Dipartimento di Scienze Chimiche e Farmaceutiche

CORSO DI LAUREA MAGISTRALE in Biotecnologie Mediche

curriculum: Nanobiotecnologie

NANOBIOTECNOLOGIE

Prof. Lucia Pasquato

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5 + 1 CFU

Anno Accademico 2021/2022

CONTENUTI DEL CORSO

- **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

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

MODALITÀ svolgimento della VERIFICA

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

ORARIO

Lezioni: 4 ore la settimana

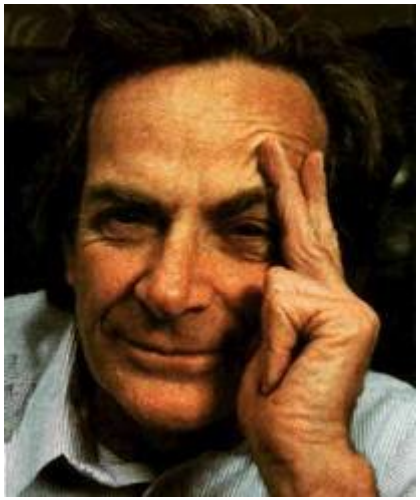
martedì 9.15 – 11.00
giovedì 9.15 – 11.00

Ricevimento studenti:

su appuntamento via e-mail

LABORATORIO: 11, 18 e 25 novembre, 14:30-18:30, terzo piano Ed. C11

Nano — The Interdisciplinary Science



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 Brittanica 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 Brittanica.*"

What is nano?

nano deriva dal greco $\nu\alpha\nu o$

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.

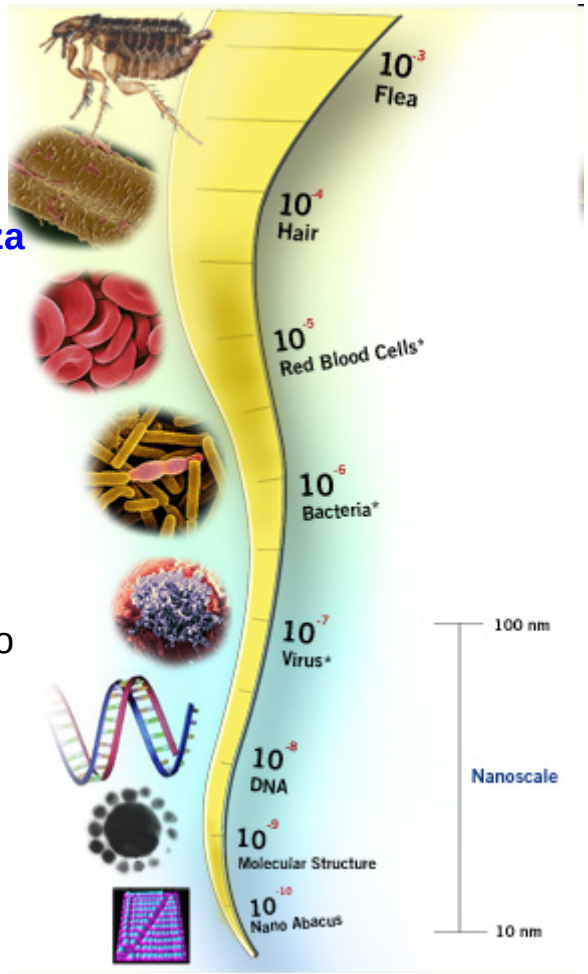
Nanoscience is a new way of thinking about building up complex materials and devices by exquisite control of the functionality of matter and its assembly at the nanometer-length scale.

