Discover the secrets of the Nanoworld

Image courtesy of Dr James Bendall, University of Cambridge, UK.
You may have heard of ‘Nano’

Nano-cars
Nano-bots
Nano-phones
Nano-cameras

‘Nano’ has become a buzz word in popular culture to just mean small.

But what is it really?
To understand nanotechnology we must first think about scale.
A nanometre is the unit of measurement used in the nanoscale.
Quite a few nanometres here!

A human hair is 40,000 – 200,000 nanometre wide.

A man’s beard grows a nanometre per second.

When a seagull lands on an oil tanker the ship dips down one nanometre.

A nanometre is about the width of 6 bonded carbon atoms.

C_{60} is a nanoparticle as its diameter is just over 1 nm.

Nanoparticles have at least one dimension within the range from 1 to 100 nanometres.
The Nanoscale
Flea 10^{-3} \text{ m or 1,000,000 nm in length}

Red Blood cells 10^{-5} \text{ m or 6000 nm in diameter}

DNA 10^{-8} \text{ m or 2.5nm in diameter.}

Nanoparticle 10^{-9} \text{ m. One dimension between 1 and 100 nm.}

Dog 10^0 \text{ m or 1,000,000,000 nm in length.}

Anything Nano is defined as having one of its dimensions smaller than 100 nanometres (nm).
A water molecule which measures approximately 0.5 nm is about as big in relation to an apple as an apple is to planet Earth.

It’s a long way down to the nanoscale!
Nanoparticles are just tiny bits of a larger material but what happens when you create such small pieces?
Tiny pieces = more

Surface area.
Surface Area

- 1cm
- 2cm
- 3cm
- 4cm
- 6cm²
- 12cm²
More surface area
= more reactivity
Nanoparticles have more surface area. This makes them more reactive since chemical reactions happen on the surface. More reactive means potentially more useful.
In a cubic centimetre of material one in 10 million atoms are on the surface but for a cubic nanometre, 80% of atoms are on the surface and potentially ready to react!
Size is the key here!
At the Nanoscale a material’s properties can change **dramatically**. These could be their boiling points, solubility or catalytic activity.

With **only** a reduction in size materials can exhibit new properties, properties they do not possess when they are on a larger or macro scale.

The normal **‘classical’** laws of physics no longer apply!
Colour changes

• For example, sometimes just changing the size of a particle can drastically alter its colour.

Cadmium Telluride

Increasing size

Nanoparticles of CdTe.
A. Eychmüller, Technische Universität Dresden
Even mechanical and electrical properties can be influenced by size!

Graphene is brittle and non-conductive

Carbon nanotubes are like graphene sheets but rolled up...however they have totally different properties.

Did you know? Carbon nanotubes are much stronger than steel yet much lighter, and they can be conductive.
So how do scientists work on such a tiny scale?
Seeing Nano
Mainly because microscopes have become more sophisticated.

The first microscopes to be developed in around 1665 opened up a whole new world for scientists. For the first time cells and structures of nature that we are familiar with now became visible. Public opinion was fearful of this voyage into the unseen world of the microscopic.
Now we have microscopes that can see even further into this world, actually to the atoms that are the very building blocks of our living world.

These more sophisticated microscopes are known collectively as Scanning Probe Microscopes or SPMs.
A Scanning Probe Microscope uses an extremely fine probe tip (sometimes ending in only a few atoms) and runs over the surface feeling for contours and shapes.

Examples include: Atomic Force Microscope, Scanning Tunnelling Microscope.
A cantilever, similar to a diving board, is attached to the tip of an Atomic Force Microscope or AFM. The whole thing moves up and down as the tip moves over the atomic–scale hills and valleys of a sample’s surface.

A laser reflects off the back of the cantilever. When the cantilever deflects, so does the laser beam. A detector in a computer records the movement of the laser and translates that data into an image, such as the images on the right.

This is a diagram of an Atomic Force Microscope, or AFM.

Images courtesy of T. Oppenheim, Cambridge University
A scanning tunnelling microscope works by having a tiny probe which scans across a surface picking up variations in the current that runs between itself and the atoms on the surface. This probe is made of conducting material (usually Tungsten) and the very end of it is only 1 atom wide!

