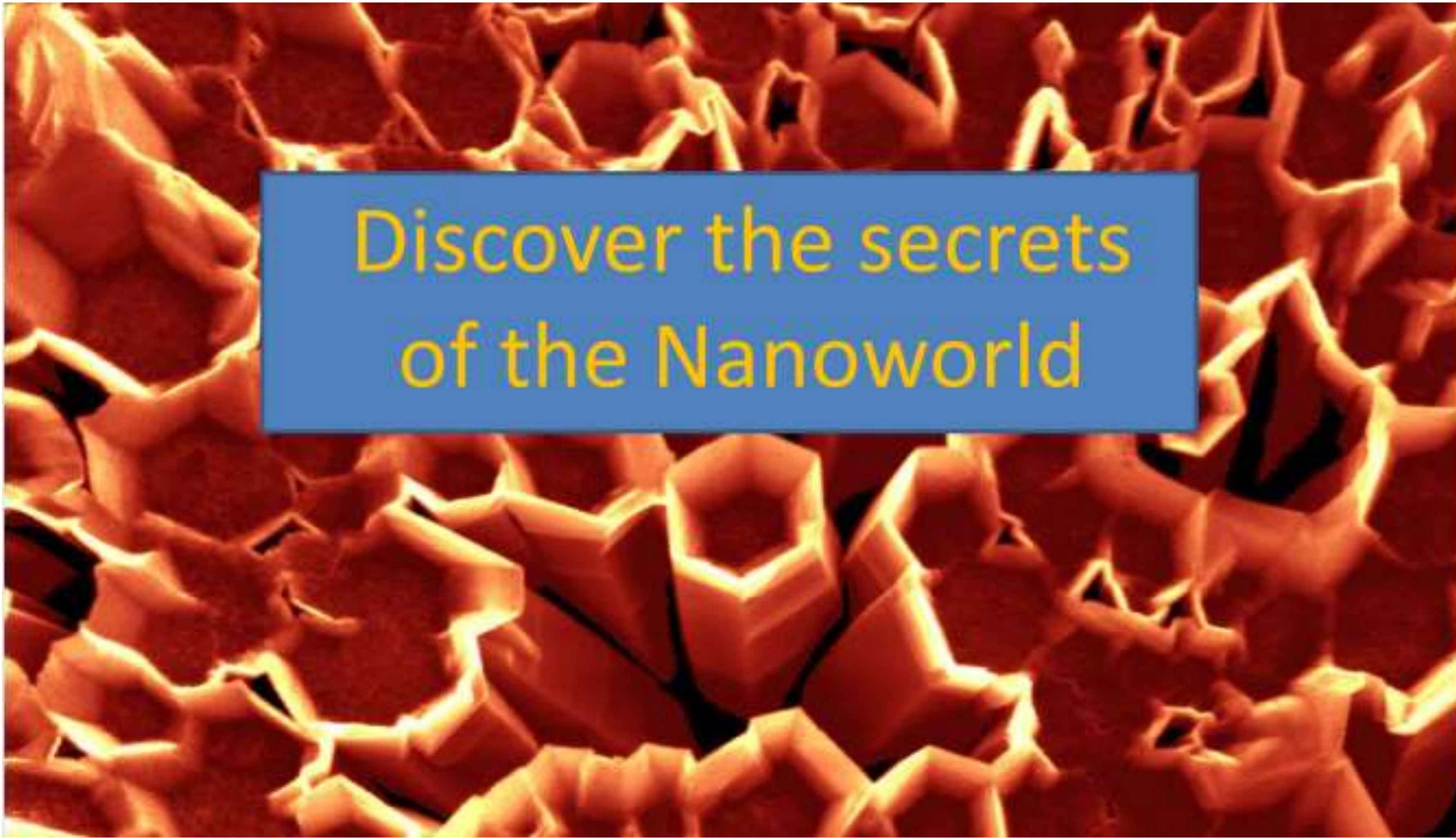

Discover the secrets
of the Nanoworld

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?

What is Nano?

To understand nanotechnology we must first think about scale.

A metre is about the distance between the tip of your nose to the end of your hand. A **nanometre** is a **billionth** of a metre.

$$\frac{1}{1,000,000,000}$$

A nanometre is the unit of measurement used in the nanoscale.

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

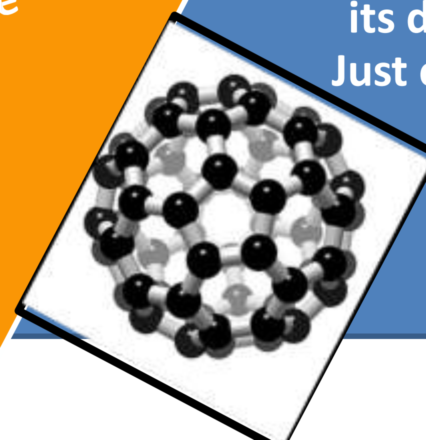
A man's beard grows a nanometre per second.

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.