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

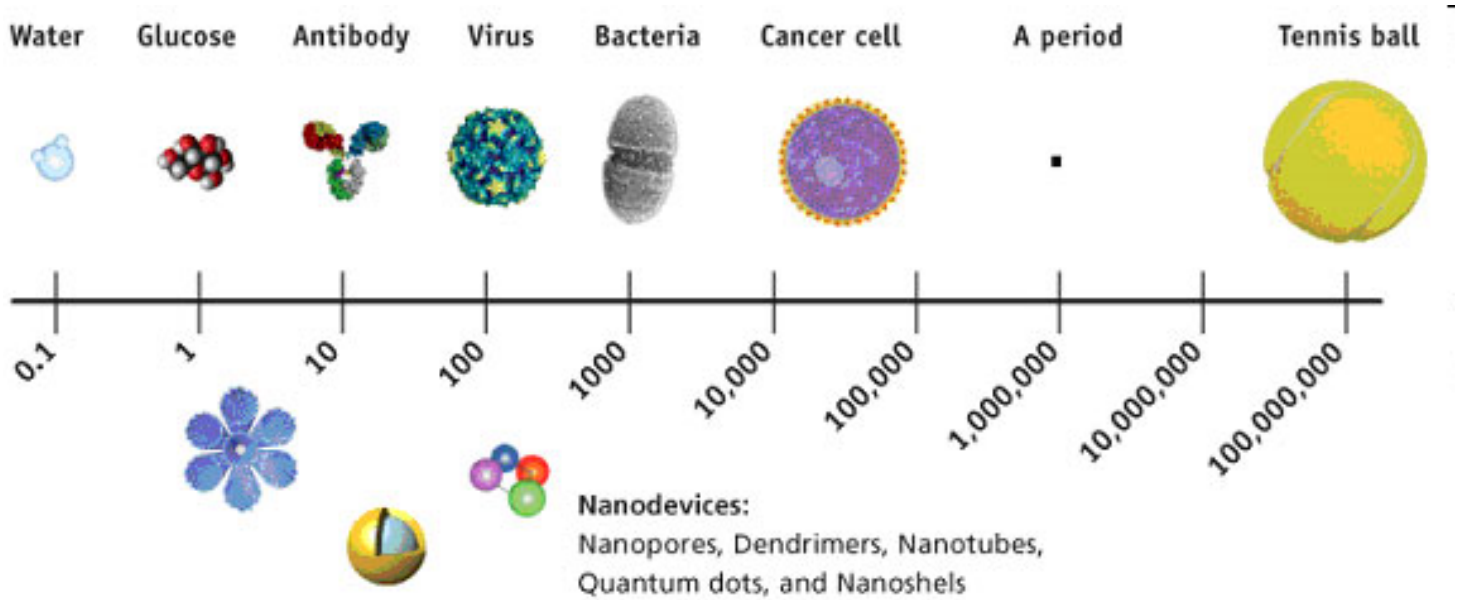
Nanoscale

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*
metro	**m**	**unità base SI della lunghezza**
centimetro	cm	$1x10^{-2}$ m (0.01 m)
millimetro	mm	$1x10^{-3}$ m (0.001 m)
micrometro	μm	$1x10^{-6}$ m
nanometro	nm	$1x10^{-9}$ m la billionesima parte di 1 metro o 10 Å

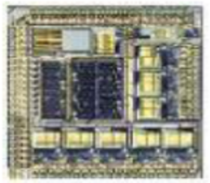


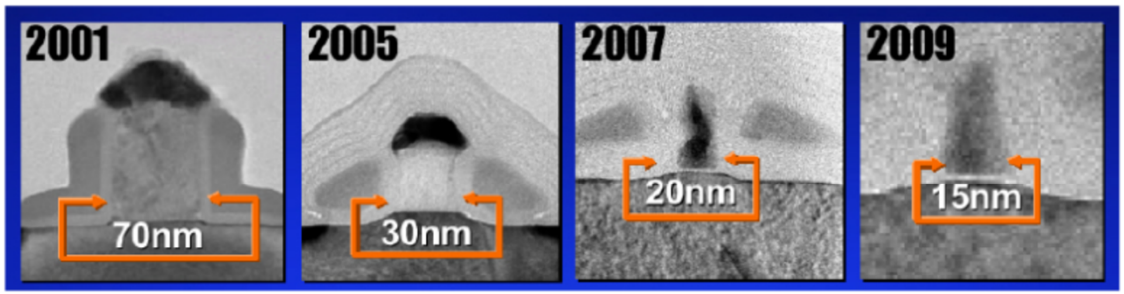
nanometer


Water
Glucose
Antibody
Virus
Bacteria
Cancer cell
A period
Tennis ball
0.1
1
10
100
1000
10,000
100,000
1,000,000
10,000,000
100,000,000
Nanodevices:
Nanopores, Dendrimers, Nanotubes,
Quantum dots, and Nanoshels

Why Nano?

