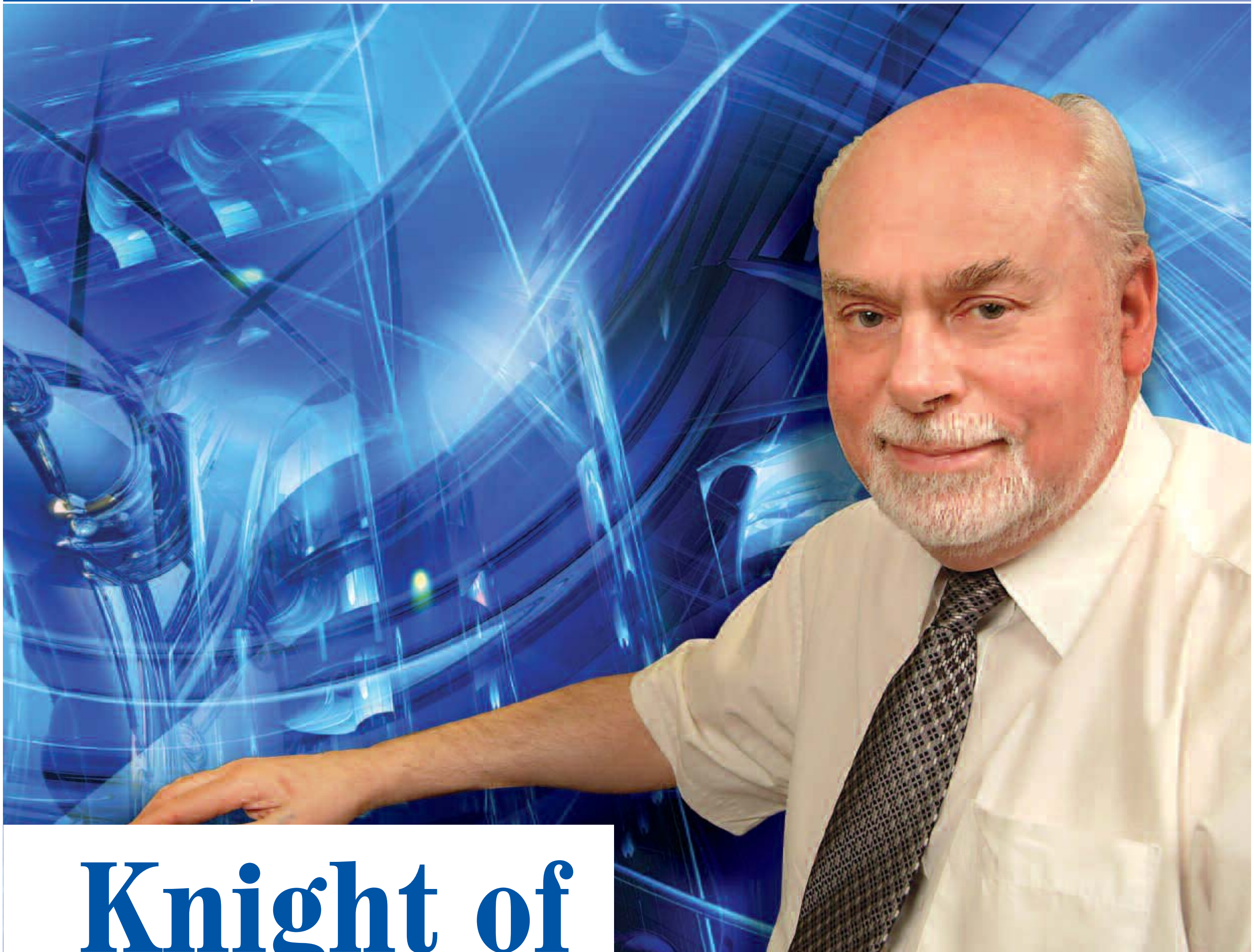


Knight of the Nano-realm

As he prepares to receive his Knighthood, Ottilia Saxl asks Sir Fraser Stoddart, Director of the California NanoSystems Institute about his Eureka moment, why making molecules is like playing with Lego, and what still gets him up at 5am!