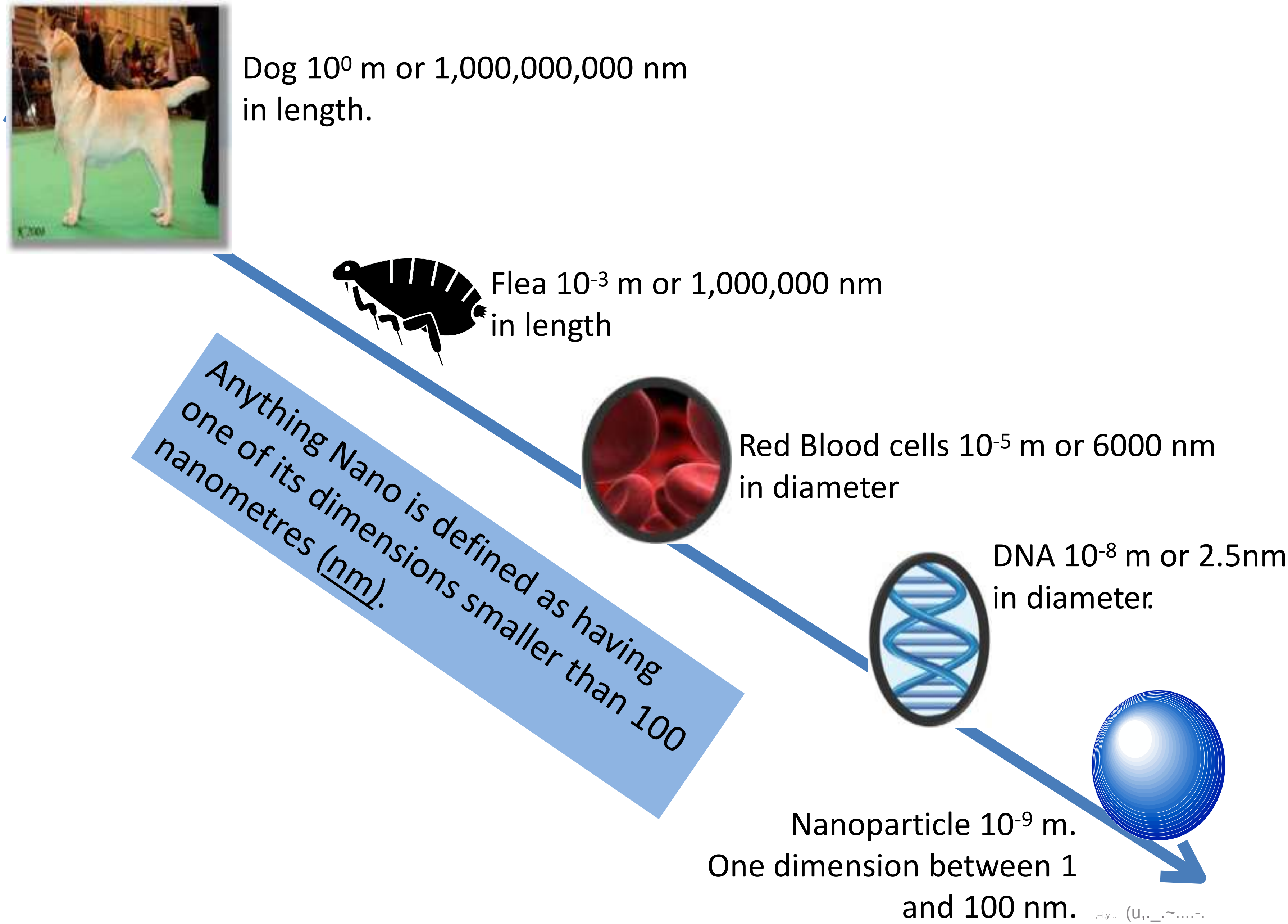
Nanoparticles have at least one dimension within the range from 1 to 100 nanometres.

Quite a few nanometre here!