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





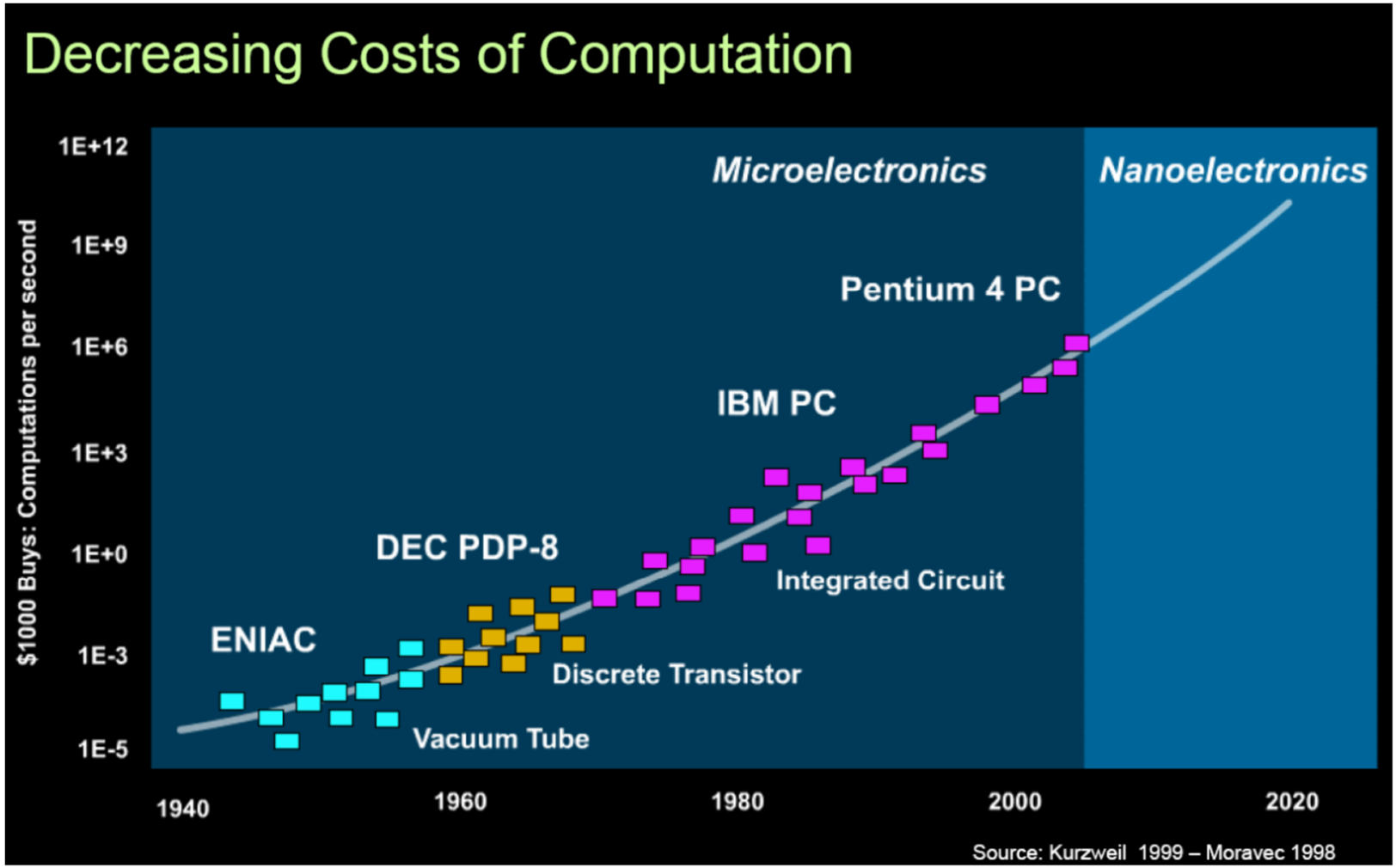
Intel's transistors

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

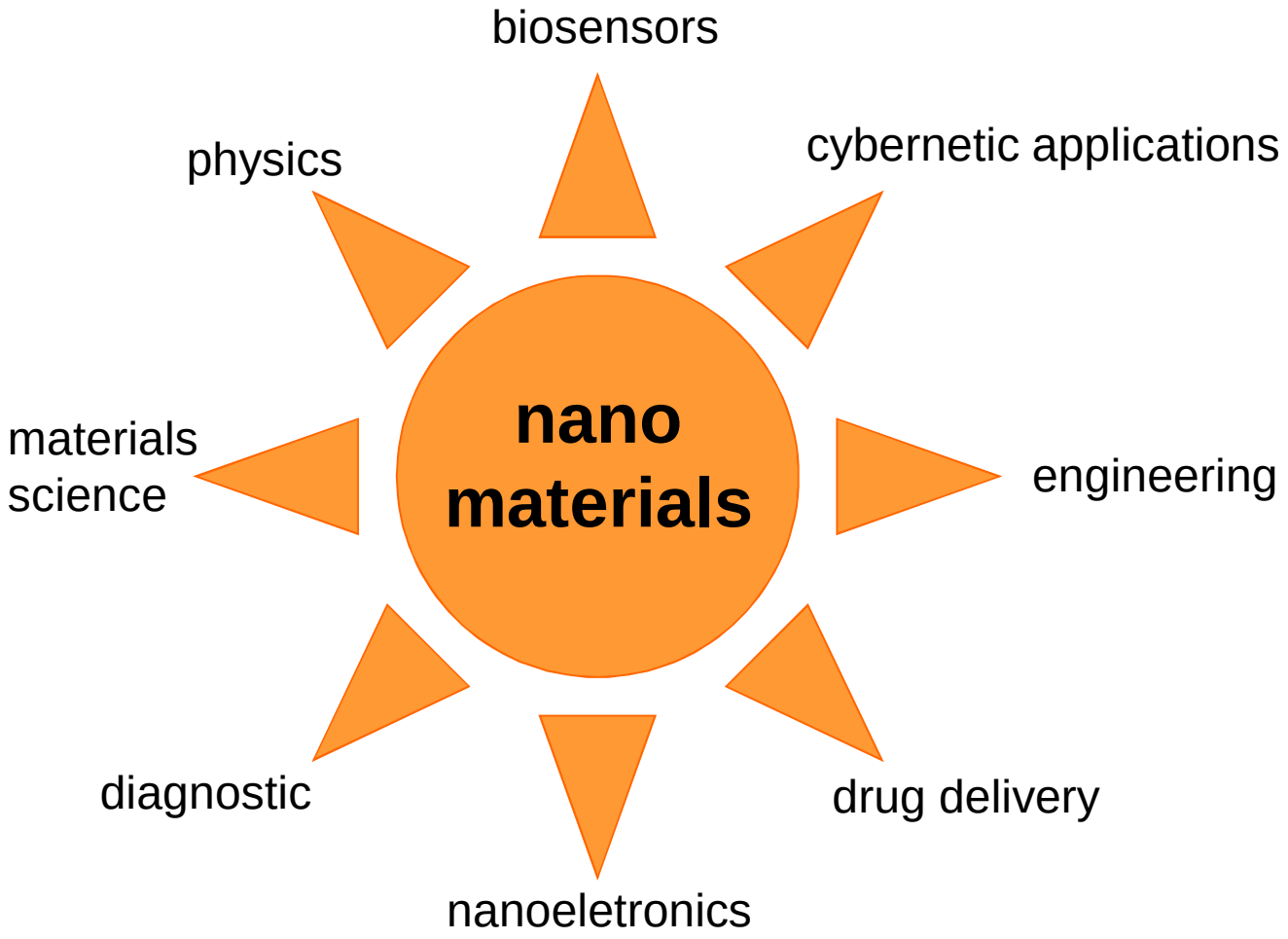
- to enhance performance and produce new properties and applications

- for many types of systems (mechanical, biological, chemical, optical) in addition to electronic

Why Nano?


Decreasing Costs of Computation
$1000 Buys: Computations per second
1E+12
1E+9
1E+6
1E+3
1E+0
1E-3
1E-5
Microelectronics
Nanoelectronics
Pentium 4 PC
IBM PC
DEC PDP-8
Integrated Circuit
ENIAC
Discrete Transistor
Vacuum Tube
1940
1960
1980
2000
2020
Source: Kurzweil 1999 – Moravec 1998

design, creation and characterization of nanostructures and nanostructured materials



Nanotechnology and Nanochemistry

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)

