



UNIVERSITÀ  
DEGLI STUDI  
DI TRIESTE



**DSCF**

Dipartimento di  
**Scienze Chimiche  
e Farmaceutiche**

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**CORSO LM in Biotecnologie Mediche e Diagnostiche**

**NANOBIOTECNOLOGIE**

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Codice team: **18odtco**

5 + 1 CFU

Anno Accademico 2024/2025

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# CONTENUTI DEL CORSO

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- **introduzione all'insegnamento:** presentazione del programma e modalità della verifica

**Introduzione ai nanomateriali**, classificazione di materiali, sistemi, dispositivi nanostrutturati. Scala delle dimensioni coinvolte ed effetto sulle proprietà. Descrizione di alcune proprietà.

- **monostrati organici in 2-D e in 3-D**
  - Tecniche nanolitografiche, preparazione di dispositivi per lo studio di biomolecole, DNA, Proteine, ecc.
  - Preparazione, purificazione, caratterizzazione, modifica di nanoparticelle ibride organiche-inorganiche  
Applicazioni di nanoparticelle  
Tossicità
  - fullereni, nanotubi di carbonio e altri carbon based (nano)materials  
proprietà, sintesi, applicazioni
  - Liposomi, dendrimeri e nanoparticelle polimeriche  
applicazioni

## MATERIALE DIDATTICO

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files di diapositive del docente su MsTeams  
alcuni articoli di letteratura su MsTeams/MOODLE

## MODALITÀ svolgimento della VERIFICA

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valutazione relazioni e attività di laboratorio ed esame orale:  
discussione sull'attività di laboratorio e poi domande su altri  
argomenti presentati a lezione.

## ORARIO

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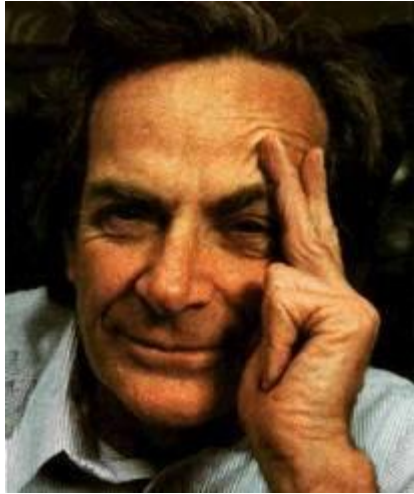
**Lezioni:** 4 ore la settimana

mercoledì 10:15 – 12.00 Aula A6/C11  
venerdì 10.15 – 12.00 Aula A7/C11

**Ricevimento studenti:**

su appuntamento via e-mail

**LABORATORIO:** 24 ottobre, 7 e 14 novembre, 9-13, terzo piano Ed. C11



In December of **1959**, the eminent physicist **Richard Feynman** (1965 Physics Nobel Prize) described the future in a groundbreaking talk entitled “**Plenty of Room at the Bottom**” about the physical possibilities for “*making, manipulating, visualizing and controlling things on a small scale,*” and imaging that in decades to come, it might be possible to arrange atoms “*the way we want.*”

*“Why cannot we write the entire 24 volumes of the Encyclopaedia Britannica on the head of a pin?”*

*“..... and there is no question that there is enough room on the head of a pin to put all of the Encyclopaedia Britannica.”*

# What is nano?

**nano** deriva dal greco *νανο*

**Nanoscience** refers to the science and manipulation of chemical and biological structures with dimensions in the range from 1-100 nanometers.

Nanoscience building blocks may consist of anywhere from a few hundred atoms to millions of atoms. On this scale, new properties (electrical, mechanical, optical, chemical, and biological) that are fundamentally different from bulk or molecular properties can emerge.

Nanoscience **is about creating new chemical and biological nanostructures**, uncovering and understanding their novel properties, and ultimately about learning how to organize these new nanostructures into larger and more complex functional structures and devices.

Nanoscience **is a new way of thinking** about building up complex materials and devices by exquisite control of the functionality of matter and its assembly at the nanometer-length scale.

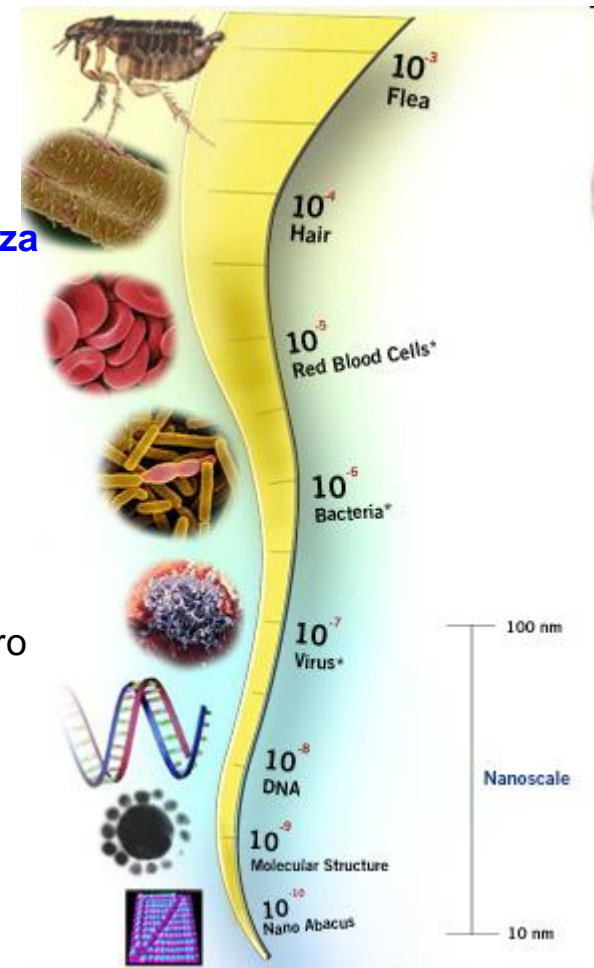
Nanoscience inherently bridges disciplinary boundaries. The "nano" length scale requires the involvement of chemical concepts at the atomic and molecular level.

# Nanoscale

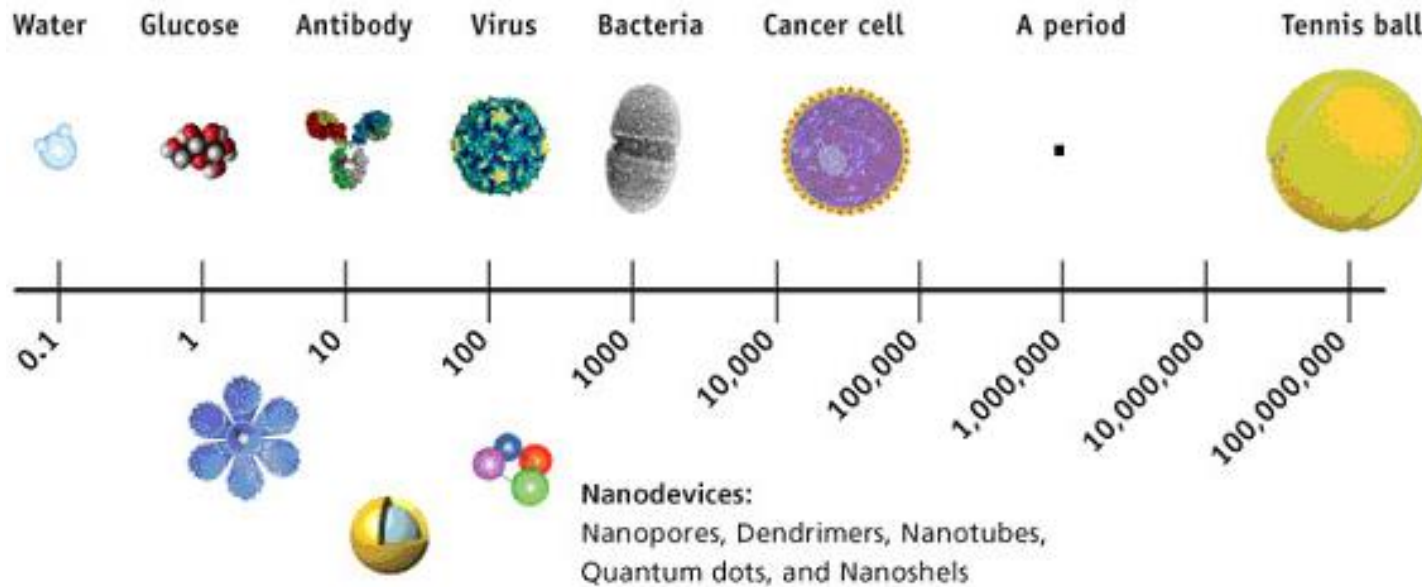
Nanoscale objects have at least one dimension (height, length, depth) that measures between 1 and 999 nanometers (1-999 nm).