C_{60} is a nanoparticle its diameter is Just over 1 nm

The Nanoscale

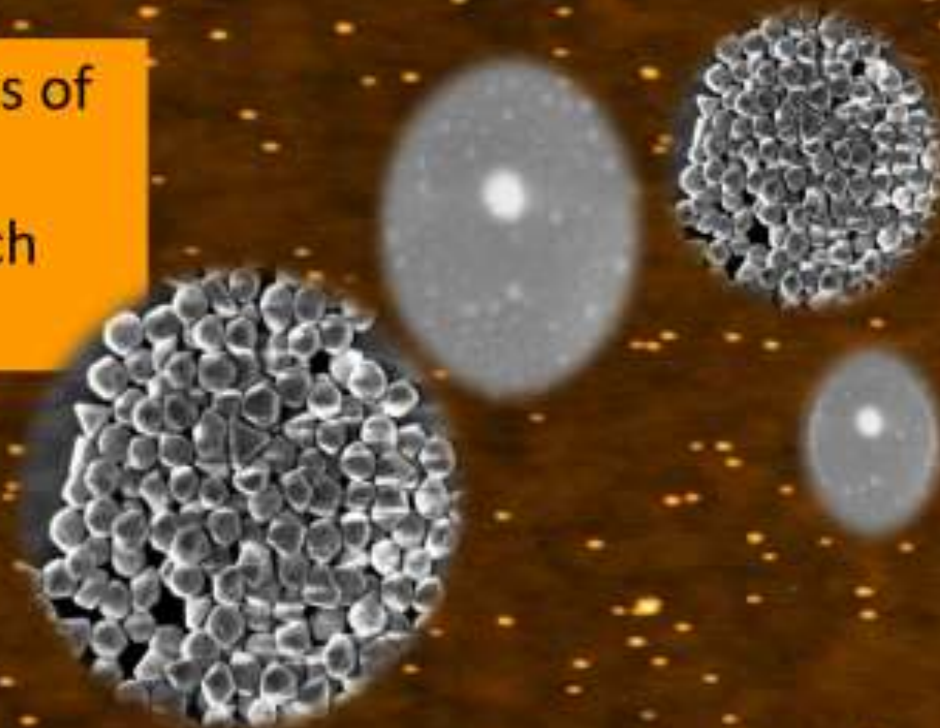

Dog 10^{0} m or 1,000,000,000 nm in length.
Flea 10^{-3} m or 1,000,000 nm in length
Red Blood cells 10^{-5} m or 6000 nm in diameter
DNA 10^{-8} m or 2.5nm in diameter.
Nanoparticle 10^{-9} m. One dimension between 1 and 100 nm.
Anything Nano is defined as having one of its dimensions smaller than 100 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

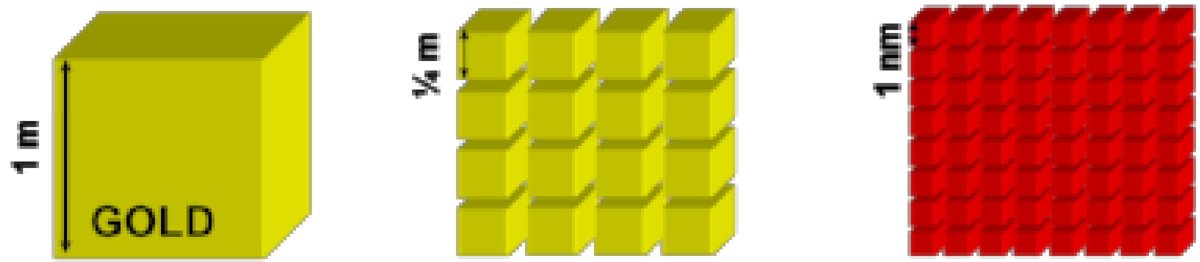
Nanoparticles are just tiny bits of a larger material but what happens when you create such small pieces?



Images of gold nanoparticles courtesy of Prof Paul [illegible], Cambridge University.

Tiny pieces = more…….

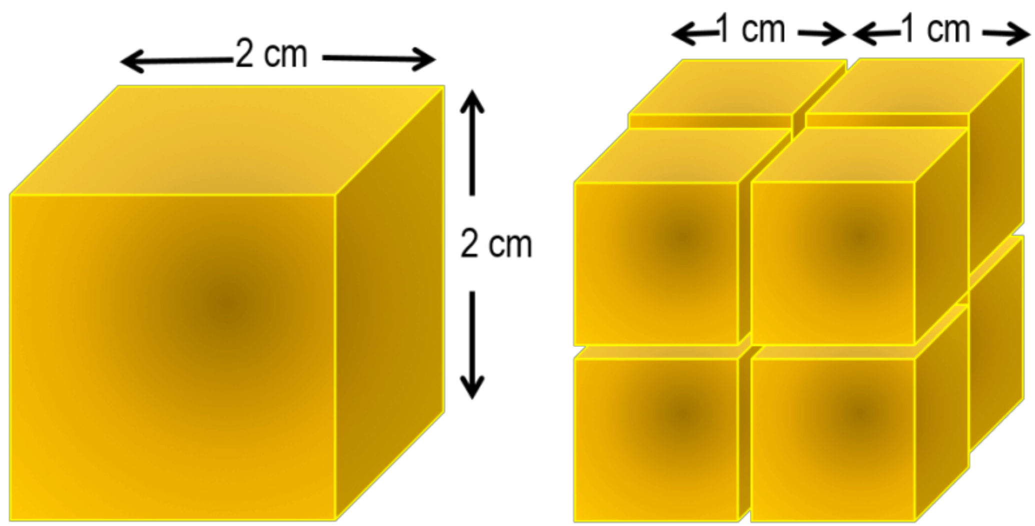
Surface area.



Each side = 1 meter
Mass ≈ 43,000 lb
Surface Area (SA) = 6 m^2
≈ 8 ft x 8 ft room

Each side = 1/4 meter
Mass ≈ 43,000 lb
SA = 24 m^2

Each side = 1 nanometer
Mass ≈ 43,000 lb
SA = 6 billion m^2 ≈ 2500 $miles^2$
Area of Delaware = 2490 $miles^2$

