

Beyond Classical Nanoscience

Cozzarelli prize winner Professor Kenneth Dawson speaks to Claire O'Connell (BSc 1992, PhD 1998) about new developments in Bionanointeractions.

There can be little as exciting in science as exploring a brand new area of research. And that's exactly where a group of UCD scientists find themselves, looking at how tiny nanoparticles, only a hundred millionths of millimetres in size, interact with living material.

By figuring out how to get nanoparticles inside living cells, the team at the NanoBio Institute hope to enable new ways of delivering therapeutic drugs to currently hard-to-reach parts of the human body, and thereby challenge conditions like cancer, viral infections and neurodegenerative diseases.

They can also immediately support efforts to ensure that nanotechnology is implemented safely throughout the world, says Professor Kenneth Dawson, who directs NanoBio at UCD.

Professor Dawson also leads the BioNanoInteract Strategic Research Cluster, which integrates scientists from UCD, TCD, UCC, UL, NUIM, DIT, and UU and industry partners such as Intel, Biotrin, ThermoFisher, DePuy, Deerac Fluidics, Cellix and Glantreo.

With funding of €7.2 million from Science Foundation Ireland, the cluster is now examining the complex questions of how nanoscale materials interact with living materials, like cells in the body.

The route to pioneering studies in "bionanointeractions" has taken Professor Dawson around the world and into scientific disciplines beyond his initial specialism of physical chemistry.

Born in Antrim, he studied chemistry and mathematics at Queen's University Belfast, but even then he was keen to widen his scope and took an active interest in philosophy and politics.

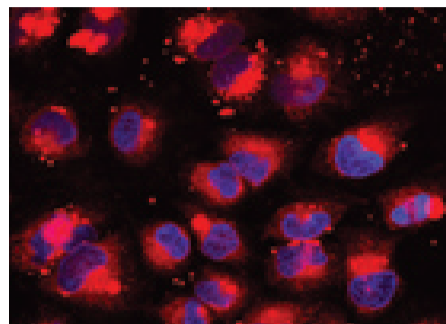
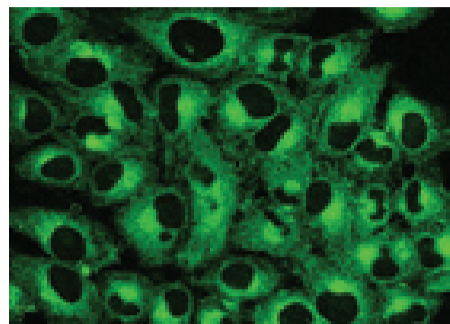
While completing his D.Phil. at Oxford University on the structures that hold molecules together, he was elected a Weir fellow and rubbed shoulders with great minds from other disciplines such as philosophy and history.

"It was a really interesting environment, Oxford, because I was still able to pursue those other interests," he recalls. "And it was a real eye-opener to see the similarity between scientific and non-scientific minds. If you meet someone who is truly brilliant then there's very little difference between scientists and non-scientists."

After Oxford he moved to the United States and worked in the stimulating environments of Cornell and UC Berkeley, developing an interest in the emerging field of complex matter and how objects assemble.

"We looked at 'complex things' like liquid crystals for watches, drug delivery systems, and tried to find some sort of simplicity in those things, to capture rules, capture understanding," he explains.

When President Mary Robinson visited Berkeley, the university asked Professor Dawson to accompany her around campus, and they got talking about home. "I had been out of touch for a while with what was happening in Ireland," he recalls. "Her view at the time was about the candle in the window and homecomers, and I was really taken with it. I thought I could do more now in Ireland than in the Ireland I grew up in. And of course she was right."



A confocal microscope image of cells exposed to polystyrene nanoparticles. The green colour in image 1 and the red colour in image 2 are the nuclei of the cells stained with a dye that colours only the nucleus. The nanoparticles are not visible directly due to their size, they are only 40 nanometres in size. However by inserting a special fluorescent dye inside the nanoparticles, you can see the light they emit. In this image you can see the combined fluorescence of many millions of nanoparticles inside the cell. (1 nanometre is a millionth of a millimetre)

Further prompting by UCD's then president Dr Paddy Masterson convinced Professor Dawson to apply for the chair of physical chemistry and he took up the post in Belfield in 1992.

By then Professor Dawson was interested in how complex matter interacts with living material, and he worked on getting colloids, or suspensions of small particles with DNA inside them, inside cells. "I was beginning to ask the questions why do they go in or not go in," he says. "We learned to set the standards of physical science for biological research to far beyond what was then felt necessary, and we also learned to work well across into the world of biology."

But in practice, the experiments were frustratingly inconclusive, and Professor Dawson describes it as a depressing time. "We had a really good team, it's just that people viewed it very naively, and we made a lot of mistakes. If there's one thing I would emphasise from that period of life it's how many things we tried and how many failed. While we had a very enlightened EU programme manager who considered the work to be pioneering, I worried about the lack of practical progress."

But Professor Dawson now realises the apparent failures of that dark time taught him much along the way. As well as forging links with leading scientists around the world, his experiments with colloids fostered a deeper understanding of how cells interact with small particles.

So when people began to tout nanoparticles as a route to deliver drugs to cells, he realised he had long been asking some of the same questions. "It became clear that nanoscience was going to be the enabler," he says, explaining that at the nanoscale, the properties of materials can alter quite dramatically: "At that level everything changes and the surfaces of the particle become quite different from flat surfaces."

And now as medical research tries to harness nanoparticles to deliver therapeutic drugs into previously inaccessible parts of cells, Professor Dawson is in a position to take a wide-angle view beyond classical nanoscience. In particular, he is interested in looking at what happens to nanoparticles in real-life environments as they enter the body and are surrounded by thousands of proteins.

One of the main hypotheses his team is investigating is that when it is inside the body a nanoparticle does not remain bare, instead it draws onto itself a coating or "corona" of different proteins. It is this outer cloak that interacts with the cell, he argues, and understanding the dynamics of this outer

coating is key to encouraging the cell to internalise and interact with the nanoparticle.

This is a big departure from how chemists and physicists who are interested in information-technology applications look at nanoscience, and it involves working in much more complex situations, explains Professor Dawson.

And it's not just theory. To demonstrate, he plays a video on his laptop of nanoparticles that his team successfully targeted right into the nucleolus, at the heart of a cell. After the disappointments of previous years, he describes seeing that result as a "canonical moment".

"This is so exciting because it makes contact with what I have been trying to do for years, to find the fundamental principles that govern what is happening in very complex systems that will have relevance in everyday life," says Professor Dawson.

He's not alone in that sentiment. So profound is their contribution to the field that the prestigious National Academy of Sciences in the US awarded Professor Dawson's UCD team and their collaborators in Sweden the 2007 Cozzarelli Prize in physical sciences for a paper on understanding the nanoparticle-protein corona.

The researchers are continuing to work out how a particle's size and environment affect the corona, and how the corona changes over time. Understanding these behaviours could have a revolutionary effect on how we treat disease, according to Professor Dawson, allowing drugs to be targeted through engineered nanoparticles into parts of the body that were previously out of bounds.

"This is a sort of turning point," he says. "These are the processes the cells use. We are just getting in by harnessing them because that's how cells work and nature deals with things in the body. We are just learning how to create our things as part of the body's system and we are probing how it all works. This will have a lasting effect on nanomedicine."

Claire O'Connell (BSc 1992, PhD 1998) is a freelance journalist.



Professor Kenneth Dawson