## *unità di misura abbreviazione descrizione*

<b>metro</b>	<b>m</b>	<b>unità base SI della lunghezza</b>
centimetro	cm	$1 \times 10^{-2}$ m (0.01 m)
millimetro	mm	$1 \times 10^{-3}$ m (0.001 m)
micrometro	$\mu\text{m}$	$1 \times 10^{-6}$ m
nanometro	nm	$1 \times 10^{-9}$ m la billionesima parte di 1 metro o $10 \text{ \AA}$

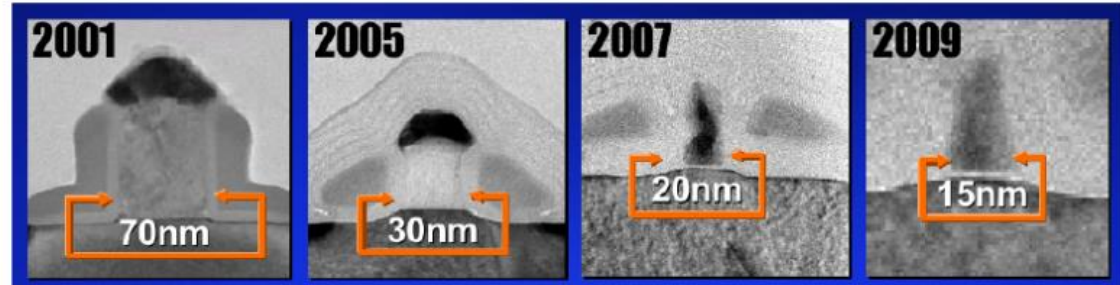
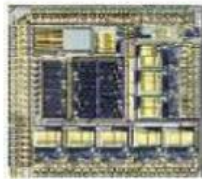


# nanometer



# Why Nano?

Much of the motivating force and technology for nanotechnology came from integrated circuit industry



Intel's transistors

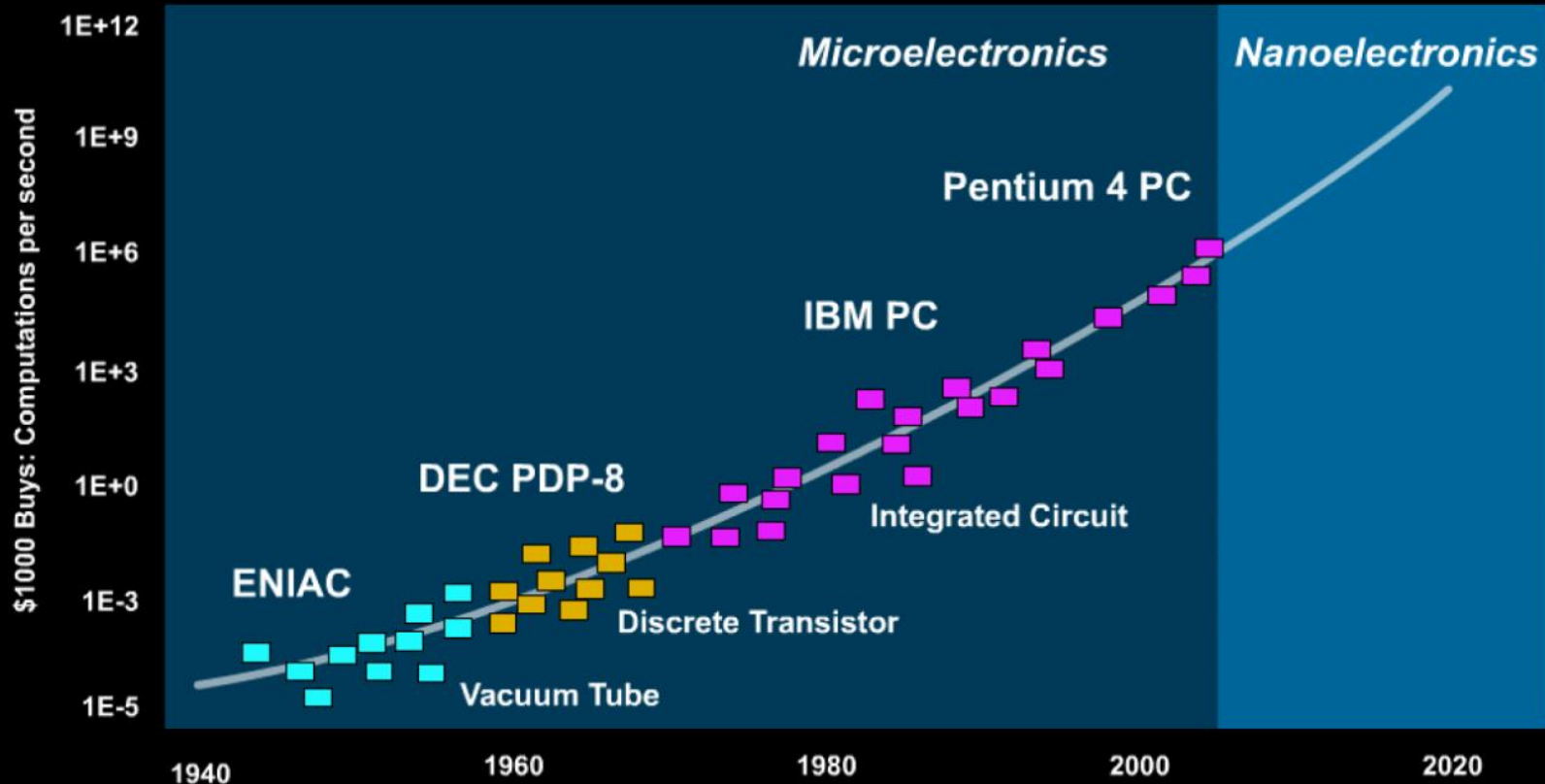
As with the fabrication of integrated circuits, **nanotechnology** is based on building structures and systems at very small sizes

- to enhance performance and produce new properties and applications
- for many types of systems (mechanical, biological, chemical, optical) in addition to electronic