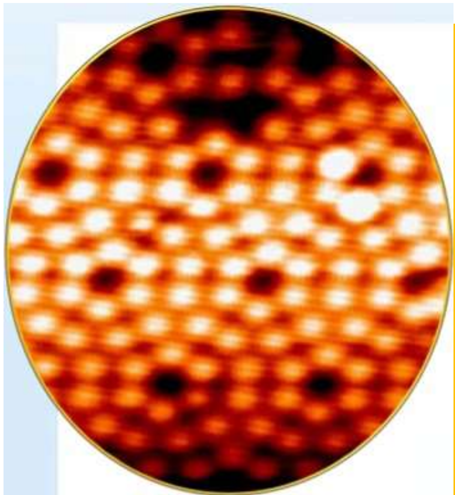


# of Cube (s)	Dimensions (cm)	Surface Area (l x l x 6 cm^2)	Volume (l x l x l cm^3)	Surface Area/Volume ratio
1	2 x 2	(2 x 2 x 6) = 24	(2 x 2 x 2) = 8	3
8	1 x 1	8 (1 x 1 x 6) = 48	8 (1 x 1 x 1) = 8	6

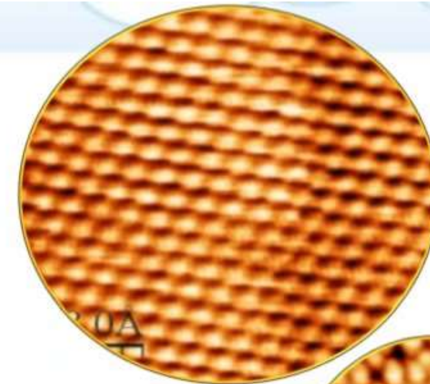
<u>More surface area</u>

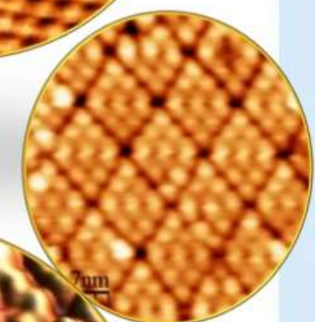
<u>= more reactivity</u>

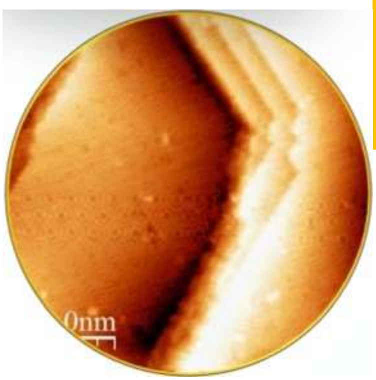
Nanoparticles have more surface area. This makes them more reactive since chemical reactions happen on the surface.
More reactive means potentially more useful.

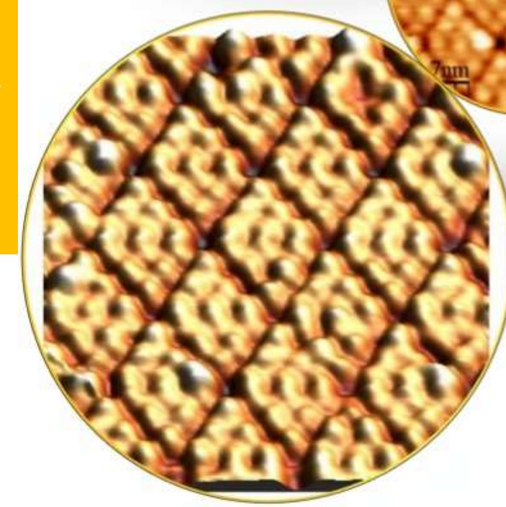


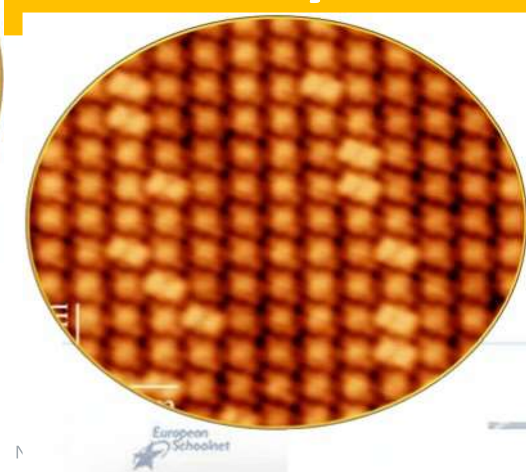
In a cubic centimetre of material <u>one in 10 million</u> atoms are on the surface but for a cubic nanometre, <u>80%</u> of atoms are on the surface and potentially ready to react!











Images courtesy of Dr Colm Durkan, Cambridge University.

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.

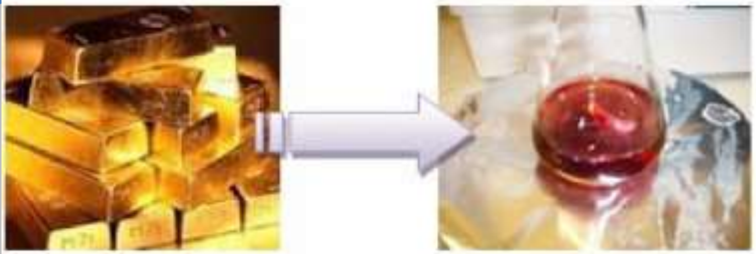
With **only** a reduction in size materials can exhibit new properties, properties they do not possess when they are on a larger or macro scale.