What do you think is the greatest challenge for nanotechnology today?
The need is to tackle BIG problems. As a director of the California NanoSystems Institute, I say: "Let's try to achieve everything we possibly can within the bounds of our talent base." We try to model ourselves on Leonardo da Vinci – one minute designing helicopters, the next minute painting the Mona Lisa.

There is a revolution going on in science and technology, the likes of which we have not seen in 500 years. Everyone is being challenged in this age opened up by IT, with information being moved around our planet in milliseconds. As I say, the need is to tackle BIG problems. This challenge requires a broad educational system, producing young researchers who are able to reach out beyond their own knowledge base and become team players. Only by bringing this kind of synergy to bear on BIG problems can the challenges in nanotechnology today be met.

What's your strategy for success at CNSI?
I am fortunate to run a research group filled with some of the brightest young minds in the world – 35 of them, to be precise. I give them a lot of freedom, and encourage them to come up with their own ideas - within certain boundaries, of course.

In such a privileged situation, I can afford to lead from behind, because my students are, by and large, productive, motivated and inventive - I have always resisted telling my students what to do but I rather see myself as their supporter and enabler.

'I told my group - we are the entrance to a gold mine - come back tomorrow morning with 39 new ideas… they often did.'

My philosophy has, to a large extent, been fashioned by the discrimination against young people that I met at the beginning of my academic career: it made my life at the time miserable and I resolved that, when the time came, I would treat young people with respect and courtesy. I challenge them in a positive way to greater and greater achievement, and it is amazing just how much a very talented individual can do.

In the US, young researchers are looked up to and revered if they are successful. They become the role models for others, and often I find their talents stretch far beyond academia - into sport, art and music, which makes it even more fun.

My job as director is one of trying to provide a first class environment for my colleagues to thrive within. I fight night and day to create opportunities for others at all levels – and I just hope that some of my efforts will be fruitful in the fullness of time.

What has been your most exciting achievement?
I had some highly memorable times when I left Sheffield University in 1978 to go on a three-year secondment to the ICI Corporate Laboratory in Runcorn. At that time, the Science Research Council had come up with a highly visionary program that allowed scientists in academe and industry to cross each others' boundaries.

I spent three years (1978-81) at ICI at a time when the Corporate Laboratory was at the height of its achievements. Many of the most able scientists in the UK were in Runcorn at that time: it was the place to do out-of-the-box things. All of what I have subsequently achieved as a scientist can be traced back in large measure to those three years! It is ironic, for I had been driven out of the Sheffield chemistry department by the turf wars that were being waged there at the time. Sometimes in life, good things rise out of adversity.

At ICI, I met up with Howard Colquhoun (now at Reading University) and we effectively worked out together the molecular basis for all the research that I subsequently pursued using the mechanical bond in chemistry. Our research, which was aided and abetted by studying the molecular recognition properties of the herbicides Diquat and Paraquat, was eventually, years later, to lead the template directed synthesis of compounds called catenanes (interlocked rings) and rotaxanes (rings on a dumbbell). It was all incredibly exciting at the time and much of the structural basis for the work was established in collaboration with X-ray crystallographer David Williams at Imperial College London.

Research on the rotaxanes led to our making of a "molecular shuttle". The work was published in the Journal of the American Chemical Society in 1991. It anticipated the subsequent development of linear molecular motors powered by chemicals, electricity and light. Research on the catenanes led to a bistable version, which was subsequently to become the basis for a one nanometre cube switch in a molecular memory device.

It was a unique time for my research group in the late 80s and early 90s. I used to say to the members of my group, "We are at the entrance to a gold mine", and I would challenge them with statements, like, "Come back to me tomorrow morning with 39 new ideas." They often did! The kind of chemistry that uses the mechanical bond appeals to the kind of minds that play with Lego and enjoy solving three dimensional puzzles. Work is just like playing with toys!