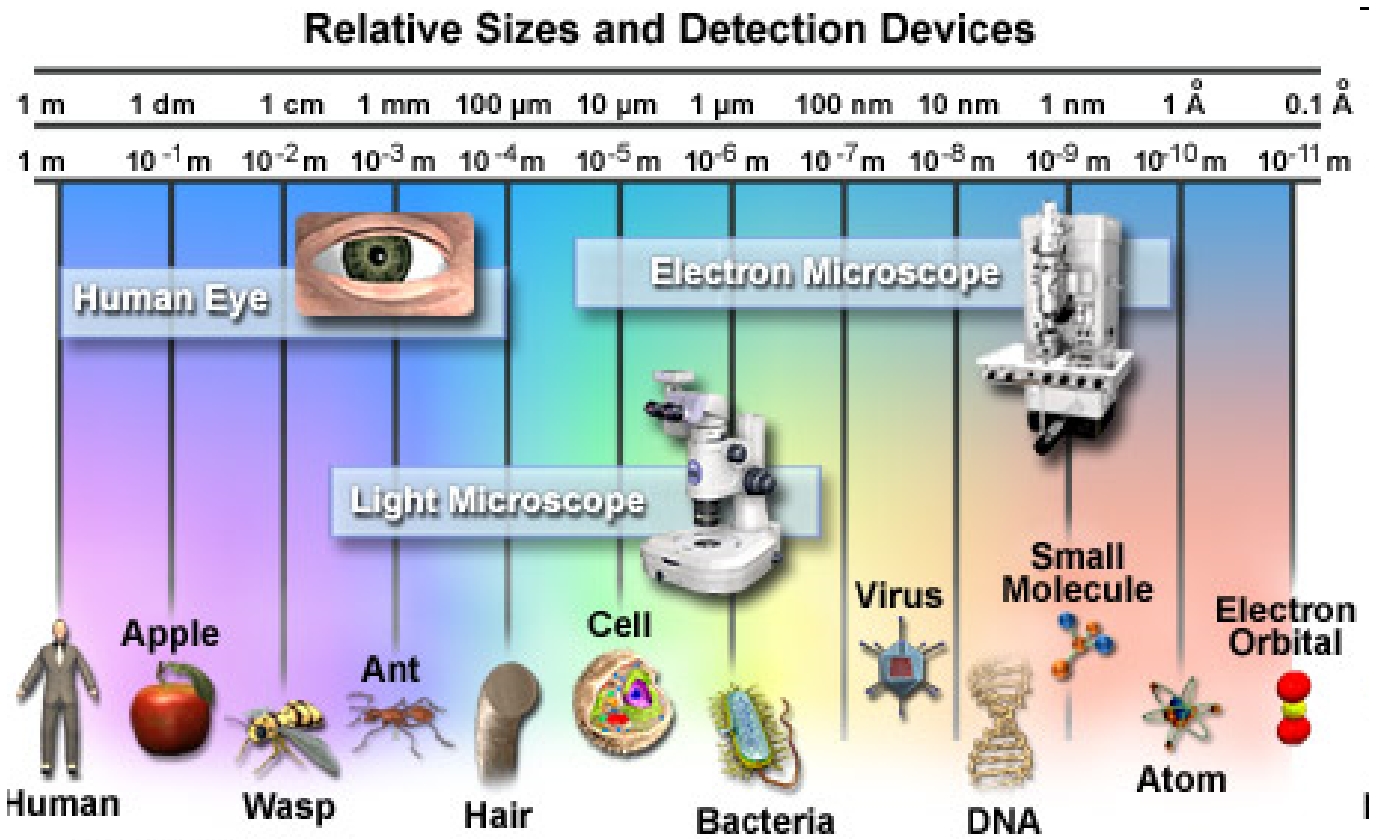


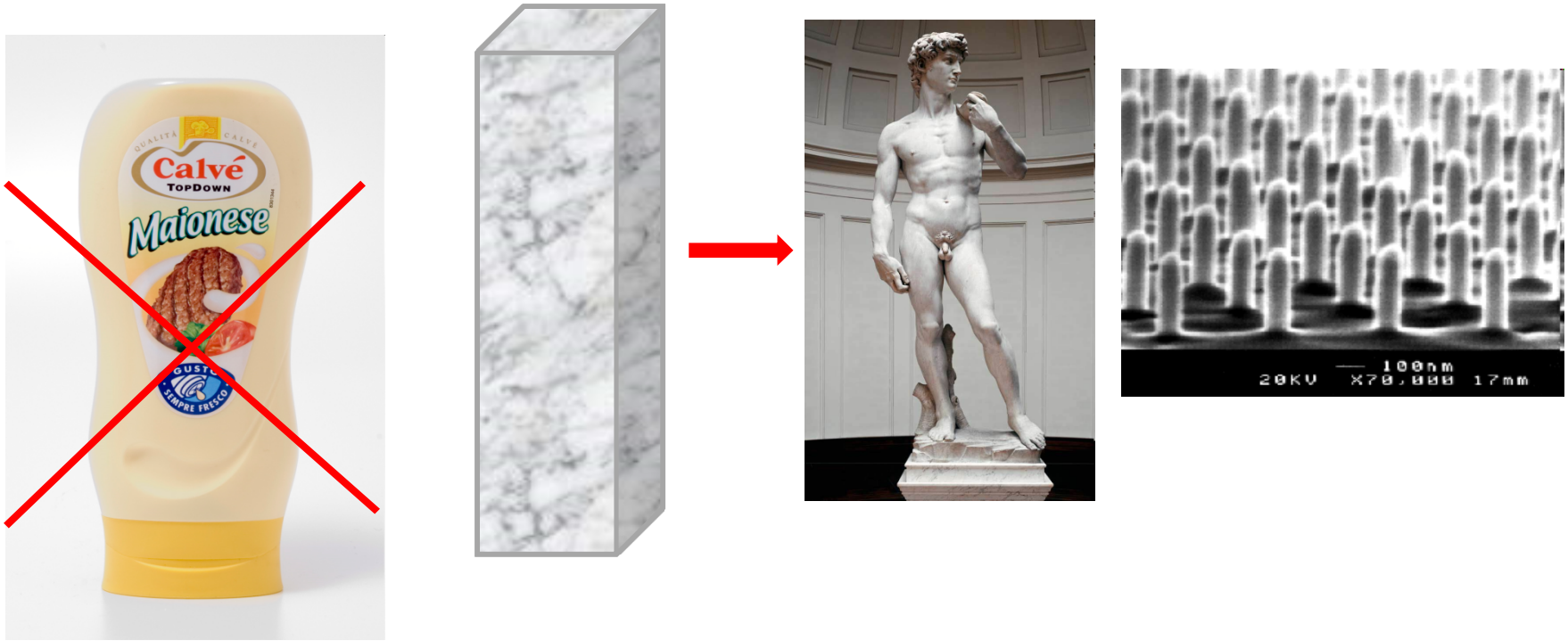
Figure 1

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.