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



MACRO NANO

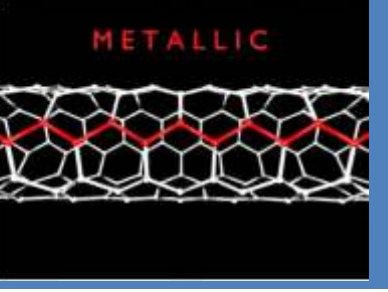
Increasing size

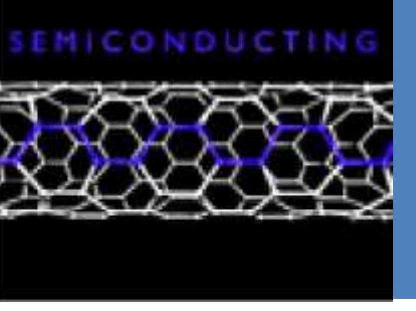
Nanoparticles of CdTe.
A. Eychmüller , Technische Universität Dresden

Even mechanical and electrical properties can be influenced by size!

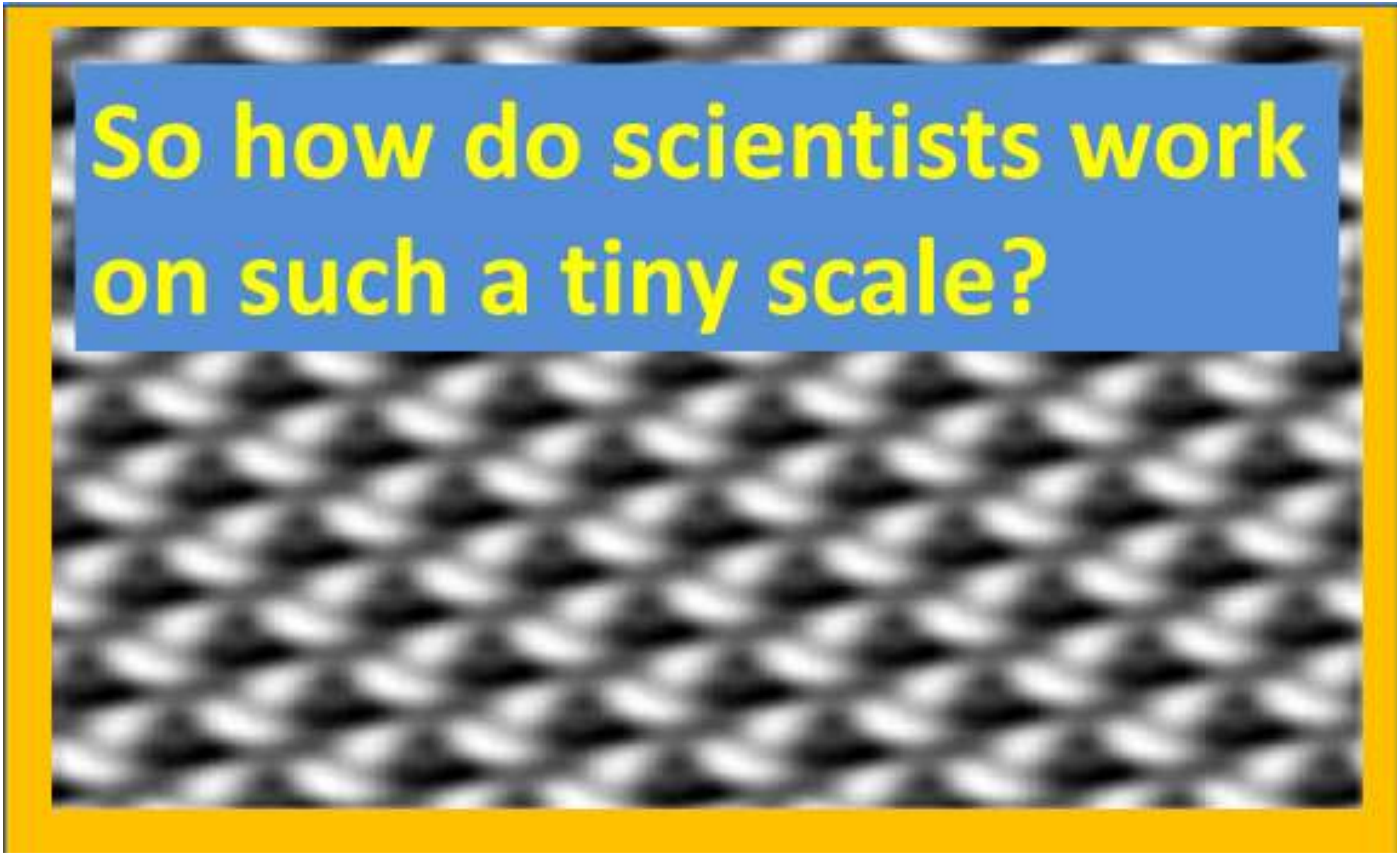
Graphene is brittle and non-conductive

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.

