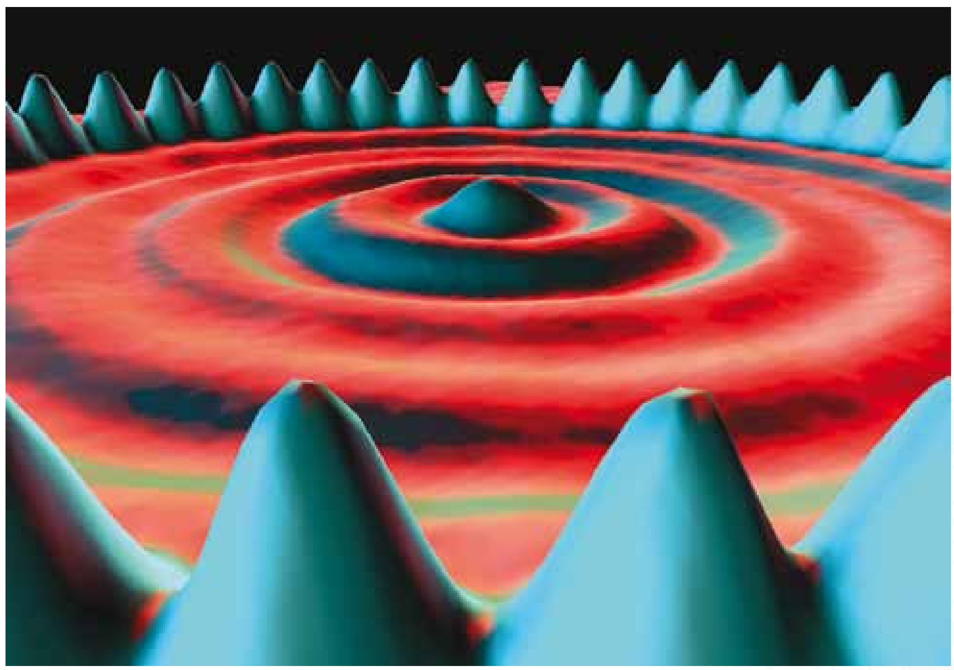
THE KAVLI PRIZE

NANOSCIENCE PRIZE EXPLANATORY NOTES

THE ability to control the basic building blocks of matter on a very small scale is one of the core themes of nanoscience. Being able to put atomic, molecular, and nanoscale sinpecies where we want them provides new understanding of quantum properties and allows us to create new structures from scratch with a wide range of potential applications.

In making their award, the Kavli Nanoscience Prize Committee has chosen two scientists whose development of unprecedented ways to control matter on the nanoscale have greatly pushed forward the boundaries of human knowledge and proved highly influential in inspiring hundreds of others to follow in their footsteps.

In 1989, Donald M. Eigler, of IBM's Almaden Research Centre, San Jose, California, US, became the first person to move an individual atom in a controlled way. This fundamental advance was the realisation of the vision of physicist Richard Feynman, who three decades earlier had outlined in a classic lecture the possibility and implications of developing the ability to manipulate matter on an atomic scale.



Quantum Corral

The discovery of the STM's ability to image variations in the density distribution of surface state electrons created in the artists a compulsion to have complete control of not only the atomic landscape, but the electronic landscape also. Here they have positioned 48 iron atoms into a circular ring in order to "corral" some surface state electrons and force them into "quantum" states of the circular structure. The ripples in the ring of atoms are the density distribution of a particular set of quantum states of the corral. The artists were delighted to discover that they could predict what goes on in the corral by solving the classic eigenvalue problem in quantum mechanics - a particle in a hard-wall box. [Crommie, Lutz & Eigler]

Eigler's breakthrough was made possible thanks to the invention of the scanning tunnelling microscope (STM) by Gerd Binning and Heinrich Rohrer in 1981, a device that made possible the imaging of atoms by measuring changes in the way electrons hop between a sharp probe and a specimen, as the probe shifts position.

He built a low temperature, high vacuum STM so that atoms could be better visualised and studied, and as a result discovered it was possible to slide individual atoms across a surface using the tip of his STM. In a landmark experiment he dragged 35 xenon atoms one at a time across a nickel surface to spell out the name of his employer. He later refined his method so that the atoms could be lifted from the surface and released in a new location.

Eigler went on to create "quantum corrals", which generated well-defined quantum wave patterns within 48 iron atoms positioned in a circle on a copper surface. In the year 2000, he demonstrated the formation of "quantum mirages" in which the energy and distribution of copper surface electrons around a cobalt atom placed at a focal point of an elliptical quantum corral were detected at the ellipse's other focal point, despite there being no second atom present.

