
Introduction, history and Timeline of Nanobiotechnology

Abstract

It all began in the winter of December 1959 in a meeting at the California Institute of Technology (CalTech) when a rather modest scientist (136 IQ compared to 142 of Einstein) who went by the name of Richard Feynman delivered a lecture titled “**There is plenty of room at the bottom**”. Although it did not include the term “Nanotechnology”, the ideas and concepts of nanotechnology were the principal objective of the lecture.

Feynman’s lecture opened up a new area of physics altogether. He described a process in which scientists could control and manipulate atoms and or anything which was in the size range 10^{-9} meters. This revolutionized the entire world of physics and now we have the use of Nanotechnology everywhere, from fluoride nano-crystals in your toothpaste to gold nano particles’ use in the early detection of Cancer to future uses of nanobots to cure diseases spontaneously.

Lecture I

Introduction

In December 1959, Richard Feynman delivered a lecture on manipulation and control of individual atoms and molecules at the California Institute of Technology called “*There is plenty of room at the bottom*”, which acted as founding step of nanotechnology and opened up a new branch all-together for Physicists.



After almost a decade in his exploration of ultra-precision machining, Norio Taniguchi used the term “nanotechnology” for the first time^[1] and later it was popularized by Drexler^[2], and thus began the journey of nanotechnology and its related branches.

The term “nano” has been derived from the Greek word “*nanos*” which means dwarf. The National Nanotechnology Initiative defines nanotechnology as “The manipulation of matter with at-least one dimension sized between 1 to 100 nanometers” (It is imperative that one of the dimensions should be between 1 to 100 nanometers for quantum mechanical effects to take place).

So how much exactly is one nanometer?

- There are 25,400,00 nanometers in one inch;
- On a comparative scale, if a marble were a nanometer, then one meter would be the size of the earth.

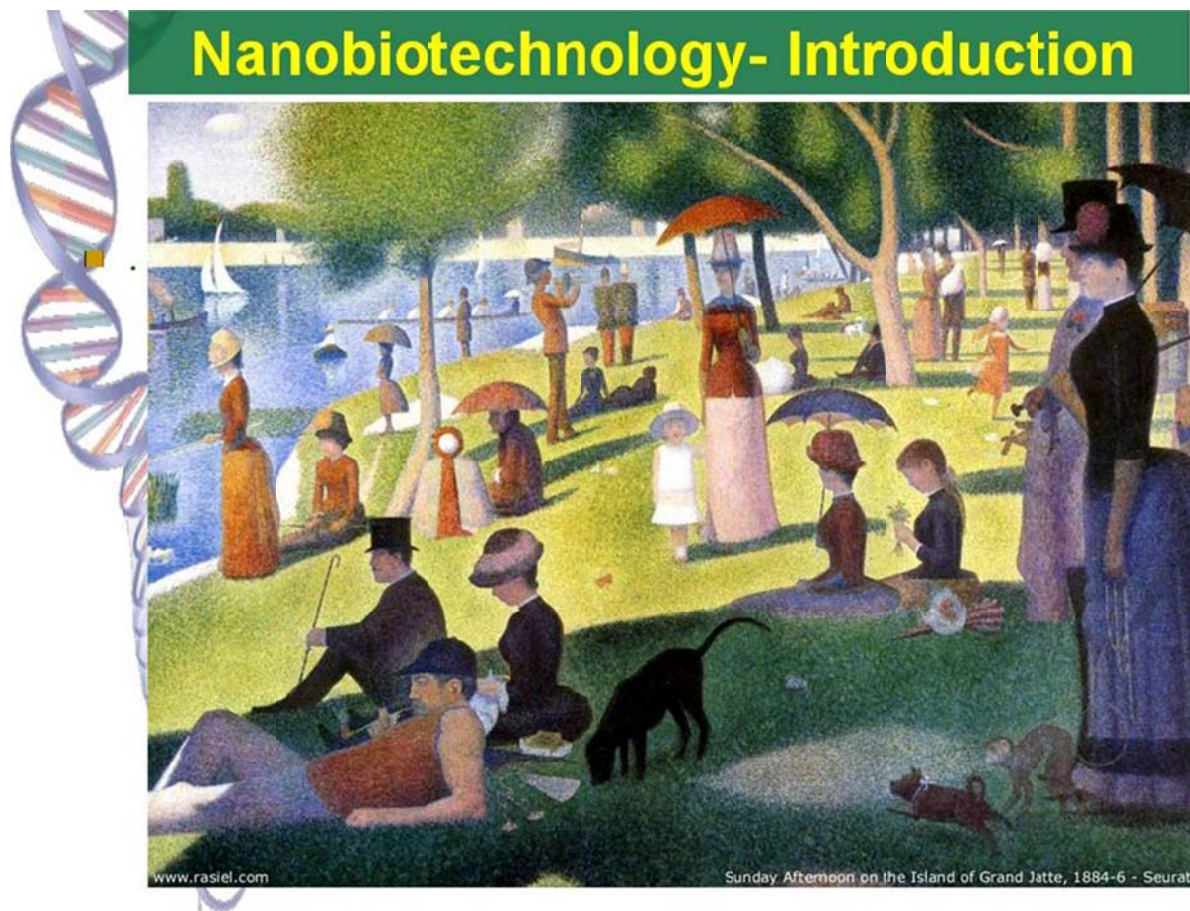
The ability to manipulate atoms and molecules at the molecular level itself is a very exciting thing, but the fact that we could use it for our benefit is even more mind-boggling. This was the exact reaction of scientists of that time, but they did not even have the apparatuses to observe these atoms, manipulating these atoms was a very far off thing. But after the ascent of the STM (Scanning Tunneling Microscope)^[3] and the AFM (Atomic Force Microscope)^[4], Nanotechnology gained a very positive push towards the right direction.