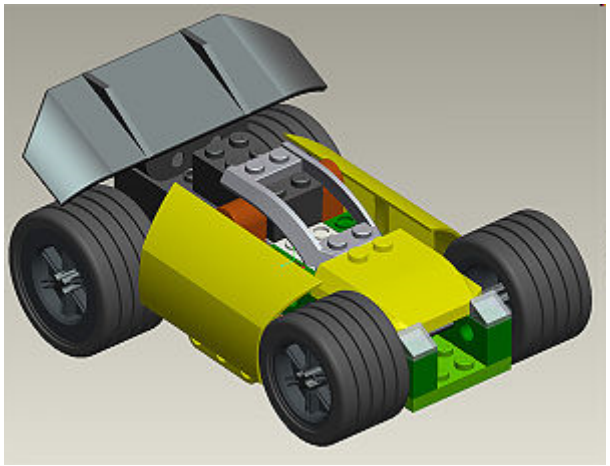
i dispositivi sono fabbricati da materiali macroscopici
attraverso un attento controllo dei processi di miniaturizzazione a livello atomico.

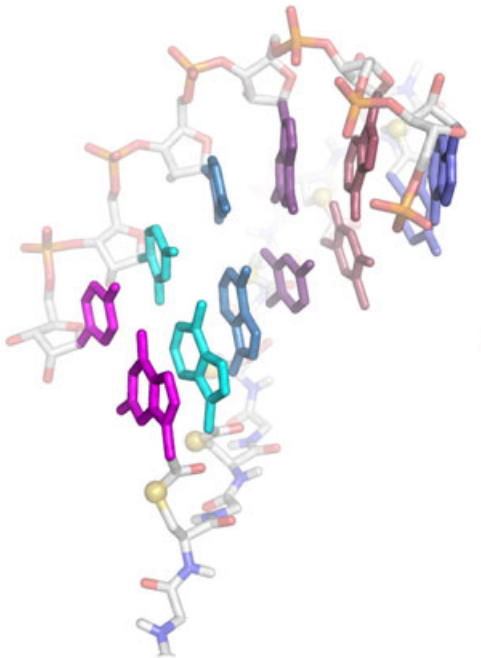
Materiali supramolecolari organici

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

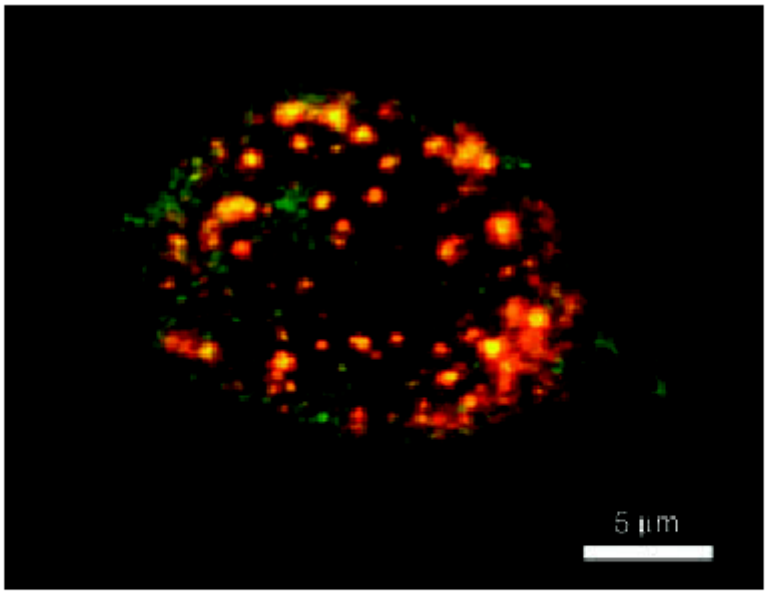


Figure 4. Image of a mammalian cell labeled with fluorescent, surfactant-stabilized, semiconductor quantum dots.[82] The resistance of these nanostructures to photobleaching makes them attractive in applications in which the sensitivity of molecular fluorophores to the exciting light is a serious impediment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