Later work included the development and operation of new logic circuits made from carbon monoxide molecules. Eigler showed that changing the orientation of one molecule could initiate a cascade of

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See also:

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The Kavli Foundation
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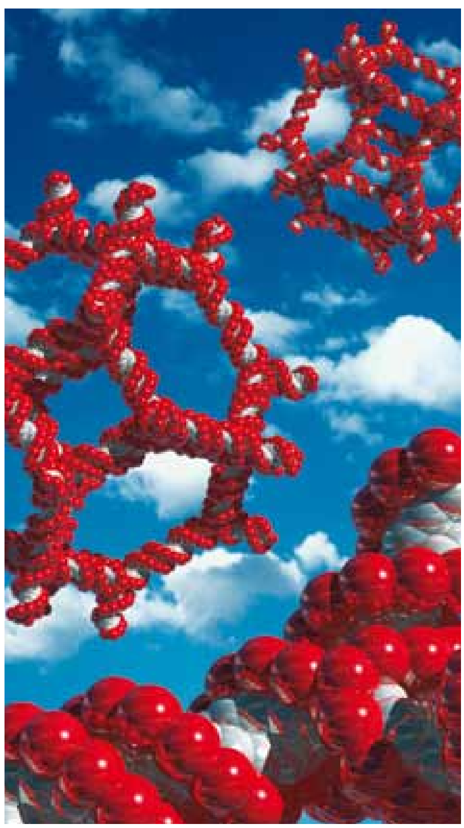
shifts in adjacent molecules. He used this phenomenon to generate the basic logic functions and other features required for computation, thereby creating the first computer circuit in which all components were of nanometer scale. Most recently he developed "single-atom spin-flip spectroscopy", which made feasible the precise measurement of the amount of energy needed to flip an atom's magnetic orientation and expanded our knowledge of the fundamental magnetic properties of atoms.

Nadrian C. Seeman, of New York University, in the US, is the founding father of structural DNA nanotechnology, a field that exploits the structural properties of DNA to use it as a raw material for the next generation of nanoscale circuits, sensors and biomedical devices. Most people are more familiar with DNA as the molecule that contains the genetic instruction set for living organisms. It is made up of sequences of the four base pairs A, T, C and G. Two complimentary strands of DNA are attracted to each other to form the famous double helix shape. Seeman realised in 1980 that this natural tendency of strands of DNA with matching base pair sequences to spontaneously attach to one another meant that synthesised short sections could be made to self-assemble into predictable forms.

Seeman worked out the rules that govern DNA strand design and assembly so as to be able to be able to create specific new shapes and structures. DNA is normally a linear molecule without branches, however a DNA molecule that self-assembles to have branches or junctions can be created if say the two halves of an individual strand attach to two separate other strands. Seeman used this technique to guide branched DNA molecules into stick polyhedra including cubes and truncated octahedrons. He also created DNA knots and Borromean rings.



Artistic rendering by Ken Eward of a DNA truncated octahedron constructed in Ned Seeman's Laboratory.

He went on to develop structures that were robust enough to be used as scaffolding for both crystalline lattices and nanomechanical devices, and created two-dimensional periodic arrays of DNA. Seeman used robust two dimensional arrays of DNA to make metallic nanoparticles assemble into a checker board pattern. He designed the first DNA-based nanomechanical device, as well as robust individually-addressable 2- and 3-state nanomechanical devices. He developed ways in which DNA could be used to operate a robot arm, to capture target species, and to translate DNA sequences into polymer assembly instructions. Later he developed DNA-based "walkers" as a step towards creating devices that can move cargo, for example drugs, in molecular machines and in biomedical devices. More recently he has developed programmable DNA-based assembly line.

Professor Arne Skjeltorp, of the University of Oslo, and chairman of the Kavli Nanoscience Prize Committee, said: "Donald Eigler's demonstration of the ability to move individual atoms on a surface with atomic precision provided credibility and inspiration to what was at the time the emerging field of nanoscience. It could also be described as the research event that gave birth to nanotechnology.

"Nadrian Seeman's invention of DNA nanotechnology is unprecedented as a method to control matter on the nanoscale. In many ways it is still early days for the field, however one day it promises to turn the basic molecular components of life into a means of producing a wide range of novel devices in fields ranging from electronics to biology."

By Nic Fleming, science writer