# Why Nano?

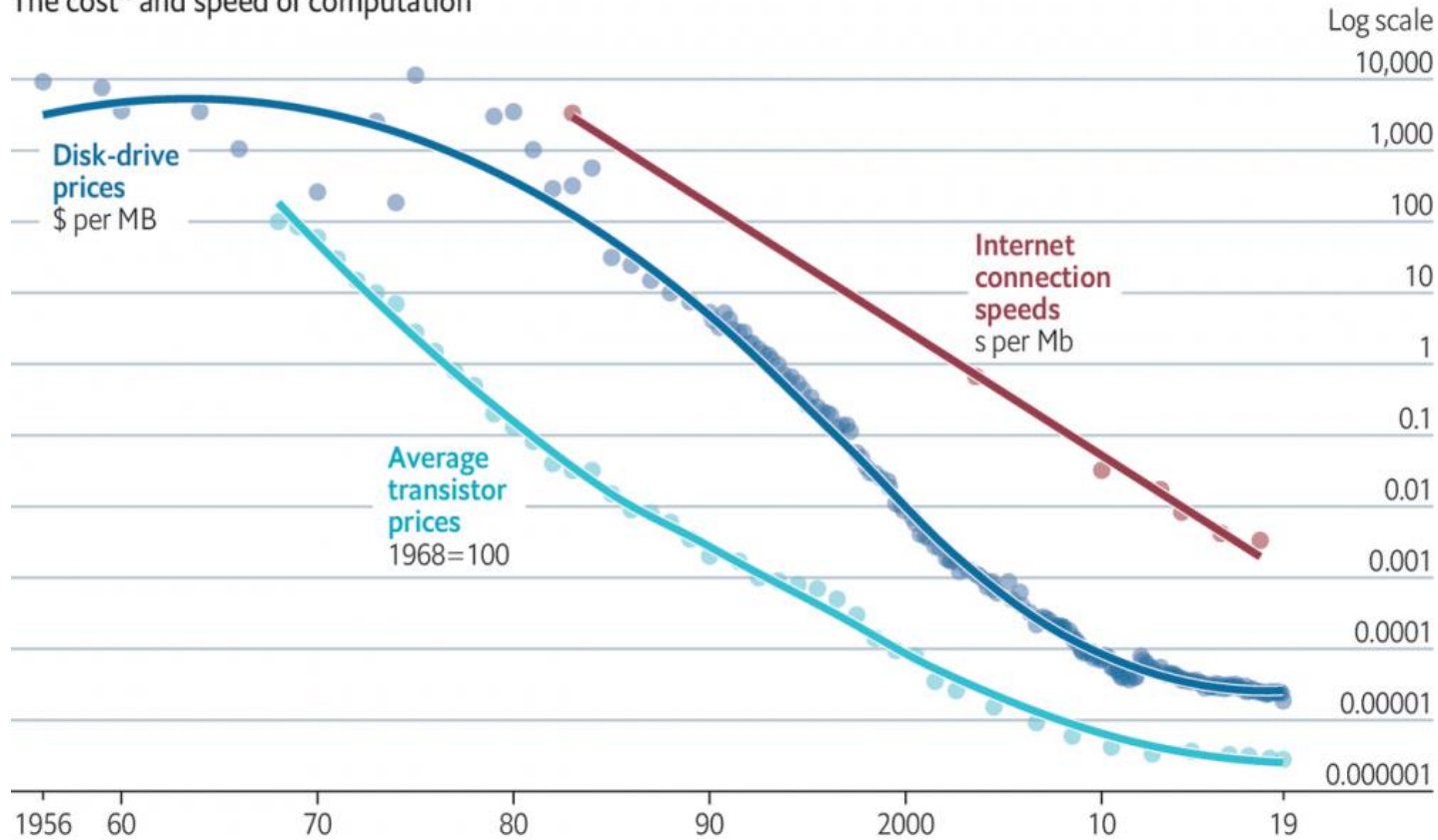
## Decreasing Costs of Computation



Source: Kurzweil 1999 – Moravec 1998

## Decline and fall

The cost\* and speed of computation



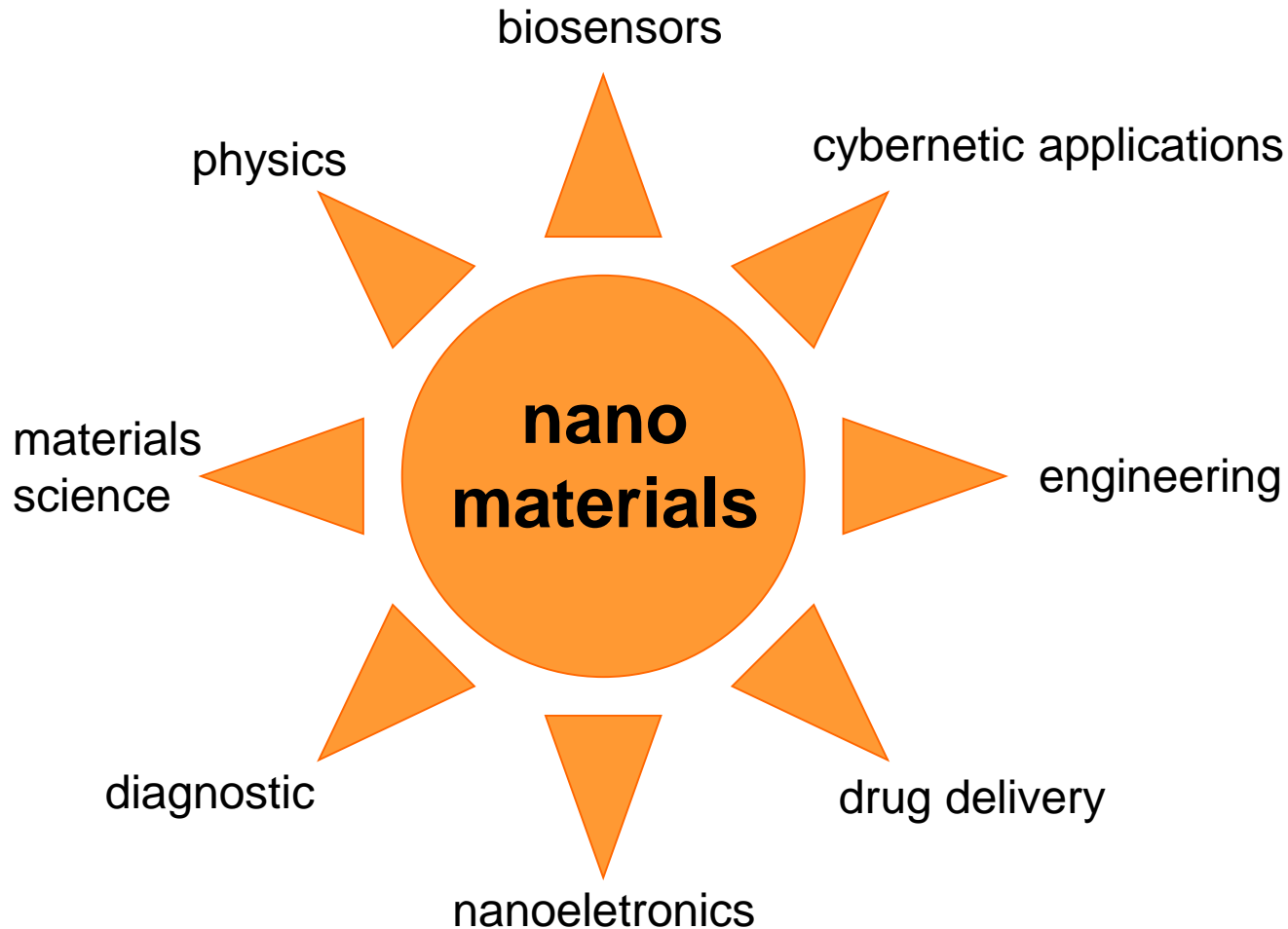
Sources: John C. McCallum; Gordon Moore; The Linley Group; Nielsen Norman Group; *The Economist*

\*Nominal prices

The Economist

The Economist: The price of computation today is roughly one hundred-millionth what it was in the 1970s, when the first microprocessors became commercially available (see chart). According to figures collected by John McCallum, a computer scientist, a megabyte of data storage in 1956 would have cost around \$9,200 (\$85,000 in today's<sub>10</sub> prices). It now costs just \$0.00002.

# design, creation and characterization of nanostructures and nanostructured materials



**Nanotechnology** is ...

*...research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1 –100 nm ...*

*National Science Foundation*

Le nanotecnologie operano in un ambito d'investigazione **multidisciplinare**, coinvolgendo molteplici settori di ricerca, tra cui:

- biologia molecolare,
- chimica,
- scienza dei materiali,
- fisica (sia applicata che di base),
- ingegneria meccanica,
- ingegneria chimica ed elettronica.

**Nanochimica:** l'insieme dei processi chimici che consentono di fabbricare nanomateriali a partire da semplici mattoni, “building blocks” e lo studio delle proprietà chimiche e della reattività dei nanomateriali.

# how do you observe something so small?

Tools are needed to image, analyze, and manipulate very small features  
-Scanning Probe Microscopy, including the Atomic Force Microscope (AFM) and Scanning Tunneling Microscopy (STM)