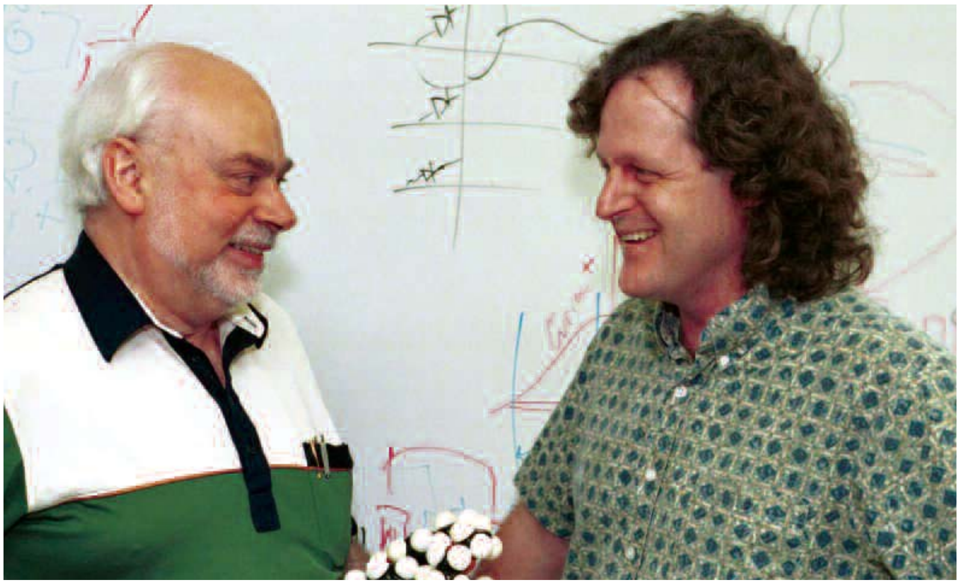
What made you leave the UK for the US?
I made the move, partly for professional and partly for personal reasons. I came to the US on 1st July 1997 – and my lab was up and running four days later, the day after Independence Day. I'd had a marvellous time in Birmingham - the university was incredibly supportive of chemistry - a total of approximately £10 million was spent during the 1990s on renovating the chemistry department before I left. This investment marked the beginning of a turnaround in infrastructure for chemistry in UK universities, and many others followed Birmingham's example.

On 19th February 1992, two days after I had given my inaugural lecture at Birmingham, my wife suffered a brain haemorrhage. She recovered slowly only to discover in the August of that year that she had cancer of the breast. In the UK by 1997, the prognosis was not good. But when we moved to the US, the UCLA Medical Center transformed her situation overnight. She was no longer considered to be someone who was on her deathbed: her cancer was described as a "chronic disease", for which oncologists could offer at least 50 different ways of treating. Our move to the States gave her another five years: she was able for most of that time to work in support of my research group and also to accompany me on some of my travels worldwide. A part of me feels that she might still be alive today if we had been in the US in 1992 at the outset of her cancer.

'Chemistry is for people who like playing with Lego and solving 3D puzzles… Work is just like playing with toys.'

The reason that the UK lags behind the US in cancer treatment is because young doctors are not being trained in a way that equips them properly for the work ahead. In the US, medical students are obliged to spend four years at university, reading for a science degree: they take classes in maths, physics, chemistry, biochemistry, biology etc. before they can even apply to go to medical school! Lecture theatres in the chemistry and biochemistry departments at

UCLA are packed with "pre-meds" eager to do well before the best of them move on to medical school. By contrast, medical schools in UK universities stopped the requirement for premeds to attend science courses taught in science departments back in the 70s.



Fraser Stoddart shares a joke with James R. Heath, Caltech's Elizabeth W. Gilloon Professor of Chemistry

Just imagine if science departments in UK universities were still packed to the seams with medics, dentists and engineers - they would not be in the slightest danger of being closed down!

'We try to model ourselves on Leonardo da Vinci – one minute designing helicopters, the next minute painting the Mona Lisa.'

Cancer is, importantly, a multi-dimensional problem. Young people wishing to become oncologists need to be trained to think and work in a multidimensional way to tackle the BIG problems. In some ways, the advent of nanotechnology will serve to encourage this multi-dimensional approach, since nanotechnology is a uniting discipline that brings together all disciplines.