Even though nano-science and nanotechnology as a branch of science is quite new, nanoscale materials have been used from a long time. If you might have seen the stained glass windows of medieval churches, you have seen a spectacle of nano-science magic. The artists creating these stained glass windows used alternate sized silver and gold particles. The process they used to create these glass windows led to the changes in the composition of the materials they were working with.

In the present scenario, scientists use a wide variety of techniques and methods to create nanoscale devices as they are more durable, have a higher strength, lighter weight and other enhanced properties than materials of normal sizes ($>10^{-9}$).

Essence of Nanotechnology

Beauty of Fine Dots – Making sense of small nothings – Seurat :Sunday afternoon on the Islands of Grand Jette.



Michael Faraday provided the first description, in scientific terms, of the optical properties of nanometer-scale metals in his classic 1857 paper. In a subsequent paper, another author (Turner) points out that: "It is well known that when thin leaves of gold or silver are mounted upon glass and heated to a temperature which is well below a red heat ($\sim 500\text{ }^{\circ}\text{C}$), a remarkable change of properties takes place, whereby the continuity of the metallic film is destroyed. The result is that white light is now freely transmitted, reflection is correspondingly diminished, while the electrical resistivity is enormously increased

The term "nanotechnology" was first coined by Eric Drexler in 1981, while a graduate student at MIT.

A nanometer is about three to five atoms wide.

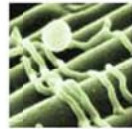
The idea behind nanotechnology-- manipulating atoms to build things-- was actually first proposed by Nobel-prize winning physicist Richard Feynman in 1959.

Nanobiotechnology is an emerging field of research at the crossroads of biotechnology and nanoscience, and involved in many different disciplines, including physicists, chemists, engineers, information technologists, and material scientists, as well as biologists.

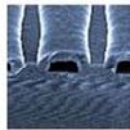
Nanoscale materials (nanoparticles, nanopores, nanoshells, nanostructures, etc) allow highly sensitive detection by specific interactions with various biomolecules on both the surface and inside the cells.

What is Nanobiotechnology?

Biotechnology is the application of technological innovation as it pertains to biological and life sciences.

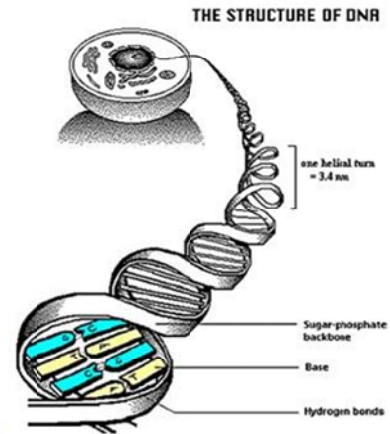


Nanobiotechnology incorporates biotechnology on the nano-scale.