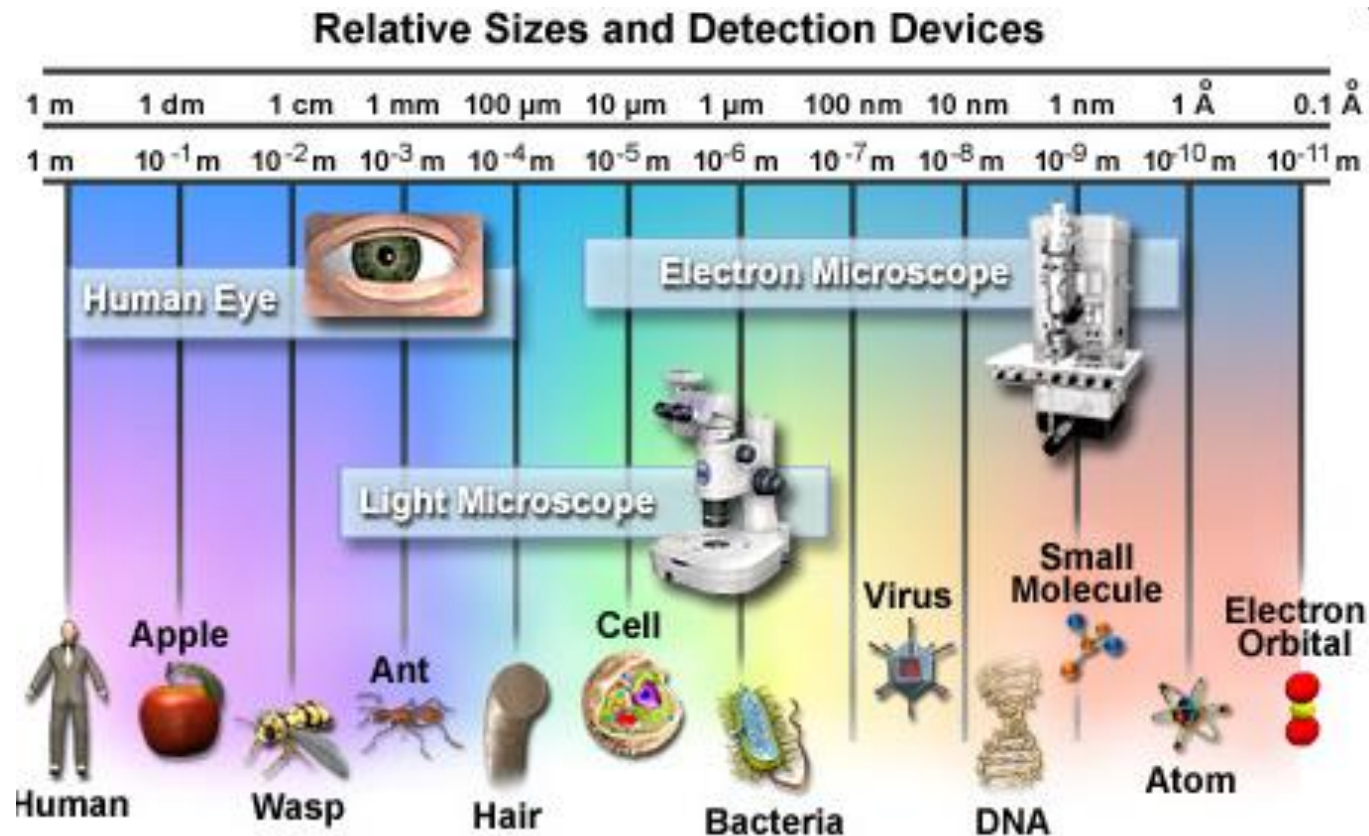


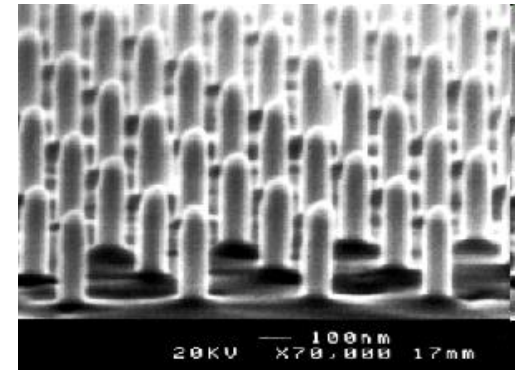
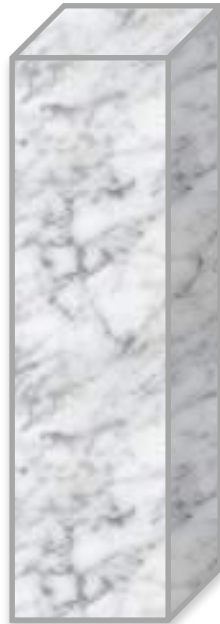
Figure 1

# Materiali supramolecolari organici

## *metodi di sintesi e fabbricazione di nanomateriali*

approccio **top-down**: ricavare un oggetto più piccolo da uno più grande.

Questa tecnica comporta la riduzione delle dimensioni di un materiale fino a 10-100 nm.



i dispositivi sono fabbricati da materiali macroscopici attraverso un attento controllo dei processi di miniaturizzazione a livello atomico.

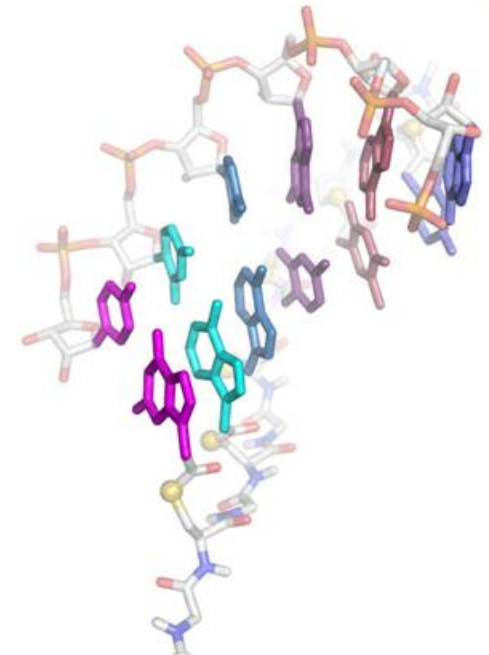
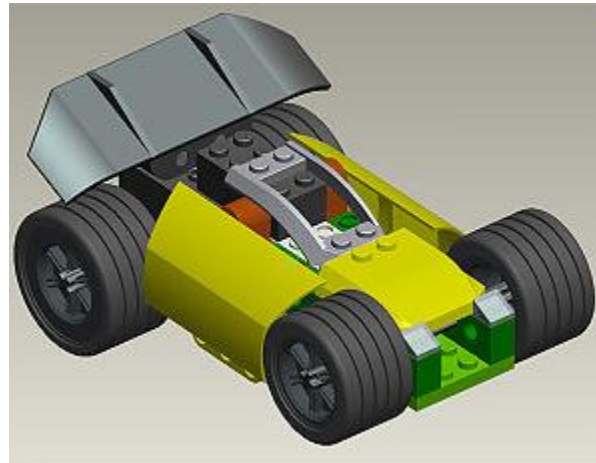
# Materiali supramolecolari organici

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## *metodi di sintesi e fabbricazione di nanomateriali*

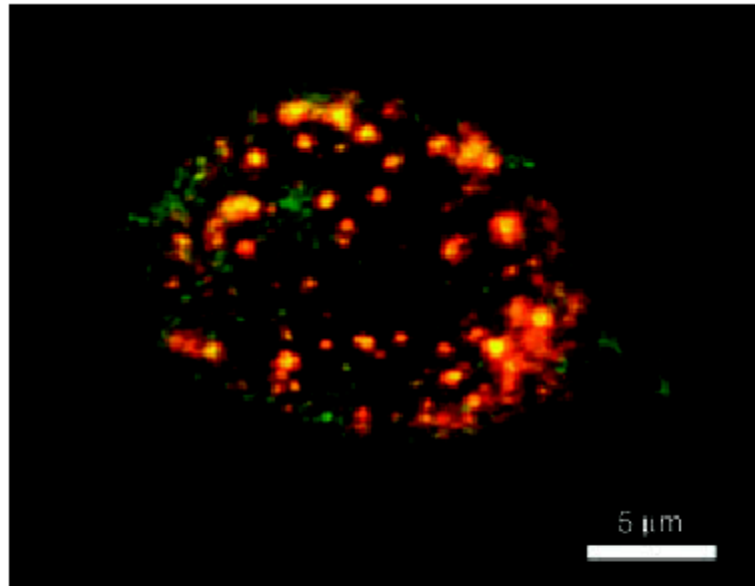
approccio **bottom up**: costruire dal basso usando elementi unitari, “building blocks”, per formare oggetti di dimensioni maggiori.

Il prodotto finale si ottiene assemblando progressivamente gli elementi costitutivi – atomi, ioni, molecole, nanoparticelle – per formare congegni, dispositivi, macchine a livello molecolare.



