategy. We especially value the ease of engagement and the proactive and creative approach of the AMBER team."

**Glantrao**

"Glantrao is committed to expanding our co-operation with the AMBER centre. We currently have one active project with the centre through UCC and see multiple opportunities for us to work together on future projects. Our company is innovation driven and working with the AMBER team gives us access to the expertise and facilities needed for developing new technologies and products."

**DePuy**

"AMBER researchers are working with DePuy Ireland to support their R&D programmes on materials and process technologies for existing and future orthopaedic devices. Orthopaedic implants, such as hip and knee systems, make a dramatic contribution to the quality of life for millions of patients globally. The materials and coatings used in and on these devices are critical in delivering clinical benefit and improving patient outcomes. DePuy Ireland’s collaboration with AMBER continues to grow and provides DePuy Ireland with access to the Centre’s wide range of expertise and facilities. Alongside technical advances, the collaboration has also provided the opportunity for a number of AMBER researchers to continue their R&D careers at DePuy Ireland post their studies."

**Emeron**

"AMBER has been a valuable partner in the execution of the Glanbia R&D strategy. We especially value the ease of engagement and the proactive and creative approach of the AMBER team."

**Henkel**

"Henkel has worked with AMBER researcher Professor Yumi Gun’Ho in the past and have been actively looking at opportunities for collaboration recently in multiple areas, particularly in the development of novel materials for 3D printing. We see significant overlap in the expertise at AMBER and in what our company is doing in Ireland and our plans for future research and development. We look at AMBER as a potential strategic partner and hope to further develop our relationship with the centre in the future."

**Integra**

"AMBER researchers are working with DePuy Ireland to support their R&D programmes on materials and process technologies for existing and future orthopaedic devices. Orthopaedic implants, such as hip and knee systems, make a dramatic contribution to the quality of life for millions of patients globally. The materials and coatings used in and on these devices are critical in delivering clinical benefit and improving patient outcomes. DePuy Ireland’s collaboration with AMBER continues to grow and provides DePuy Ireland with access to the Centre’s wide range of expertise and facilities. Alongside technical advances, the collaboration has also provided the opportunity for a number of AMBER researchers to continue their R&D careers at DePuy Ireland post their studies."

**Sigmoxic**

"Sigmoxic’s national and international reputation as a leading research-based, innovative company is greatly increased through a number of project outputs: publication in scientific papers, presentations at national and international conferences and intellectual property strengthening. The interaction between the R&D teams of Sigmoxic and Trinity College Dublin has been very fruitful. It helped expand the knowledge-base of the Sigmoxic research team in this field of research but also contributed to inform formulation development in-house. The project management, out-reach and engagement with the team leaders at AMBER is exceptional. Likewise, the dedication and openness to ideas and developing concepts, both basic and applied is world-class."

**Solvotrin**

"Solvotrin build value by translating both basic and applied science into a practical, value-added product."

**Trinity Green Energy Ltd**

"TGE was able to attract and recruit the world class academic talent needed for the Trinity Green Energy project because of AMBER. Their people and reputation is the beacon that attracts the best international scientific talent and this allows business to get the best possible commercial result."

**Henkel**

"Henkel has worked with AMBER researcher Professor Yumi Gun’Ho in the past and have been actively looking at opportunities for collaboration recently in multiple areas, particularly in the development of novel materials for 3D printing. We see significant overlap in the expertise at AMBER and in what our company is doing in Ireland and our plans for future research and development. We look at AMBER as a potential strategic partner and hope to further develop our relationship with the centre in the future."

**Adama Innovations**

"This kind of niche, targeted program worked very well for Adama Innovations, and allowed a very small start-up to mature its technology and explore further markets. We would not have had the resources to devote to these R&D efforts, which are of longer term strategic value to the company, without the AMBER program."

**Sigmoid**

"Sigmoid’s national and international reputation as a leading research-based, innovative company is greatly increased through a number of project outputs: publication in scientific papers, presentations at national and international conferences and intellectual property strengthening. The interaction between the R&D teams of Sigmoxic and Trinity College Dublin has been very fruitful. It helped expand the knowledge-base of the Sigmoxic research team in this field of research but also contributed to inform formulation development in-house. The project management, out-reach and engagement with the team leaders at AMBER is exceptional. Likewise, the dedication and openness to ideas and developing concepts, both basic and applied is world-class."

**CRANN/AMBER IMPACT ASSESSMENT REPORT 2007-16**

"AMBER is a meeting point of science, research and commercialization. With its infrastructure, expertise and culture, AMBER has helped Solvotrin build value by translating both basic and applied science into a practical, value-added product."
## Associated Investigators 2007—2016

<table>
<thead>
<tr>
<th>Name</th>
<th>Department/Institution</th>
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<tbody>
<tr>
<td>Dr. Ramesh Babu</td>
<td>Physics, Trinity College Dublin</td>
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<td>Dr. Shane Bergin</td>
<td>Physics, Trinity College Dublin</td>
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<td>Professor Werner Blau</td>
<td>Physics, Trinity College Dublin</td>
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<td>Professor John Boland</td>
<td>Physics, Trinity College Dublin</td>
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<td>Professor Louise Bradley</td>
<td>Physics, Trinity College Dublin</td>
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<td>Dr. Conor Buckley</td>
<td>Bioengineering, Trinity College Dublin</td>
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<td>Professor Mike Coey</td>
<td>Physics, Trinity College Dublin</td>
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<td>Professor William Coffey</td>
<td>Physics, Trinity College Dublin</td>
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<td>Professor Paula Colavita</td>
<td>Chemistry, Trinity College Dublin</td>
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<td>Professor Jonathan Coleman</td>
<td>Chemistry, Trinity College Dublin</td>
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<td>Professor Graham Cross</td>
<td>Physics, Trinity College Dublin</td>
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<td>Dr. Stephen Daniels</td>
<td>Engineering, Trinity College Dublin</td>
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<td>Professor John Dinegan</td>
<td>Chemistry, Trinity College Dublin</td>
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<td>Professor Sylvia Draper</td>
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<td>Professor Georg Duesberg</td>
<td>Physics, Trinity College Dublin</td>
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<td>Dr. Garry Duffy</td>
<td>Electronic Engineering, Dublin City University</td>
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<td>Dr. Rachel Evans</td>
<td>Physics, Trinity College Dublin</td>
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<td>Professor Mauro Ferreira</td>
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<td>Professor Yuri Guthro</td>
<td>Mathematics &amp; Statistics, University of Limerick</td>
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<td>Professor Thorfinnur Gunnlaugsson</td>
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<td>Professor Justin Holmes</td>
<td>Chemistry, University College Cork</td>
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<td>Professor Greg Hughes</td>
<td>Physical Sciences, Dublin City University</td>
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<td>Professor Paul Hurley</td>
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<td>Dr. Adriele Prina Mello</td>
<td>Biomedical Science, University College Dublin</td>
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<td>Professor Marek Radomski</td>
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