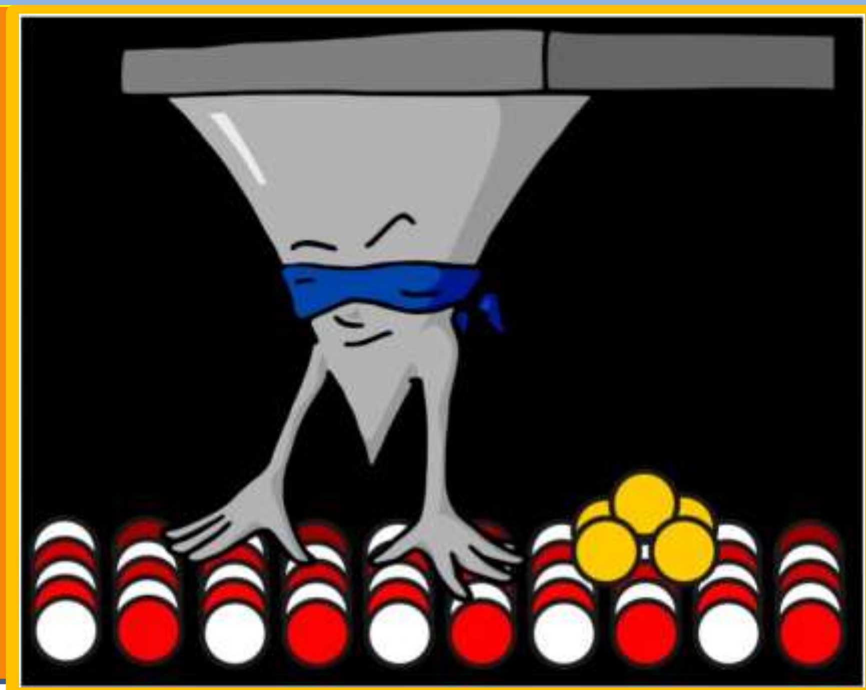
Micrographia 1665

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.

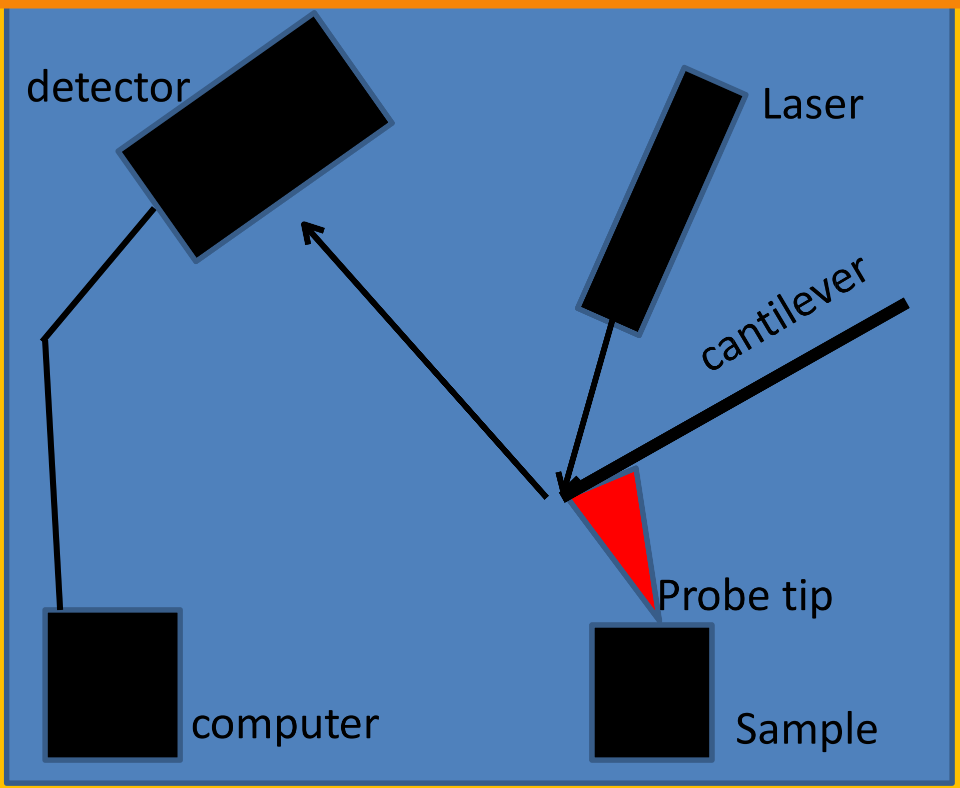
A Scanning Probe Microscope uses an extremely fine probe tip (sometimes ending in only a few atoms) and runs over the surface feeling for contours and shapes.



Probe tip feeling for shapes.

Examples include:
Atomic **F**orce **M**icroscope, **S**canning **T**unnelling **M**icroscope

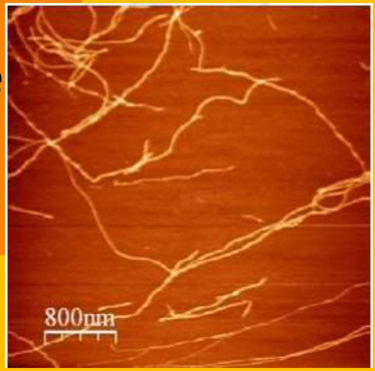
A cantilever, similar to a diving board, is attached to the tip of Atomic Force Microscope or AFM. The whole thing move up and down as the tip moves over the atomic–scale hills and valleys of a sample's surface.