## 3D-Self-Assembled Monolayers

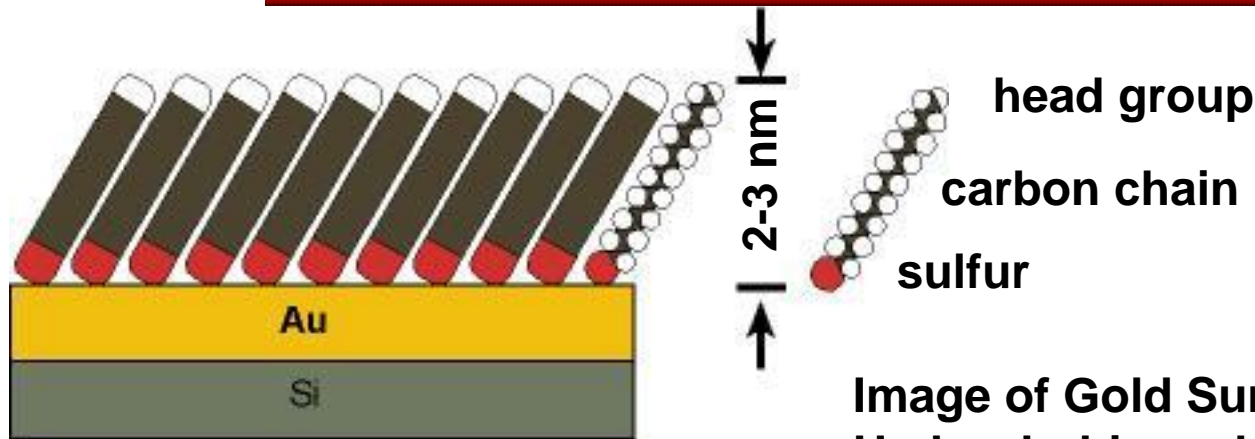
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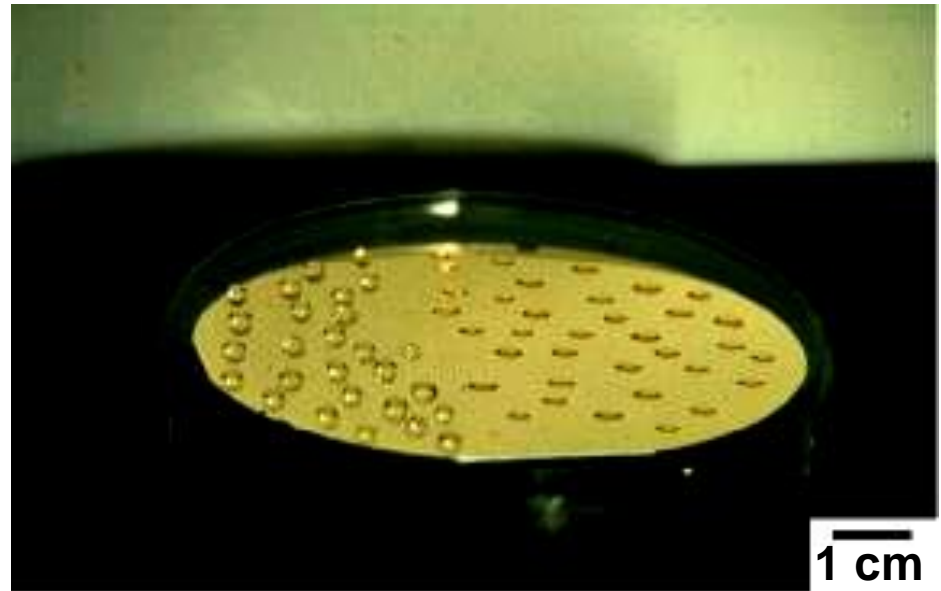
**Figure 4.** Image of a mammalian cell labeled with fluorescent, surfactant-stabilized, semiconductor quantum dots.<sup>[82]</sup> The resistance of these nanostructures to photobleaching makes them attractive in applications in which the sensitivity of molecular fluorophores to the exciting light is a serious impediment to their use.