2D-Self-Assembled Monolayers

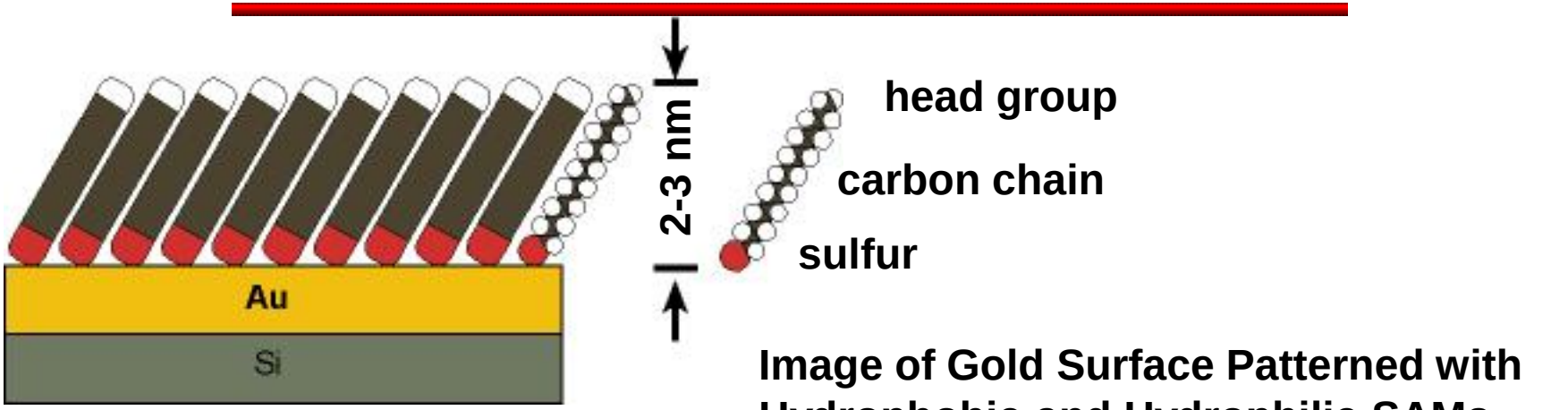
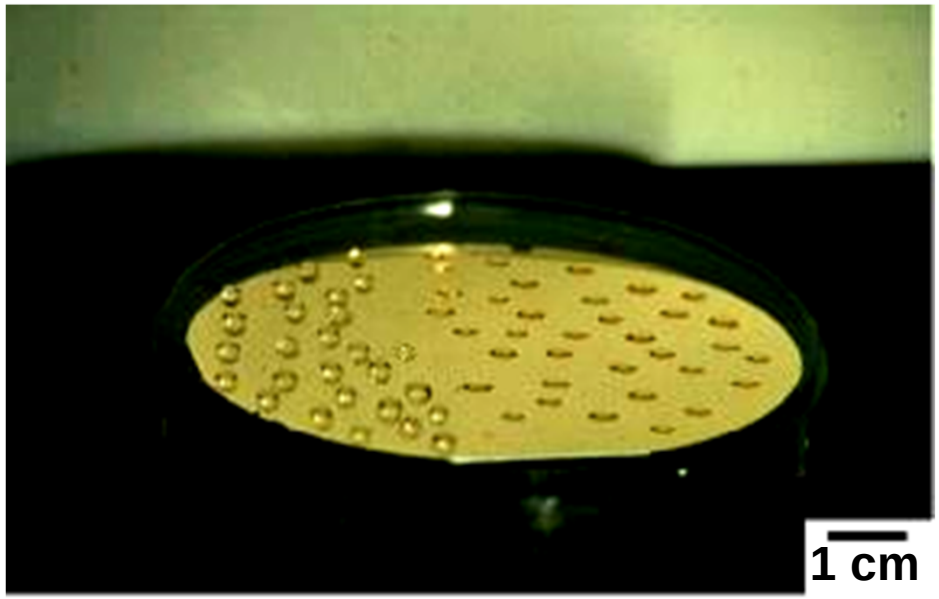
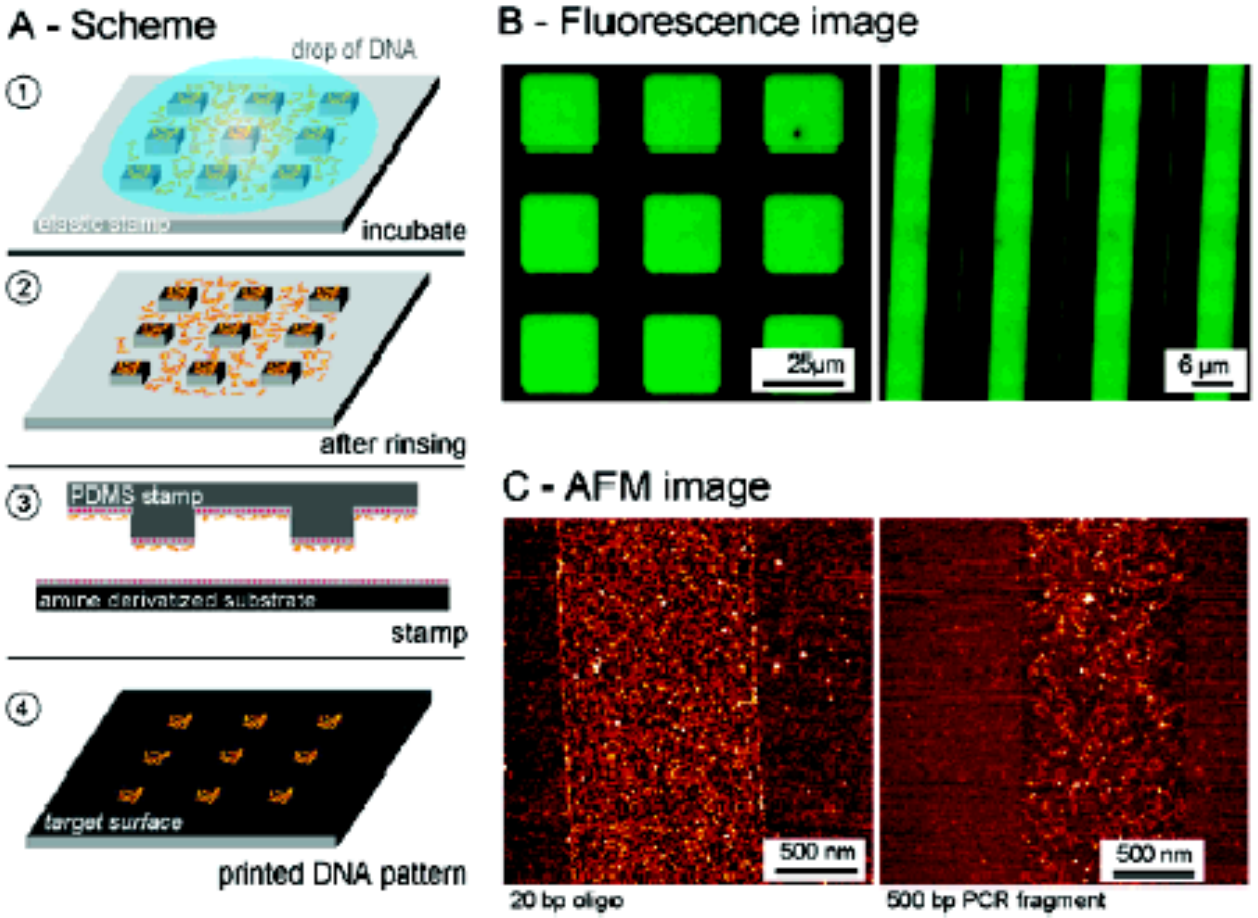


