Nanotechnology: Minimal Essentials for Clinicians

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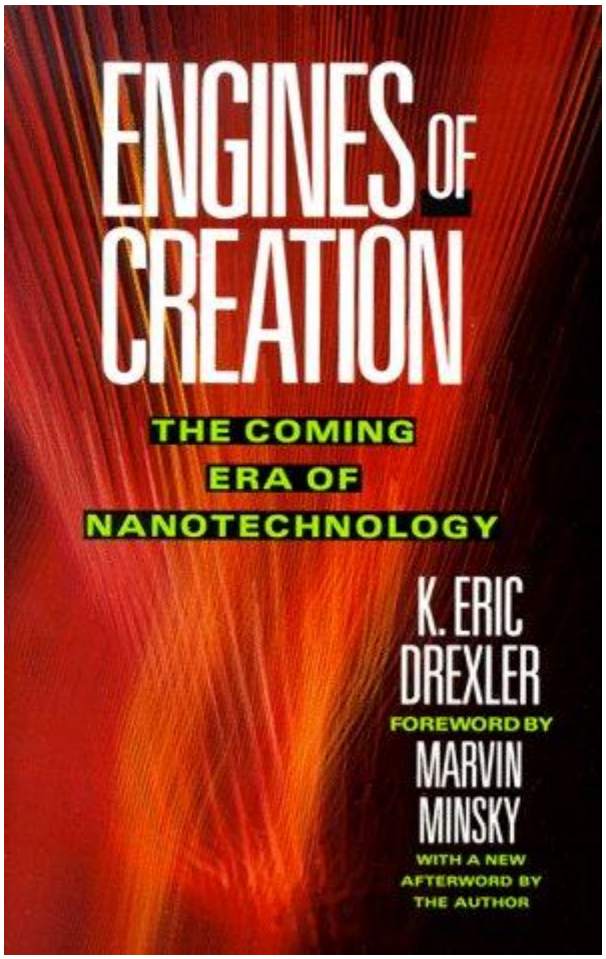
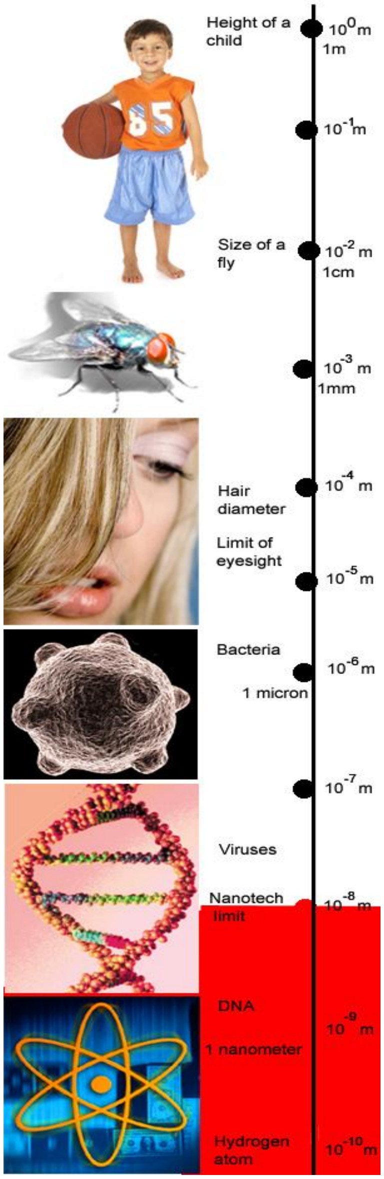
Introduction

Nanotechnology is the art and science of manipulating nanometer scale (1-100 nm) materials in a microphysical realm where quantum physics effects are usually important [1]. In this sense, nanotechnology is the engineering of molecular-level systems. It is a particularly varied field of scientific endeavor, ranging from relatively uncomplicated variations on existing products like paint and sun screen to radical but as yet largely unproven (outside of nature) approaches based upon molecular self-assembly. Nanotechnology involves the application of fields of science as diverse as quantum physics, materials science, organic chemistry, molecular biology, semiconductor electronics, microfabrication, and mathematics. It is truly interdisciplinary in nature.