# 2D-Self-Assembled Monolayers

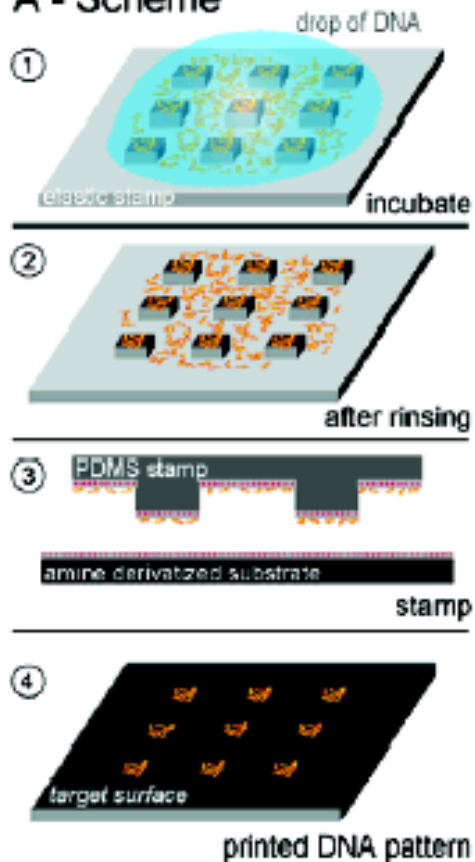


**Image of Gold Surface Patterned with Hydrophobic and Hydrophilic SAMs**

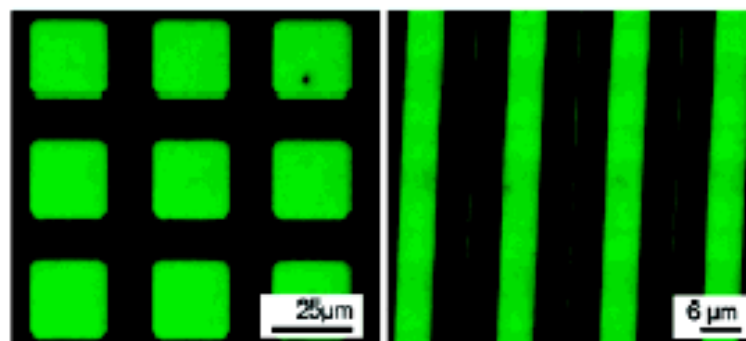


# Microcontact Printing DNA

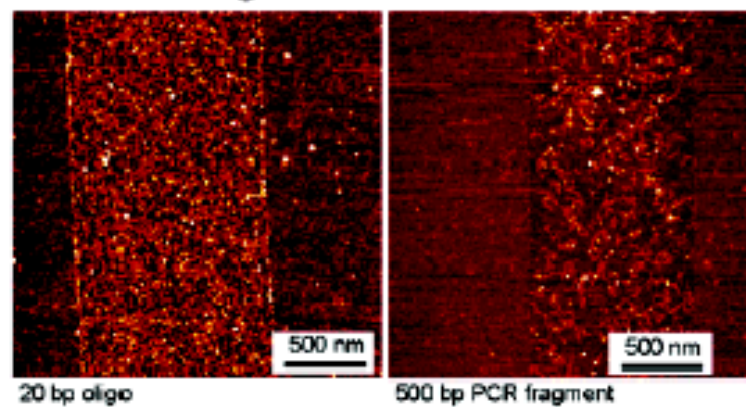
A - Scheme



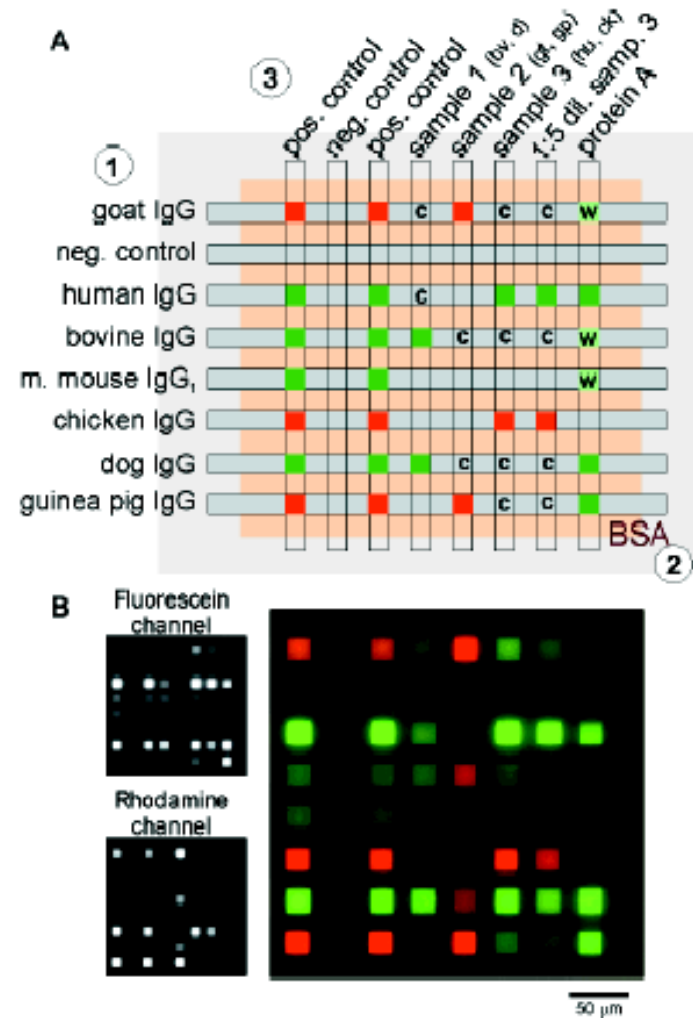
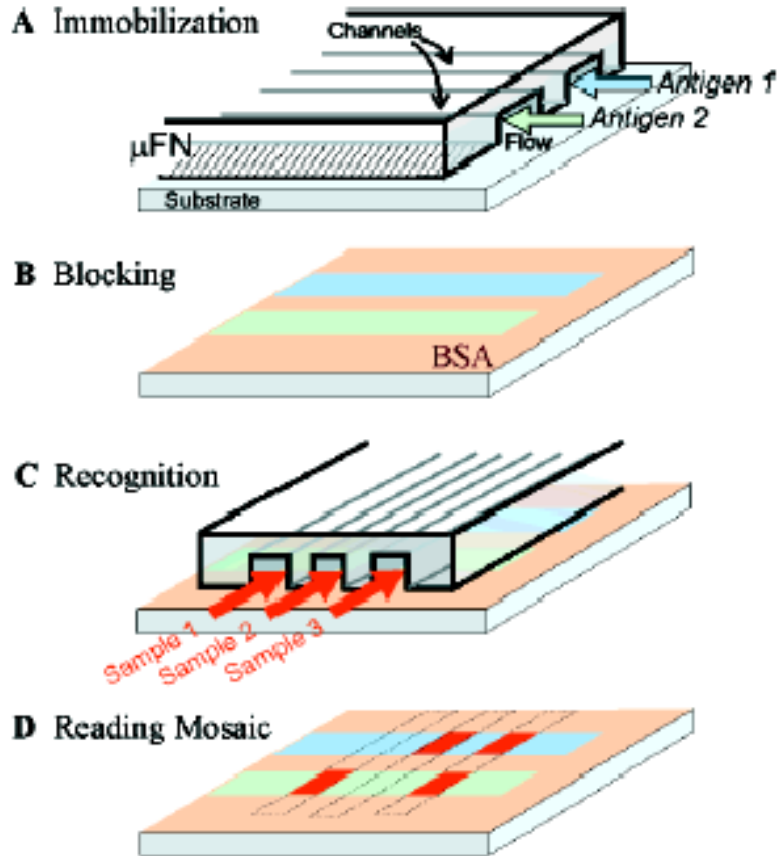
B - Fluorescence image



C - AFM image

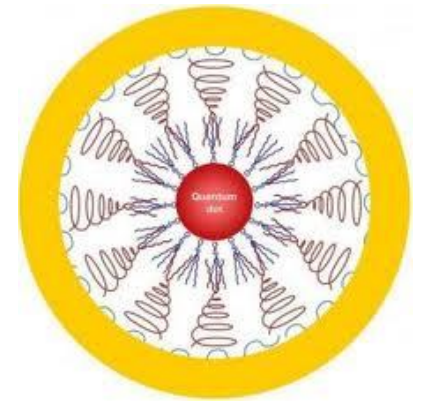
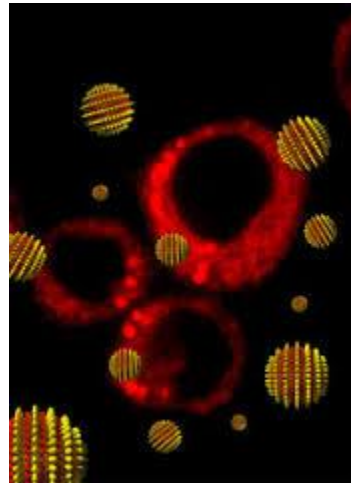
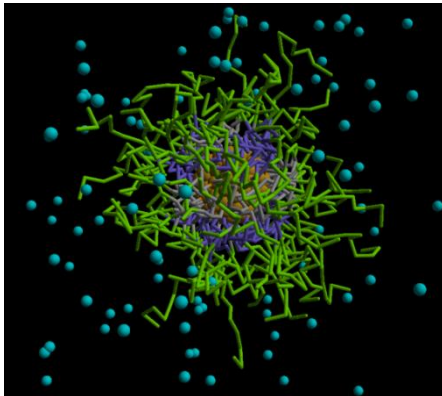
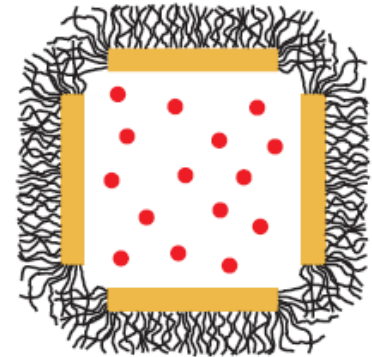
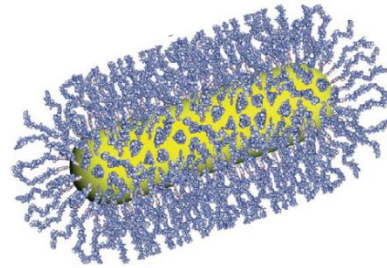
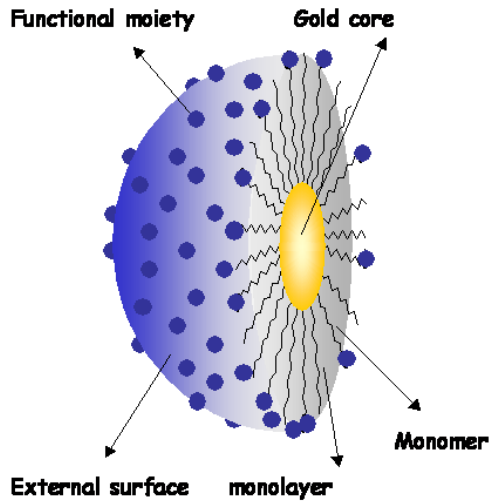


# Immunoassays



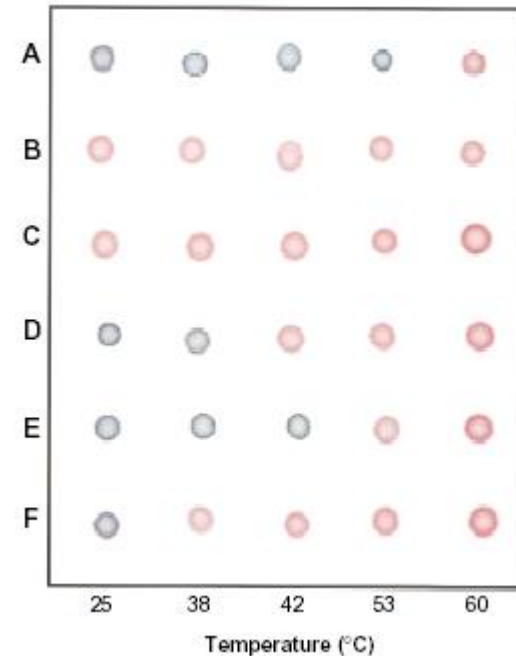
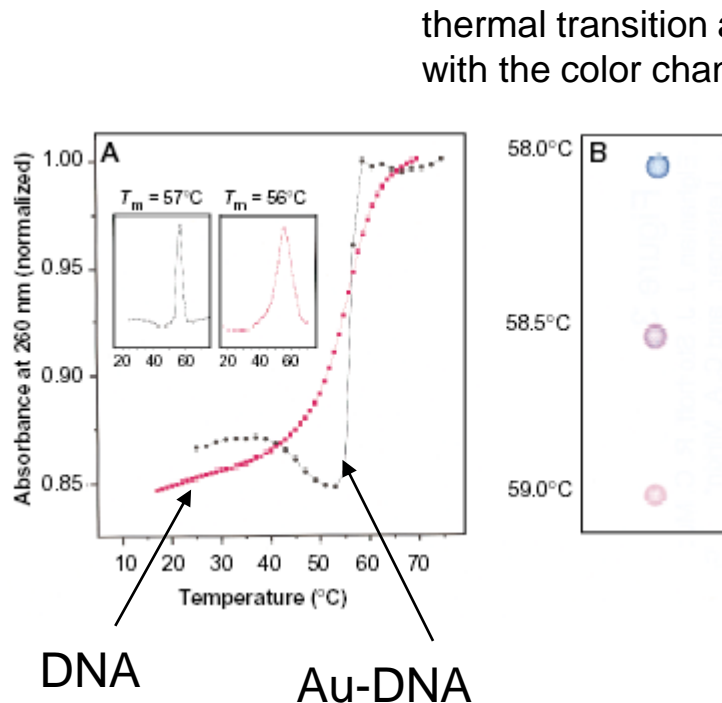
# NANOPARTICLES