These variations in current are translated into images such as the ones to the right.
The probe tips can also be used to move individual atoms.

The image shows iron atoms which have been moved individually.

Image originally created by Don Eigler, IBM corporation.
Making Nano
This idea of building things from the atoms and working up is interesting for researchers.

Computers and phones are getting smaller yet more powerful. This trend demands smaller and smaller components, getting down to the nanoscale. It makes sense to be able to create these nano-devices from the ‘bottom up’. Rather than the more traditional ‘top down’ approach to manufacturing.

Manufacturing from the ‘bottom up’ would mean less energy and less waste.
Moving atoms individually is still not a viable technique for creating nanostructures because it’s too slow. However there is another process called ‘SELF ASSEMBLY’, often seen in nature, which scientists can exploit.

Atoms, molecules or nanoparticles will arrange themselves into larger structures if they have the right properties and environments. This process plays a central role in the construction of DNA, cells, bones and viruses. These all self assemble without assistance.
Another way scientists can create nano-sized devices is a process called **lithography**. It is often used to make **computer chips**. It works in a very similar way to printing or if you were spray painting over a stencil. But **lithography** uses light or electrons instead of ink or paint.

Photolithography uses light and structures as small as around 20 nm can be made. If scientists want to make even smaller structures (around 5 nm), they use electrons instead of light, this is called **E-beam lithography**.

This is a finished structure created by E-beam lithography.
They are stronger yet considerably lighter than steel and flexible. They can behave like metals but also semiconductors, they are great at transmitting heat and they are assembled from carbon atoms.

With properties like this they could play a pivotal role in the development of new materials and future electronics.

In this image each letter is made up of hundreds of nanotubes!

Even when nanotubes are fully grown, each entity is smaller than a human blood cell.

Are an exciting discovery which could revolutionise materials of the future.
Nature is an expert in making nanoscale structures. This is why scientists look to nature for inspiration when researching how to construct at this tiny scale.
Nature’s Nano
Biomimicry is the term scientists copying nature. By studying Lotus leaves and their structure scientists have designed non-wetting materials and self-cleaning windows.

By studying butterfly wings and their nanostructures scientists have explained how light can interact differently with surfaces. This has helped design security holograms and hair products!

Even the nano structure of a Toucan’s beak has offered insight into designing ultra-light aircraft components.
Geckos’ feet have nanostructures.

Geckos’ feet are covered in tiny hair-like structures called setae. These structures can get so close to a surface that weak ‘sticky’ interactions between molecules become significant. The result is strong adhesion which is entirely due to Van der Waals forces. Scientists have been inspired by this nanostructure to create internal bandages which still adhere even in a wet environment.

Nature is experienced in working on the nanoscale and we can learn a lot from its success at creating natural nanotechnology.
Nano and you.
Nanotechnology is already in our lives.

Nanoelectronics has enabled the miniaturisation of electronic gadgets in daily use.

Some tennis balls stay bouncy for longer thanks to a nano-structured inner layer.

Socks that contain antibacterial nanoparticles of silver are supposed to keep your feet healthy and odour free.

Some tennis racquets are made from a carbon-based nanocomposite making them stronger and lighter than ever before.
Nanotechnology is already in our lives.

Some textiles are made very hydrophobic using liquid repellent nanostructures which enable them to be water and stain resistant.

Sun glasses which have a nano-structured coating are easier to clean, harder to scratch, anti-static, anti-misting and anti-bacterial.

Cosmetics and sunscreens which contain nanoparticles can promote better protection and comfort.
Studying Nano
Nanotechnology is a multidisciplinary subject as it incorporates many different areas of science and industry:
Nano future
It is the potential of Nanotechnology that makes it so interesting. Some areas where Nanotechnology could have a dramatic impact include

**Medical Applications** e.g. cancer therapy

**Information Technology** e.g. faster computers

**Energy Solutions** e.g. such as more economical fuel cells and solar cells

**Areas which have an impact on all our lives.**
www.nanoyou.eu