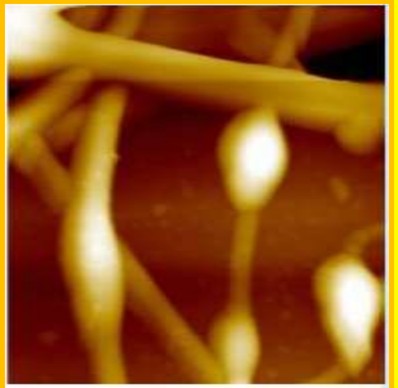


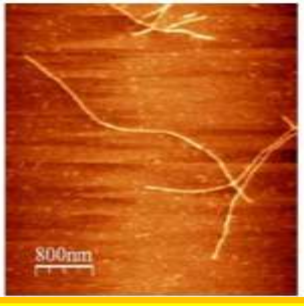
This is a diagram of an **Atomic Force Microscope**, or **AFM**

Nanoyou
Con~or1'"m

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.



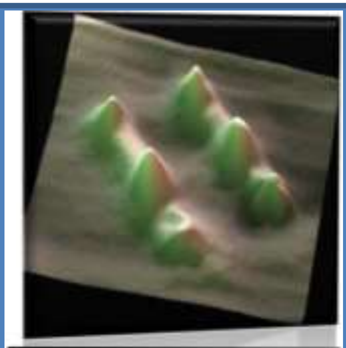


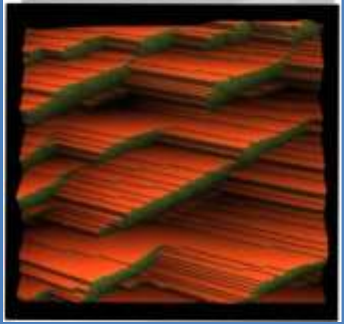


Images courtesy of T. Oppenh
Cambridge University

Scanning tunnelling microscope.

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!





A tungsten tip for STM imaging.

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.

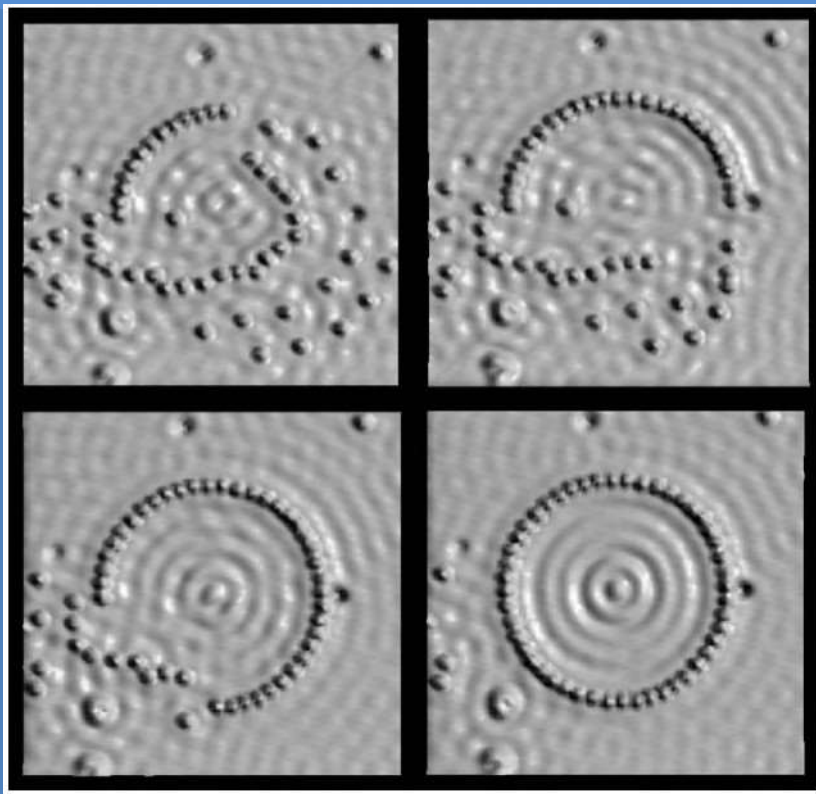


Image originally created by Don Eigler, IBM corporation.

The image shows iron atoms which have been moved individually.

Making Nano

This idea of building things from the atoms and working up is interesting for researchers.

‘TOP DOWN’

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.

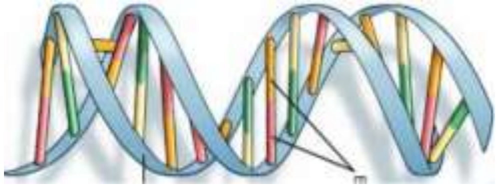
‘BOTTOM UP’

Manufacturing from the ‘bottom up’ would mean less energy and less waste.