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# Nanoparticle-based Sensors

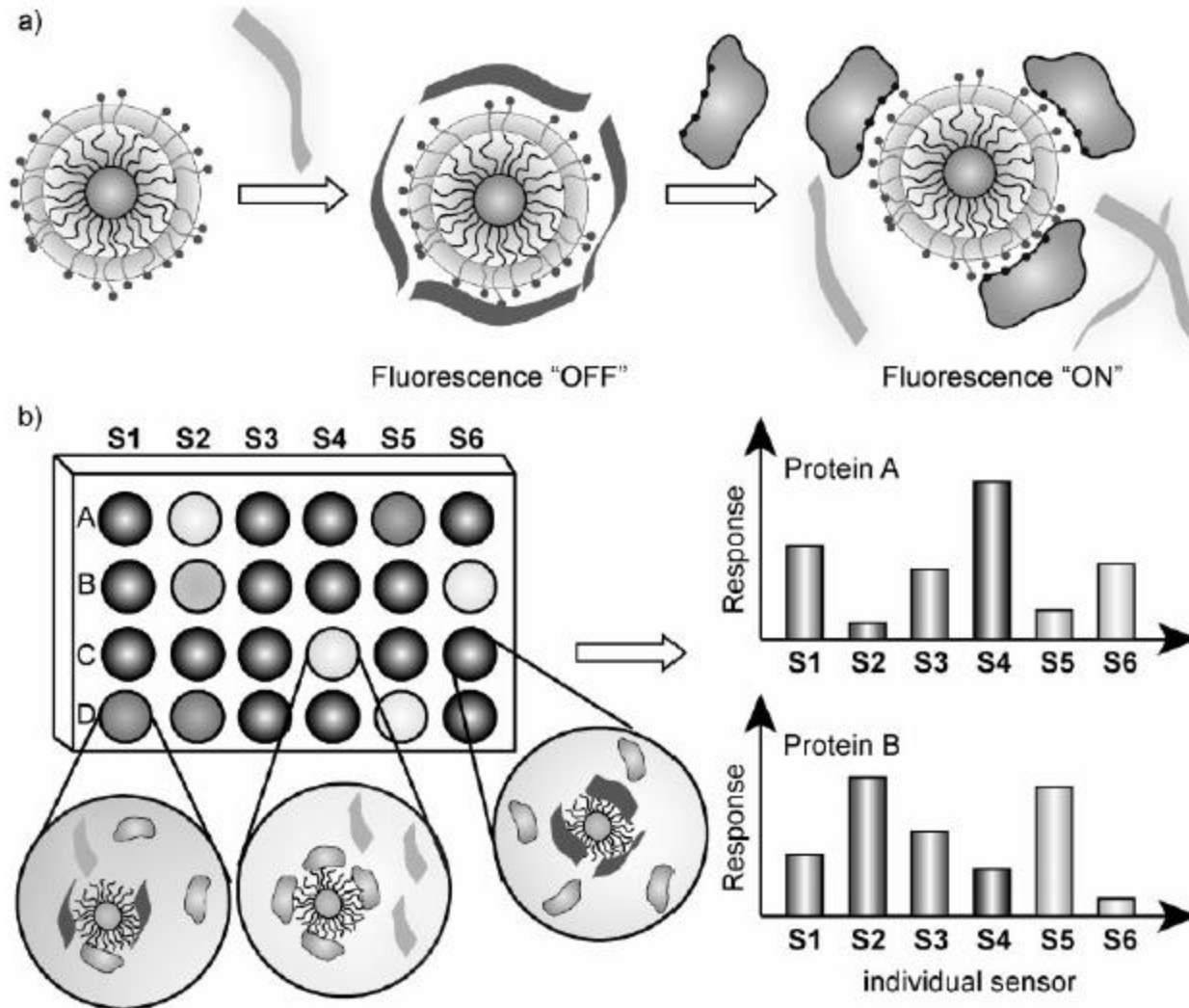
selective colorimetric detection system for polynucleotides



Selective polynucleotide detection for the target probes :  
**(A)** complementary target; **(B)** no target; **(C)** complementary to one probe; **(D)** a 6-bp deletion; **(E)** a 1-bp mismatch; and **(F)** a 2-bp mismatch. Nanoparticle aggregates were prepared in a 600- $\mu\text{l}$  thin-walled Eppendorf tube by addition of 1  $\mu\text{l}$  of a 6.6 $\mu\text{M}$  oligonucleotide target to a mixture containing 50  $\mu\text{l}$  of each probe (0.06  $\mu\text{M}$  final target concentration). The mixture was frozen (5 min) in a bath of dry ice and isopropyl alcohol and allowed to warm to room temperature. Samples were then transferred to a temperature controlled water bath, and 3- $\mu\text{l}$  aliquots were removed at the indicated temperatures and spotted on a C<sub>18</sub> reverse phase plate.

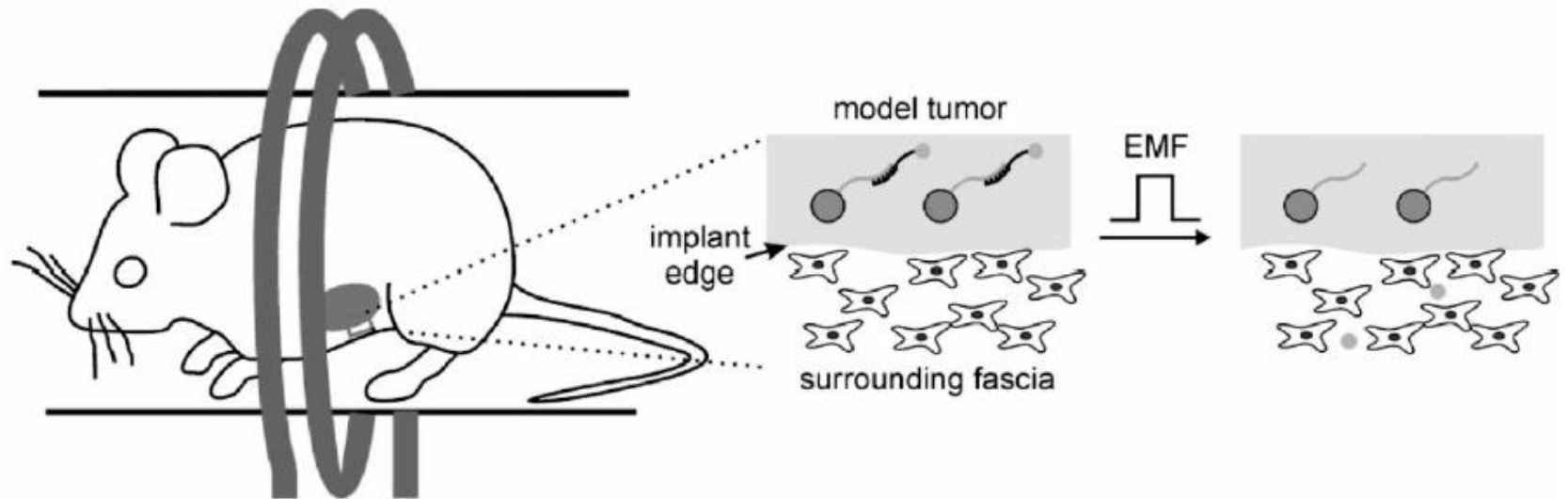
Elganian, R.; Storhoff, J.J.; Mucic, R. C.; Letsinger, R. L.; Mirkin, C. A. *Science* **1997**, 277, 1078-1081.

# Nanoparticle-based Sensors



**Figure 8.** Schematic drawing of a “chemical nose” sensor array based on nanoparticle and fluorescence assay. a) The competitive binding between protein and quenched polymer leads to the fluorescence light-up. b) The combination of an array of sensors generates fingerprint response patterns for individual proteins.