Image of Gold Surface Patterned with Hydrophobic and Hydrophilic SAMs

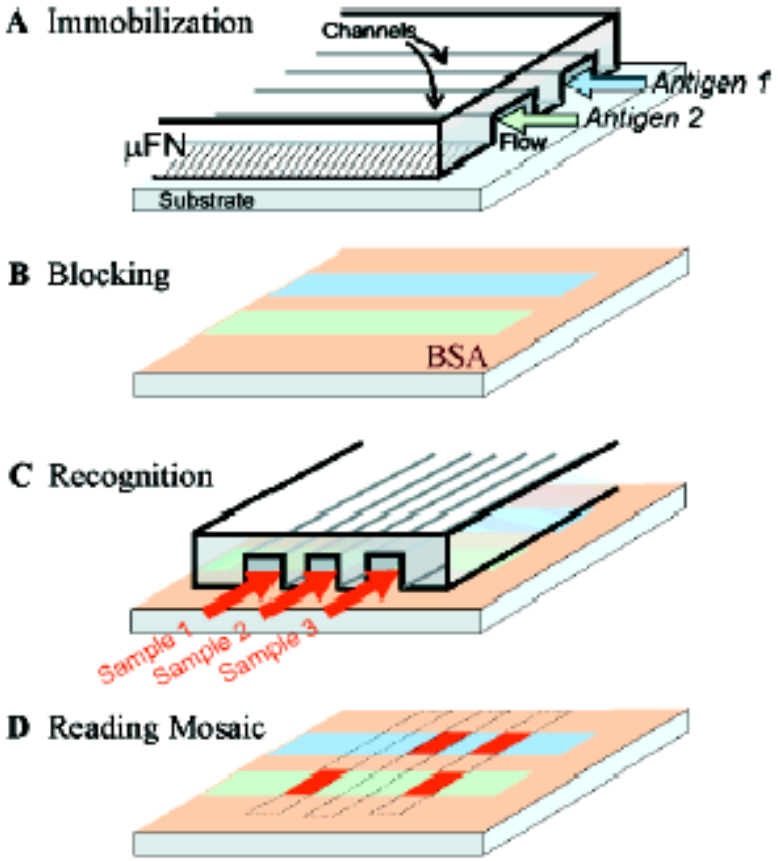


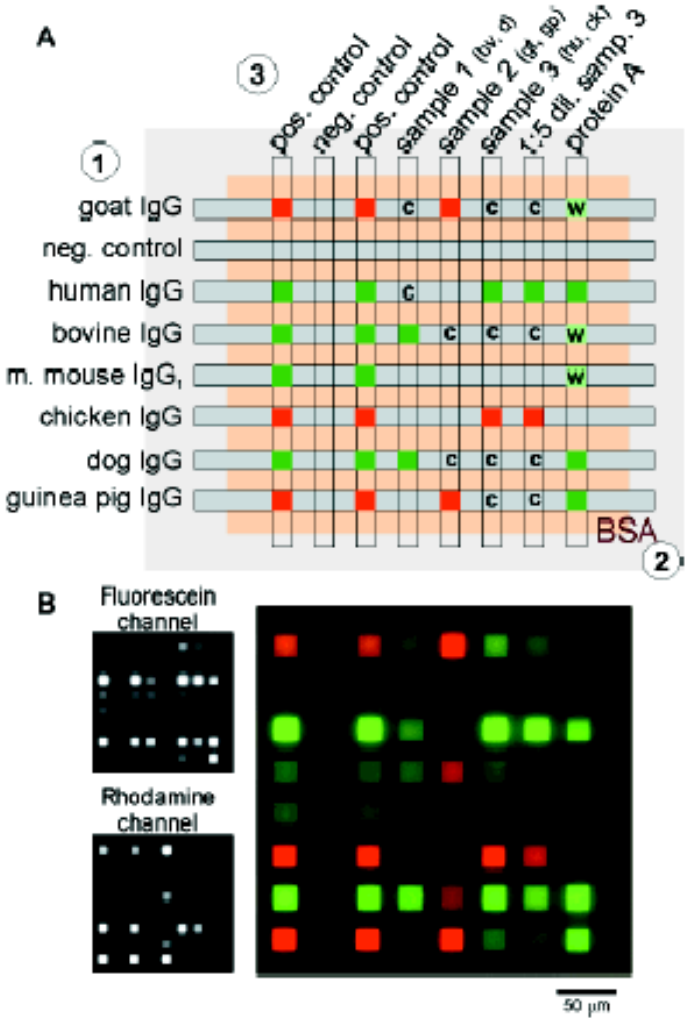
Microcontact Printing DNA



S.A. Lange, V. Benes, D.P. Kern, J.K.H. Horber, A. Bernard, *Anal. Chem.* **2004**, 76, 1641.

