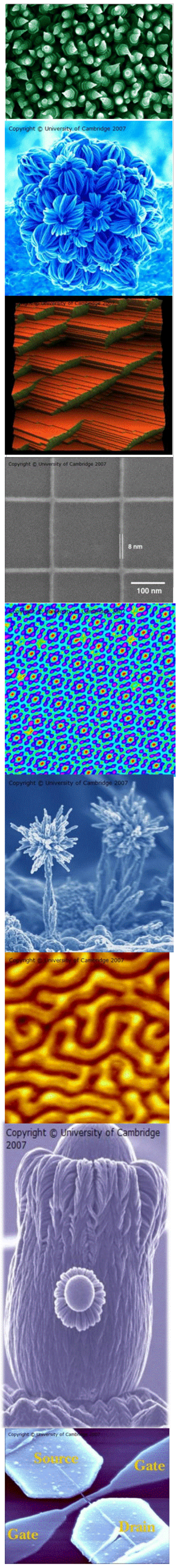
NANOTECHNOLOGY for: Medicine and Health

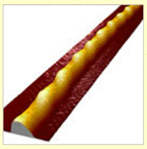


Nanotechnology provides novel tools to understand, see and treat diseases.

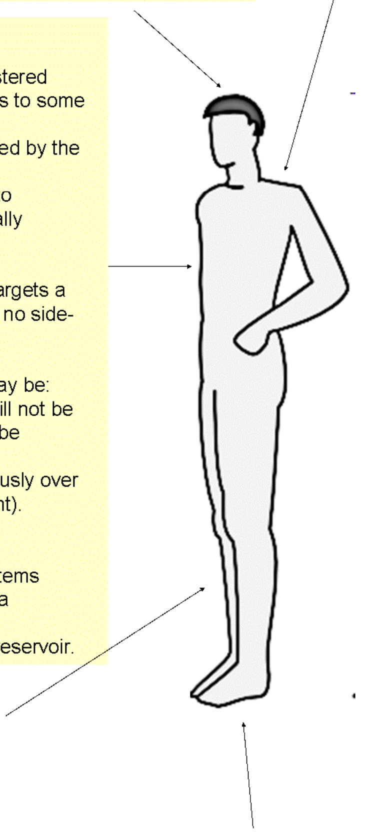
- Nanomaterials can be given biological functionalities so they can interact with cells and their constituents (proteins, lipids, DNA etc) in a specific way. If the nanomaterials are correctly functionalised they can induce or stop certain metabolic reactions.
- Nanomaterials are often the same size as (or smaller than) many biological structures and processes.

Disease understanding

The reasons for many debilitating diseases are still unknown but recent nanotechnological advances have allowed us to study biological processes in much greater depth.



An AFM image of an amyloid fibril, thought to be linked to diseases such as Alzheimer's. (image: T. Knowles, University of Cambridge)



Disease treatment

- Traditionally most drugs are administered either orally or by injection. This leads to some problems:
  - Therapeutic effects may be reduced by the time the drug reaches its target.
  - Injections can be painful, difficult to administer, expensive and potentially dangerous.

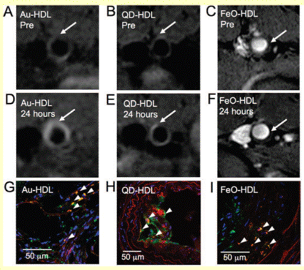
- Aim – to design a drug that solely targets a disease, quickly and accurately, with no side-effects.

- Nanosized drug delivery systems may be:
  - Target specific, so healthy cells will not be damaged and less of the drug will be required.
  - Time-released (released continuously over time to deliver continuous treatment).

- How?
  - Most nanosized drug delivery systems either entrap the molecules within a biocompatible polymer scaffold or encapsulate it within a nanoscale reservoir.

Disease imaging

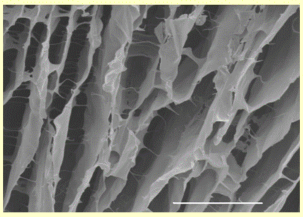
Through careful design and synthesis, multifunctional nanoparticles can be engineered to specifically bind to certain types of species in the body (e.g. cancerous cells, cholesterol). By making the nanoparticles visible to medical imaging techniques, they can be used as markers or tags to allow doctors to monitor the level and spread of disease.



These images show multimodality imaging of atherosclerosis using nanocrystal-modified high density lipoproteins. [Adapted with permission from Cormode et al, Nano Letters 8 (11) 3715 Copyright 2008 American Chemical Society]

Repair of injured or damaged tissues

New biocompatible composite materials can be synthesised which will be taken up by the body to repair damage e.g. through the use of nanoporous materials and biocompatible polymers..



This scanning electron microscope image shows a hydrogel scaffold grown for studying brain tissue engineering and nerve regeneration. (D Nisbet, Monash University, NISE Network, www.nisenet.org, licensed under NISE network terms and conditions).

Lab-on-a-chip and biosensors

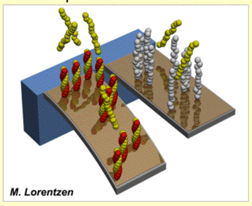
- Highly sensitive miniature diagnostic devices are being developed to give accurate, fast diagnosis from a small amount of fluid.
- Samples will not need to be sent away to a laboratory for analysis, saving time and resources.
- Miniaturized diagnostic devices include biosensors, microarrays and 'lab-on-a-chip' (LOC) devices, also called miniaturized total analysis systems (µTAS)

Lab-on-a-chip

- Miniaturised integrated laboratories that allow the separation and analysis of biological samples (e.g., blood) in a single device.
- They are made of microfluidic systems, including micro-pumps and micro-valves, integrated with microelectronic components. The device can also integrate one or more sensors.
- Nanotechnology can miniaturise the components and improve specific functions e.g. through the use of nanosized electrodes or nanopore-membranes.

Biosensors

- Designed to recognise a specific biomolecular species, and being able to signal its presence, activity or concentration.
- Examples include:



Cantilever sensors
The surface of the cantilever is functionalised with a nanometre-thick layer of coating designed to recognise specific biomolecules.

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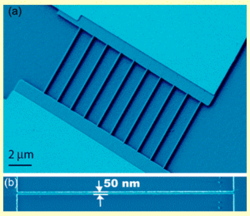
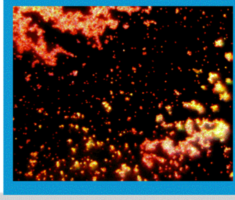


Nanowire sensor devices
The surface of a nanowire can be functionalised so specific biomolecules strongly bind, changing its electronic properties

This scanning electron micrograph depicts the functional part of a nano-biosensor containing silicon nanowires. (P Mohanty, Boston University, NISE Network, www.nisenet.org, licensed under NISE network terms and conditions).

The Vision of Theranostics

- Nanotechnology may enable the integration of disease diagnosis, imaging, therapy and follow-up into a single process – referred to as "theranostics"
- Drugs could be bound to nanoparticles (such as quantum dots) which undergo a property change (such as colour) once the drug has reached the target.
- Together with a slow, targeted release system, the nanoparticles could gradually change colour during the drug's action, therefore informing doctors of the progress of a therapy.
- An example of theranostic is the use of gold nanoshells for imaging and treating cancer cells at the same time.



An optical microscope image of gold nanoshells deposited on a glass microscope slide. (G.Koeing, University of Wisconsin-Madison NISE Network, www.nisenet.org, licensed under NISE network terms and conditions).

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