# Nanoparticles for new therapeutic strategies

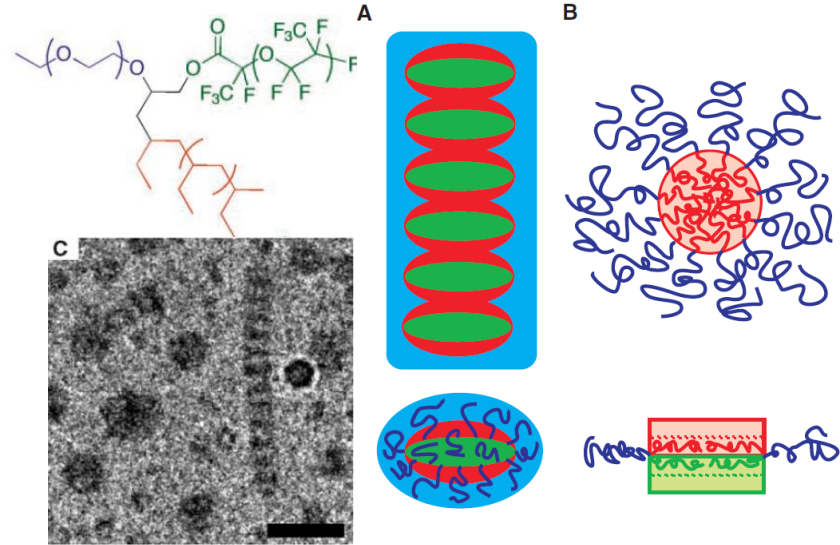


**Figure 12.** Controlled release of payloads using oligonucleotide-modified iron oxide nanoparticles for drug delivery at a remote location. Adapted with permission from [105].

# SOFT MATERIALS

## polymers/block copolymers

### block terpolymer

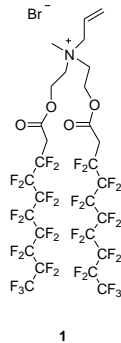
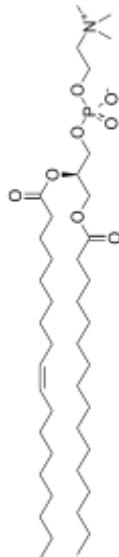
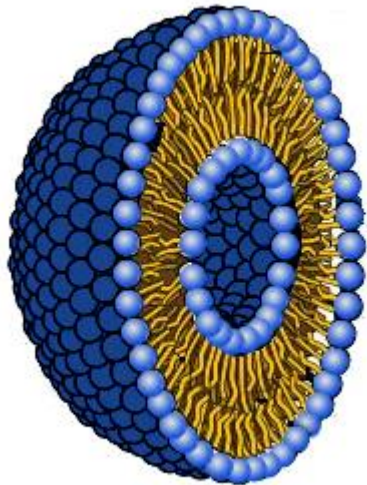


T. P. Lodge et al. *Science* **2004**, 306, 98

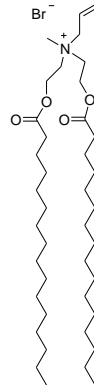
## liposomes

A **liposome** is an artificially-prepared vesicle composed of a lipid bilayer. The liposome can be used as a vehicle for administration of nutrients and pharmaceutical drugs.

Liposomes are often composed of phosphatidylcholine-enriched phospholipids and may also contain mixed lipid chains with surfactant properties such as egg phosphatidylethanolamine



1



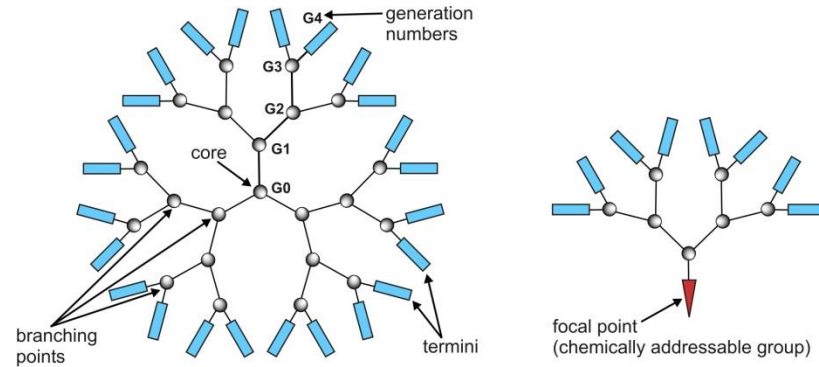
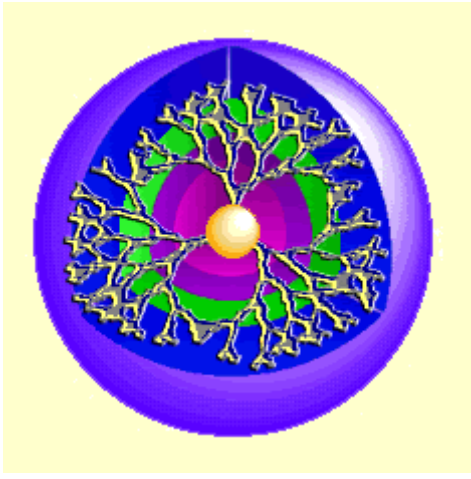
2



# DENDRIMERS

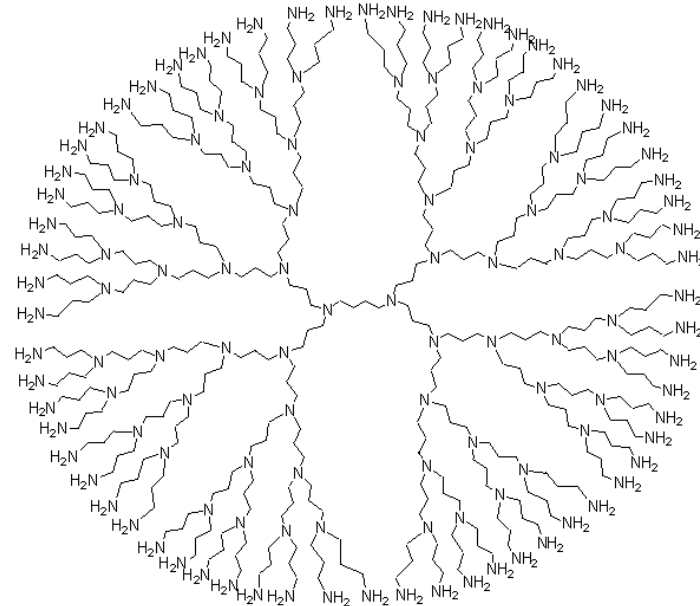
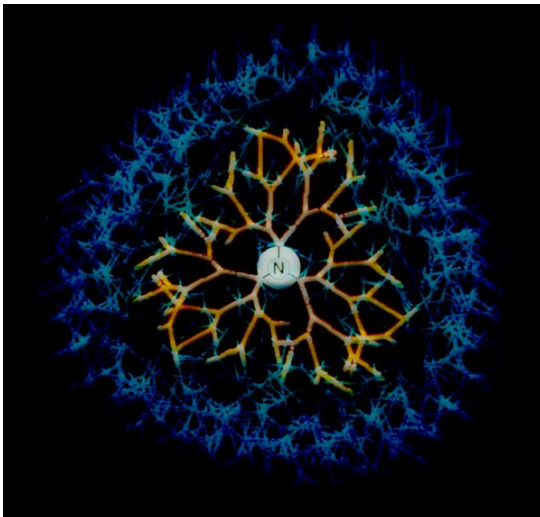
**Dendrimers** are repetitively branched molecules. The name comes from the Greek word δένδρον (**dendron**), which translates to "tree".

they are monodisperse and usually highly symmetric compounds



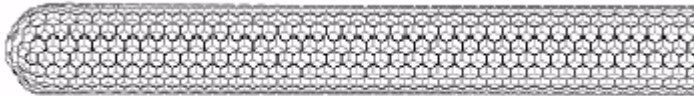
DENDRIMER

DENDRON



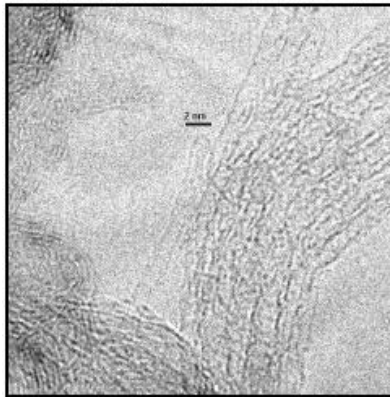
# materiali organici

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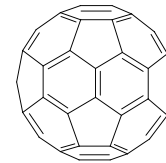


**SWCNT**  
**MWCNT**

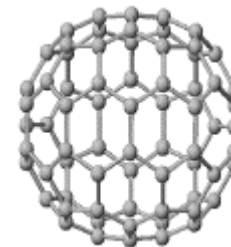
T = 1 (trasparenza elettronica)



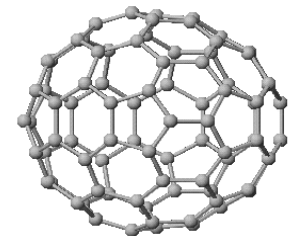
## FULLERENI



**C60**



**C70**



**C84**

## GRAPHENE