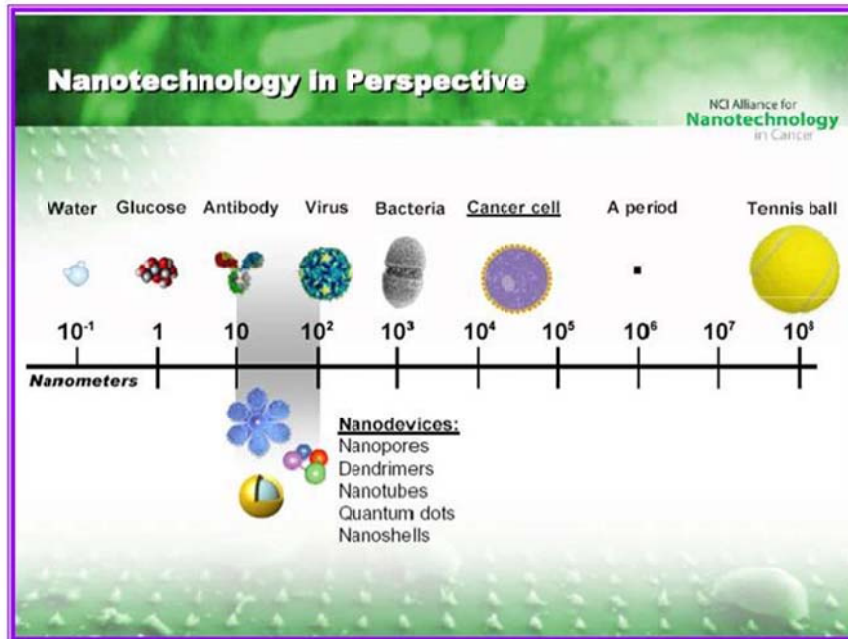


Size Ranges of Biological Material

- Cells: 100 μ m - 10 μ m
- Cell organelles (nucleus, mitochondrion): 10 μ m - 1 μ m
- Viruses: 100nm - 50nm
- Cell material (proteins, lipids, DNA, RNA): 10nm - 0.1nm

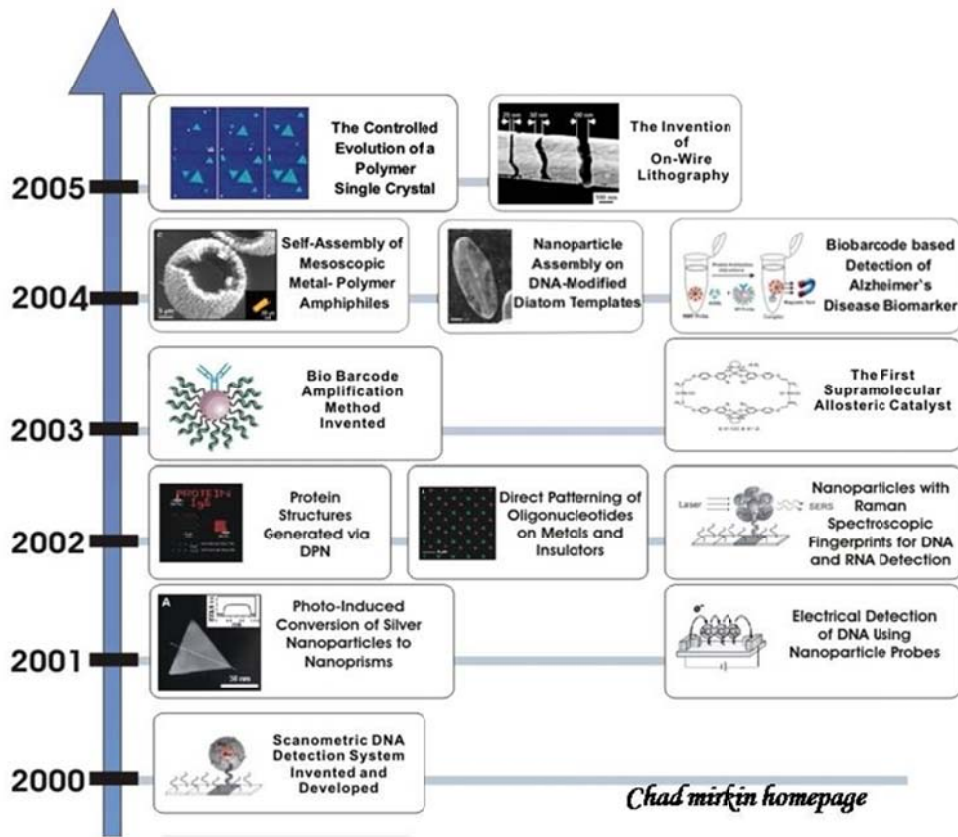


Nanotechnology



Characteristics of "nano"

- The object of biological studies is often by nature of nano scale, but in general they are not regarded as nano.
- Single molecule approach is by convention also called nano.
- Key question:
what extra information is obtained from SMA?
Great progress lately.