What differentiates research in the US from research in Europe / UK?
What can each learn from the other?
The US has adopted the Scottish educational tradition of old – namely, a broad education, implemented in the high schools right up through colleges and universities. Also, in the US, education is a serious business: a 24/7 activity for many. The problem in much of Europe is the lack of commitment to learning on a day-in, day-out basis. People leave the workplace, including the universities, for a whole month to go on holiday! In the US, people just roll their eyes at this practice. Of course, maybe we want to move too fast and work too intensely. There is a happy medium to be found.

It's no coincidence that the Netherlands and Switzerland are home to some of the top people doing nanotechnology in Europe: these countries have come a long way towards adopting the US model. It would, in my opinion, give a major fillip to the economy of any country in Europe, if that country had the courage to take on board the US academic system, lock, stock, and barrel.

Another important point is that there is far too much government control of universities in Europe, and in the UK in particular. There is no Research Assessment Exercise imposed on US universities by the federal government. The universities here establish and maintain their own standards.

What helped to drive me away from the UK – apart from the inability of the healthcare system to meet my wife's needs – was the bureaucracy and implications surrounding the Research Assessment Exercise and its teaching equivalent. It all adds up to a horrific waste of money (£40 million per round, so I am told) and energy and time (an order of magnitude more in some people's eyes).

It creates the wrong culture altogether – one where you identify weaknesses and leave departments on the (geographical) periphery exposed, e.g. the chemistry departments in Aberystwyth and Exeter. It's a nonsense. If young people from outwith the South East of the country want to go to university, are they all going to be comfortable going to places like Oxford, Cambridge, and Imperial? Also, the country needs a spectrum of higher educational institutions: one acts as a feeder for another and so on.

Which are the leading countries in nano research and development today?
Where do you think the biggest challenge to the US is coming from?
Nano is a world-wide phenomenon! The action is global. There is lots of activity in the US, Canada, Korea, Japan, Israel, and in Europe, in Switzerland, Germany and the Netherlands in particular – partly because they have embraced the American academic system to at least some extent. The Chinese (in China, Hong Kong, Taiwan and Singapore) are also very impressive. The people involved are very highly motivated and they are trying very hard to do better.

'It was the place to do out-of-the-box things… all of what I've achieved as a scientist can be traced back to those three years'

They have their eyes very firmly trained on quality: they ask all the right questions as they strive to succeed. There are so many things they want to know. How do you publish in *Nature*? How do you publish in Science? I believe that, in the fullness of time, China and India will become a force to be reckoned with in nanoscience and technology.

It's very difficult to say how the US will fare in this competition. It depends on so many things – the economy, political leadership and so on. Presently, the US is a conduit for talent from all over the world. As a whole, the world is going to face a severe shortage of talent over the next decade or so. The US will remain dependent on its ability to attract talented people from overseas.

What's on the cards for you next?
I am off to Washington to speak strongly in support of chemistry, the central science, at the National Science Foundation (NSF). I wear my chemistry unashamedly on my sleeve!

'Discrimination I met at the beginning of my academic career made my life miserable… I resolved that I would treat young people with respect'