Inspiration for the field of nanotechnology is sometimes attributed to Nobel laureate physicist Richard Feynman who, at an American Physical Society meeting at Caltech on December 29, 1959, presented a lecture entitled, "There's Plenty of Room at the Bottom," where Feynman imagined a process by which individual atoms and molecules might be manipulated [2]. Eric Drexler later took Feynman’s ideas and added the idea of computer control in his 1986 book *Engines of Creation: The Coming Era of Nanotechnolog*y [3]. (**Figure 1, above**). See also Drexler’s web site at http://e-drexler.com/ for further information.

Scales



One nanometer (nm) is one billionth, or 10^{-9}, of a meter. Conventionally, nanotechnology is taken as covering the scale of 1 to 100 nm, the lower limit is set by the size of atoms while the more or less arbitrary upper limit of 100 nm is the size where material properties become increasingly macroscopic in behavior.

Some sizes of familiar entities may help provide perspective: the spacing between carbon atoms in an organic molecule is in the range 0.12–0.15 nm, a DNA double-helix has a diameter of approximately 2.5 nm, and the smallest cellular life-forms, the bacteria of the genus Mycoplasma, are around 200 nm in length. A red blood corpuscle is about 7 microns (micrometers) in diameter, or about 7000 nm.

Figure 2 on the left illustrates the immense scales involved in the physical world. (http://www.azonano.com/work/U25R022xagK7Xgnx8hq7_files/image001.jpg)

Nanomedicine

Nanomedicine is concerned with the possible medical applications of nanotechnology, such as the use of nanomaterials for clinical purposes, as well as applications such as the development of nanosized biosensors, nanosized drug delivery systems (e.g., using polymer-based nanoparticles), and molecular nanotechnology approaches to detecting and treating disease. Current problems for nanomedicine also involve understanding the toxicity and environmental impact of nanoscale materials, as well as the use of nanotechnology to improve diagnostic imaging (**Figure 3**).