Sensitivity

The challenge:

- immunoassays work until > 10 fmolar ($\sim > 10^6$ molecules / 100 μ l)
- nucleic acid amplification (e.g. PCR, NASBA, TMA) can detect single targets, but works only for genetic material (DNA/RNA)
- no amplification method very low concentrated proteins exists

Unmet need:

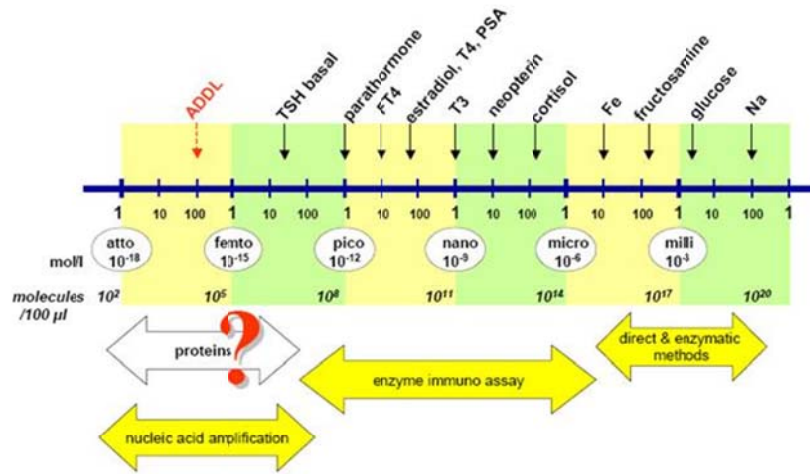
- lower assay sensitivity for proteins by several orders of magnitude

Nanotechnology potential:

- labels with better signal yield and S/N ratio
 - *quantum dots*
 - *nanoparticles*
 - *"bio-barcode assay"*

Sensitivity

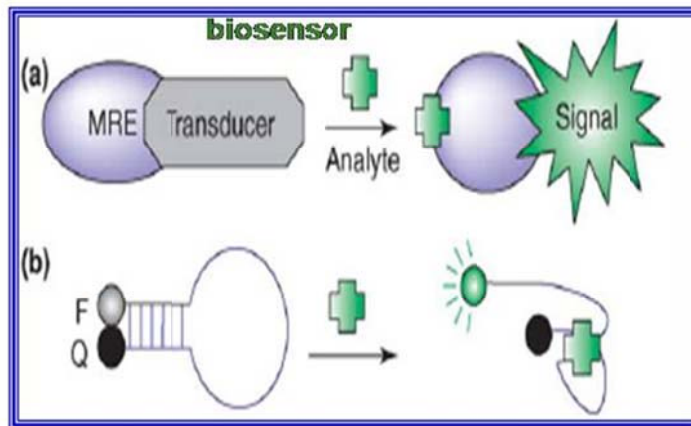
detection requirements for diagnostically relevant targets



Nanoparticle characterization is necessary to establish understanding and control of nanoparticle synthesis and applications. Characterization is done by using a variety of different techniques, mainly drawn from materials science. Common techniques are

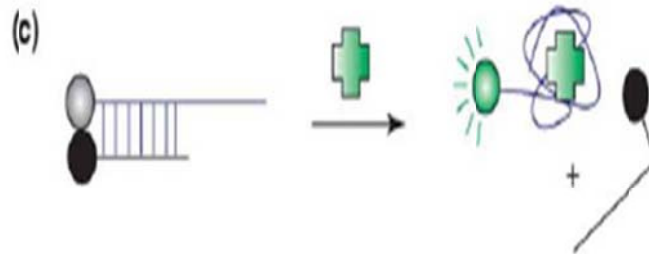
- 1. electron microscopy (TEM, SEM),**
- 2. atomic force microscopy (AFM),**
- 3. dynamic light scattering (DLS),**
- 4. x-ray photoelectron spectroscopy (XPS),**
- 5. powder X-ray diffraction (XRD),**
- 6. Fourier transform infrared spectroscopy (FTIR),**
- 7. matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF),**
- 8. ultraviolet-visible spectroscopy,**
- 9. dual polarisation interferometry and**
- 10. nuclear magnetic resonance (NMR).**