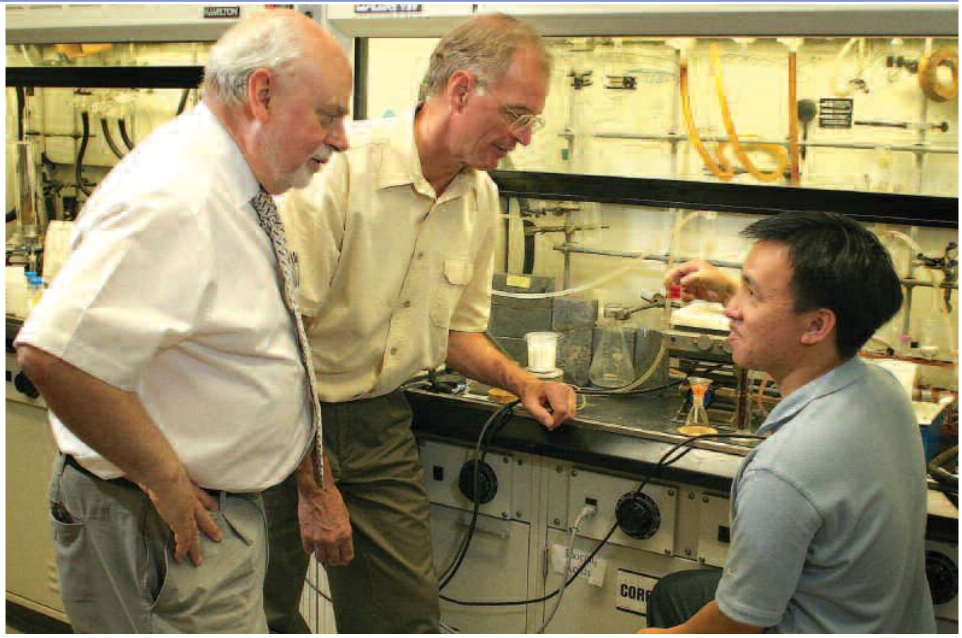
I have invited my students to come up with some ideas to help me deliver a very positive message to the NSF. My message will be to invest appropriately in chemistry, for it is chemistry, in large measure, which will be required to solve the problems that confront us on the planet today.

I will urge the NSF to make the funding possibilities in chemistry as broad as possible and to avoid being overly prescriptive. Let the scientists drive the science forward, with the minimum of interference, and let them decide what research goals should be tackled!

Where do you rate the UK as a nanotechnology player, in a global sense?
There always have been and there always will be world leaders in science in the UK. The top 10% are as good as anywhere else in the world. British scientists – including those working in the area of nanotechnology – will lift Nobel Prizes in the future, for they compete at the highest level.

My concern – as with much in British society – is that after you leave the top 10%, the situation is not so encouraging. The UK remains an interesting mix of extremely high quality and down right mediocrity.

Which countries are the movers and shakers in European nanotechnology?



J. Fraser Stoddart, with UCLA colleagues Jeffrey I. Zink, and Thoi Nguyen

The small countries are doing well. For example, the Netherlands, with major centres in Delft and at the University of Twente in Enschede.

Denmark with powerful institutes in Aarhus and Copenhagen, and Switzerland with a strong federally-funded program in nanoscience, are both making outstanding contributions to nanotechnology. Finland is doing amazingly well and Ireland is also very active, but perhaps more so in biotechnology than in nanotechnology.

If I were forced to say where the movement towards nano is going to be most profound, I would have to say in the smaller countries in Europe. They are able to adapt to change more quickly than the larger countries.

So, finally - what gets you out of bed in the morning?
I'm in the office by 5 AM for that's the way to beat Los Angeles traffic! It is my sheer addiction to science, chemical science and the nanomachines we design, create, and bring through to some potentially practical reality that drives me forward relentlessly.

And then there is my love of working with young people, some of them the very brightest and most able of their time. I gain so much pleasure from living my life on a daily basis with some of the most talented and adventuresome people on the planet, colleagues who are fearless when it comes to taking on grand challenges. It's an enormous privilege to find myself amongst such people. I'm so lucky. ■

Profile:

J. Fraser Stoddart is one of the few chemists to have created an entirely new field of chemistry, by introducing an additional bond, the mechanical bond, into chemical compounds. He has pioneered the development of the use of molecular recognition and self-assembly to make mechanically interlocked compounds called catenanes and rotaxanes, by a process he calls "Molecular Meccano".

Sir Fraser was born in Edinburgh, Scotland, in 1942. He received his BSc (1964) and PhD (1966) degrees from The University of Edinburgh, who later awarded him a DSc, in 1980, for his research into stereochemistry beyond the molecule. He is currently director of the California NanoSystems Institute (CNSI), and he holds the Fred Kavli Chair in Nanosystems Sciences at UCLA. Over the last decade he is the third most highly-cited chemist in the world, according to Thomas Scientific. In January 2007 he was appointed Knight Bachelor by Her Majesty Queen Elizabeth II, 'for services to Chemistry and Molecular Nanotechnology'.

For more information, see his website: http://stoddart.chem.ucla.edu/.