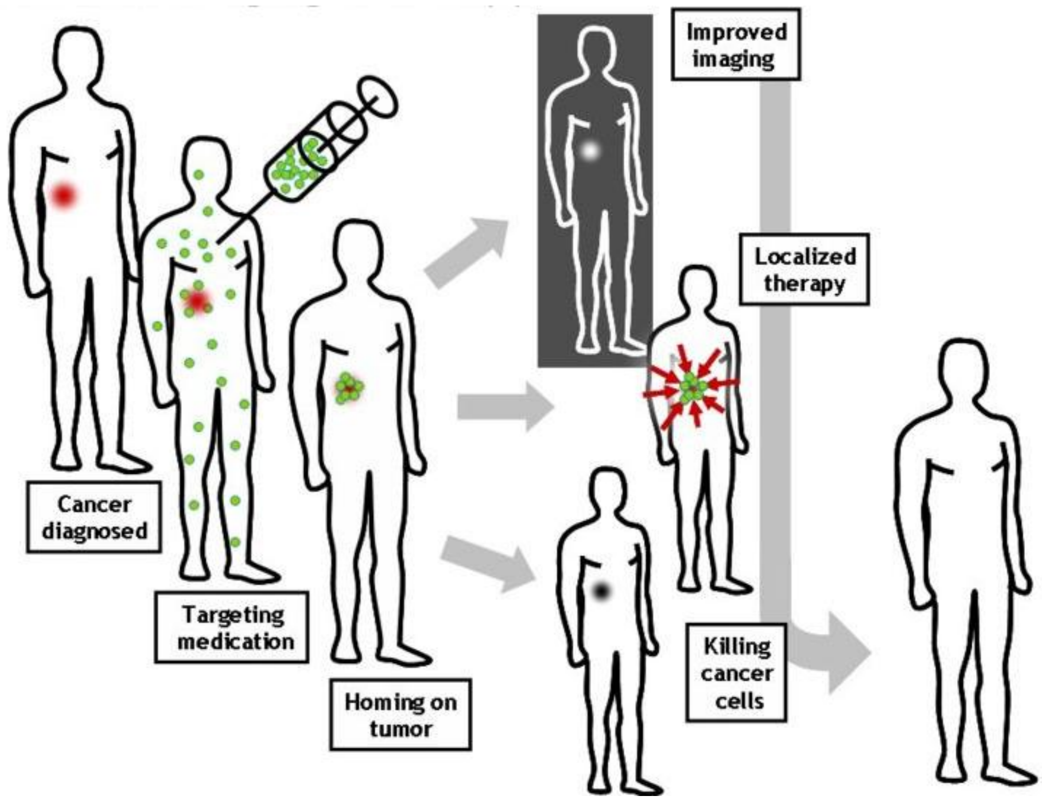


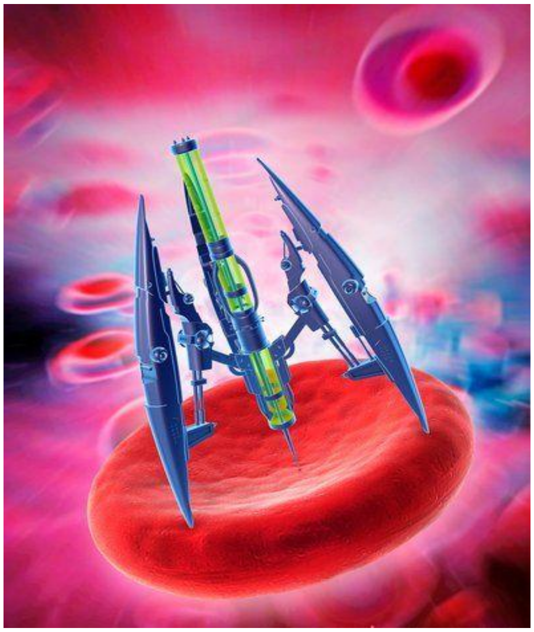
Figure 3. A schematic illustration showing how nanoparticles might be used to help treat cancer. After a cancer is found, a medication that targets the tumor might serve to improve the quality of the image of the tumor, might help kill the tumor directly, or might facilitate localized therapy. In particular, quantum dots (nanoparticles with size-tunable light emission), when used in conjunction with magnetic resonance imaging can produce exceptional images of tumor sites.
Image source: http://en.wikipedia.org/wiki/File:MolecularImagingTherapy.jpg

Nanopharmacology

Nanopharmacology is an new and exciting inter-disciplinary field involving delivery of pharmaceuticals through nanotechnology methods like the use of nanoparticles or liposomes. When designed to avoid destruction by immunological defense mechanisms (a field of active research), nanoparticles can be used to improve drug delivery, since cells take up these nanoparticles because of their size, whereas larger particles end up being removed from the body.

Nanorobots and Cell Repair Machines

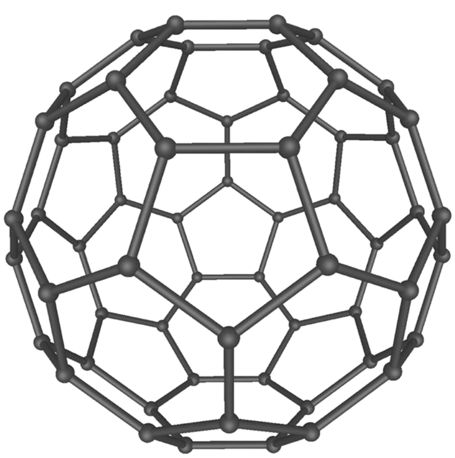
Both science fiction writers and futurists have wondered about the possibility of using nanorobots ("nanobots") for clinical purposes such as detecting/repairing cellular damage and fighting invading



infectious organisms. Such nanodevices might even be imaged working inside the body using magnetic resonance imaging if 13C atoms rather than the natural 12C isotope of carbon is used, since 13C has a nonzero nuclear magnetic moment. The ultimate aim would either be cellular repair or, where that is not possible, to induce apoptosis. Some of the most critical challenges for such an initiative include [1] finding a means to power the device, [2] finding a means to control the device, and [3] ensuring that the device does not injure the patient in some unanticipated way. **Figure 4** above provides an artist's conception of a nanorobot injecting a red blood corpuscle with a drug. (Image Credit: http://www.sciencephoto.com/media/ 96509/enlarge).