Molecular Beacon Approach as a biosensor

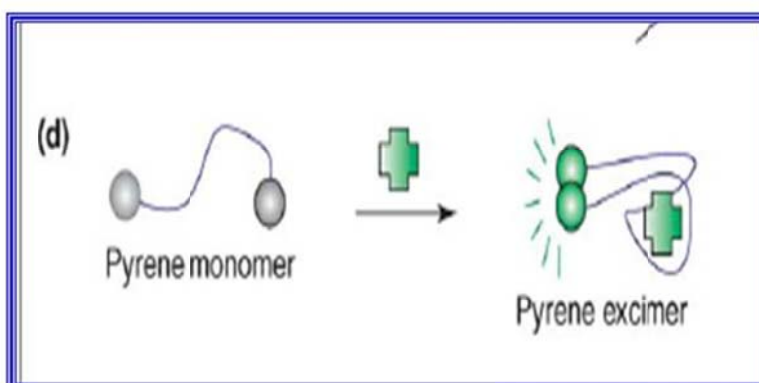


N. K. Navani & Yingfu Li (2006) curr.opin. Chem. @iol.10:1 . 1-10

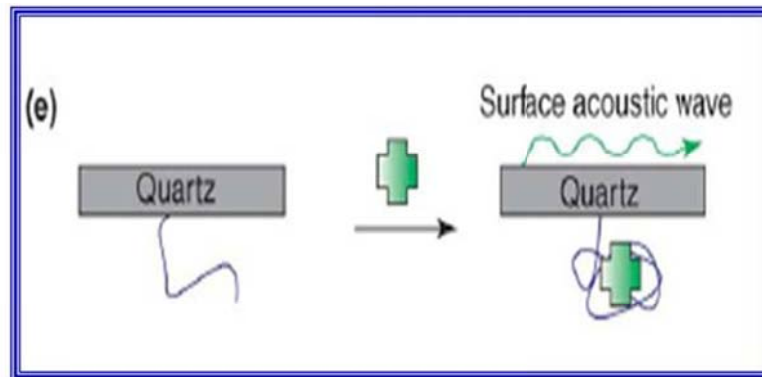
Duplex to complex switching Approach



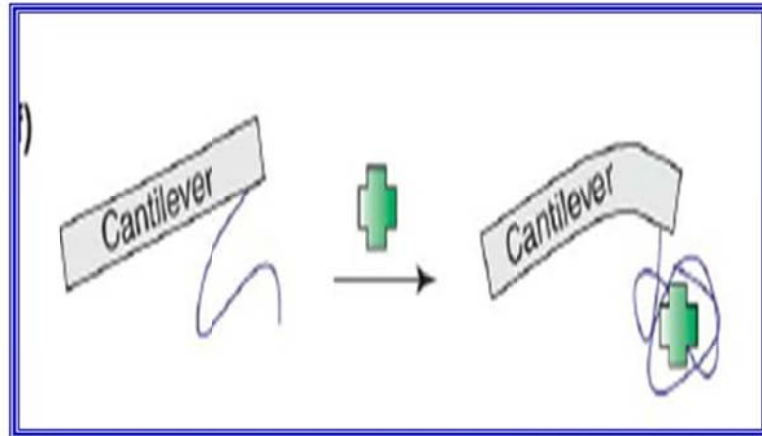
Excimer Aptamers



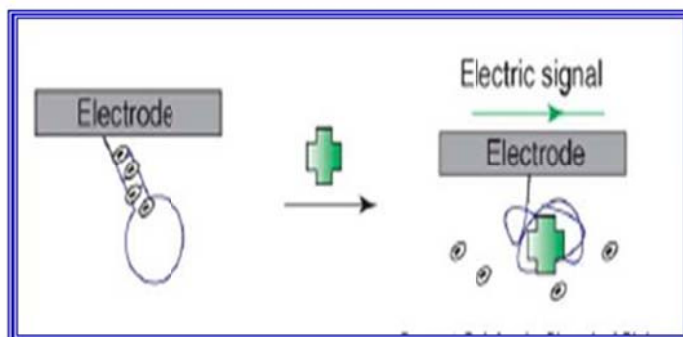
Acousting sensing



Cantilever based sensing



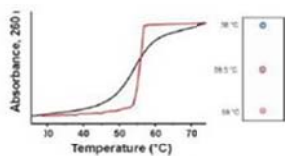
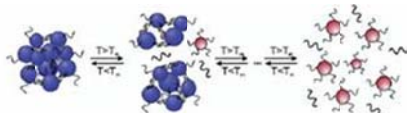
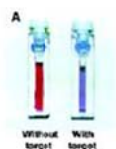
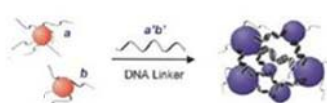
Electrochemical sensing



Aptamer for Aptamer-Protein interaction

Gold nanoparticle based sensing

DNA-labeled gold nanoparticles



- very sharp melting range (1 °C)
- precise detection of single base mismatch
- improved assay performance

Jin et al., 1644 J. AM. CHEM. SOC. 9 VOL. 125, NO. 6, 2003

What have we learnt?

- Not much just got sensitized about the field of nanobio technology.



**The Future is Coming Sooner Than You
Think**