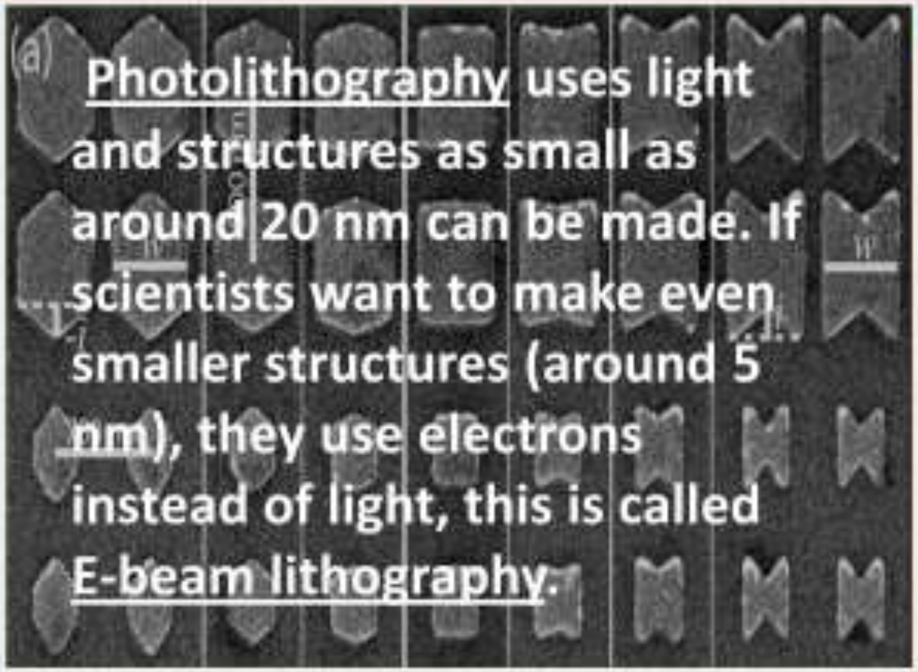
Nanoyou Consortoum.

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.

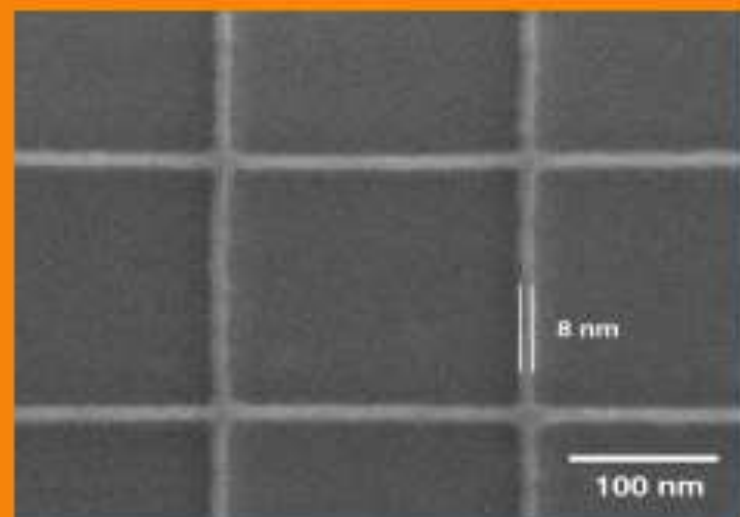


Another way scientists can create nano-sized devices is a process called lithography. It is often used to make computer chips. It works in a very similar way to printing or if you were spray painting over a stencil. But lithography uses light or electrons instead of ink or paint.



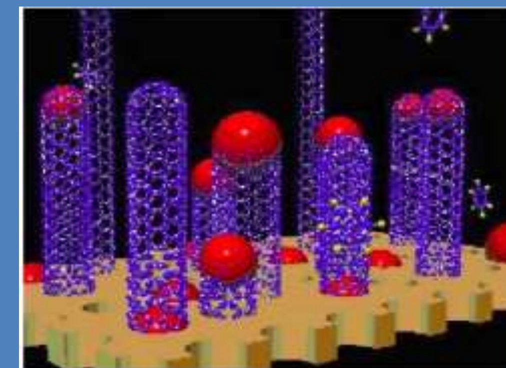
Nanoyou Consortium.

This is a finished structure created by E-beam lithography.



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

Are an exciting discovery which could revolutionise materials of the future.



Courtesy of Stephan Hoffman, Cambridge University.

They are stronger yet considerably lighter than steel and flexible. They can behave like metals but also semi-conductors, they are great at transmitting heat and they are assembled from carbon atoms.

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

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


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

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!

Butterfly wings under the microscope

Even the nano structure of a Toucan's beak has offered insight into designing ultra-light aircraft components.

Geckos' feet have nanostructures.

Image credit: A. Dhinojwala, University of Akron

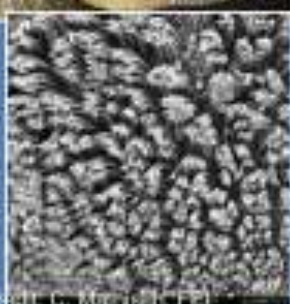


Image credit: C. Mathisen, FEI Company

Image credit: A. Kellar, Lewis & Clark College

Geckos' feet are covered in tiny hair-like structures called setaes. 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.

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 multi-disciplinary subject as it incorporates many different areas of science and industry:

Engineering

Chemistry

BIOCHEMISTRY

Medicine

Electronics

Biology

Food Technology

Computer science

Cosmetics

Sustainable energy

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.