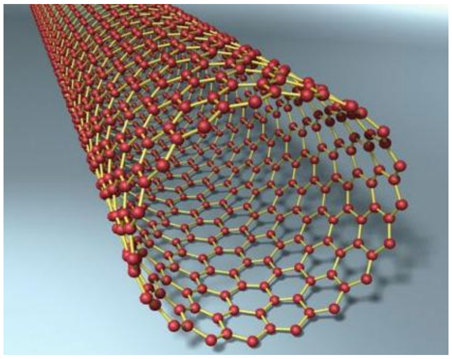
Special Structures

Research in nanotechnology has led to a number of developments in molecular configuration that



show special promise. These include the buckyball, a spherical fullerene molecule with the molecular formula C_{60} (**Figure 5, left**, source: http://upload.wikimedia.org/wikipedia/commons /4/41/C60a.png) as well as other fullerene molecules such as carbon nanotubes (cylindrical fullerenes, **Figure 6, below,** source: http://static.guim.co.uk/sys-images/Guardian/Pix/pictures

/2008 /05/20/nanotube.article.jpg). (The name “fullerene” was coined to honor Buckminster Fuller, whose geodesic domes it resembles.)



In the case of nanotubes, their special molecular structure results in particularly useful physical properties, such as high tensile strength and excellent electrical and heat conductivity. (Of interest, the chemical bonding of nanotubes is composed entirely of sp^2 bonds, similar to those of graphite. These bonds provide nanotubes with their unusual tensile strength.)

Safety

A number of safety issues in relation to nanotechnology are being studied, as it not well known what happens when nanoparticles are dispersed into the environment [4,5]. It is suspected, however, that nanoparticles of materials that are harmless at their full size may be harmful at sizes small enough to enter cell nuclei and “wreck havoc” by causing nuclear changes. On the other hand, it is exactly this possibility that has some nanotechnology researchers are exploring as a novel means to overcome cancer drug resistance, since one of the tricks cancer cells use to evade anticancer therapy is by producing a protein that pumps drugs out of the cell before these compounds can exert their clinical effects. One idea is to use iron oxide-titanium dioxide nanoparticles to bypass this pump and enable cancer drugs to reach the cell nucleus [6].

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Further Reading (All papers are "Free Full Text" with *no subscription barrier*)

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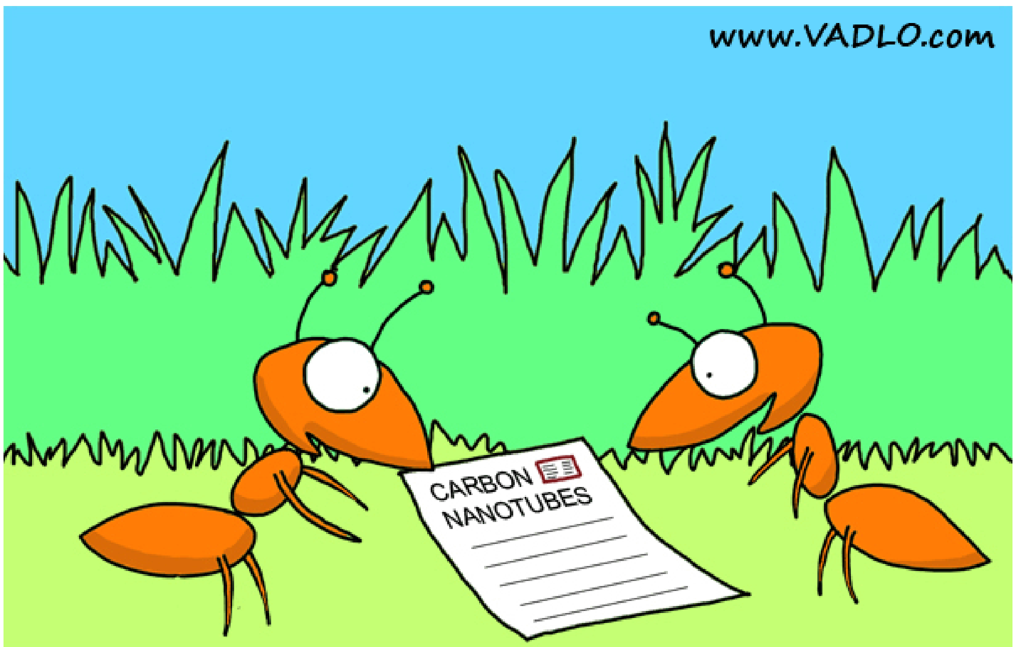

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