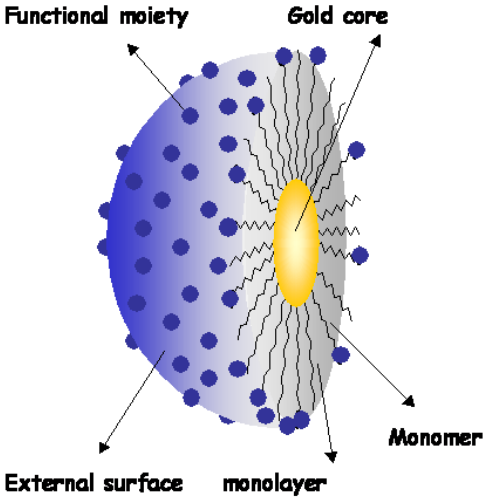
Immunoassays

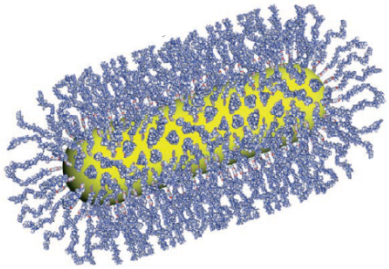


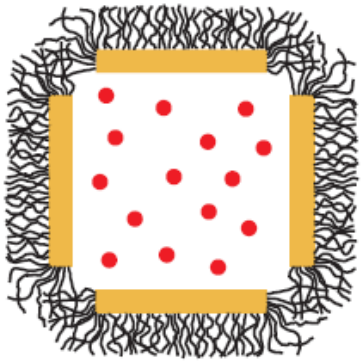


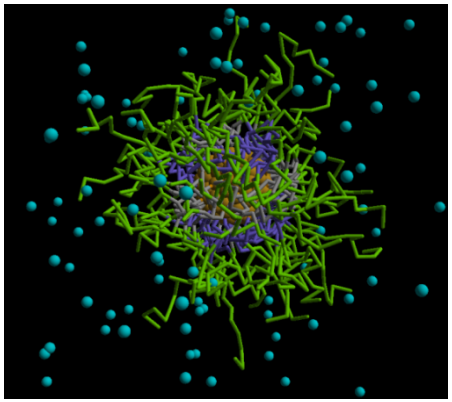
A. Bernard, B. Michel, E. Delamarche, *Anal. Chem.* **2001**, 73, 8.

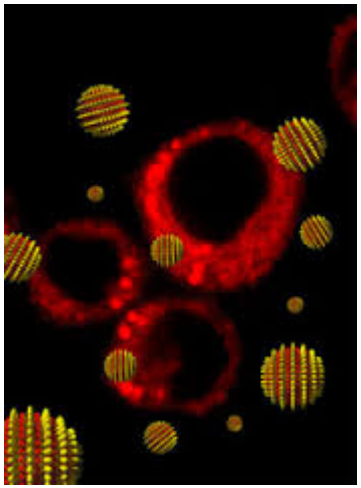
NANOPARTICLES

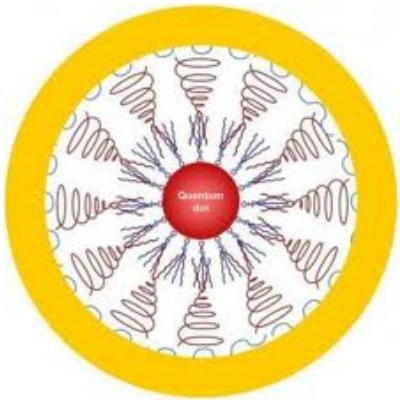








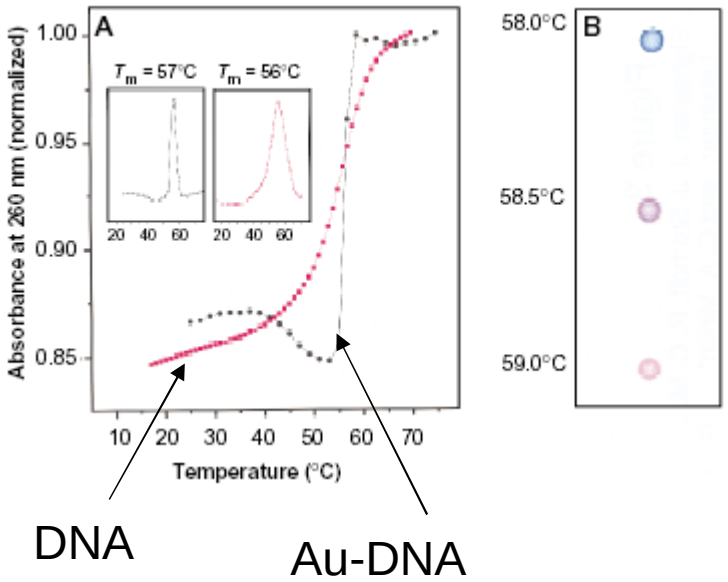


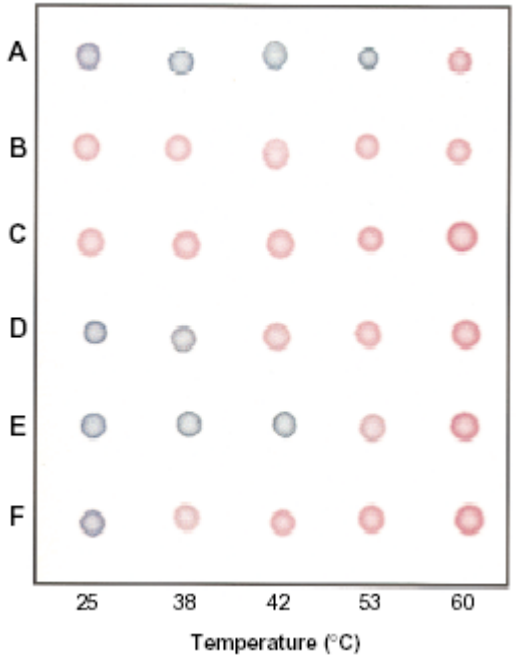


Nanoparticle-based Sensors

selective colorimetric detection system for polynucleotides

thermal transition associated with the color change





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-μl thin-walled Eppendorf tube by addition of 1 μl of a 6.6μM oligonucleotide target to a mixture containing 50 μl of each probe (0.06 μM 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-μl aliquots were removed at the indicated temperatures and spotted on a C_{18} 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

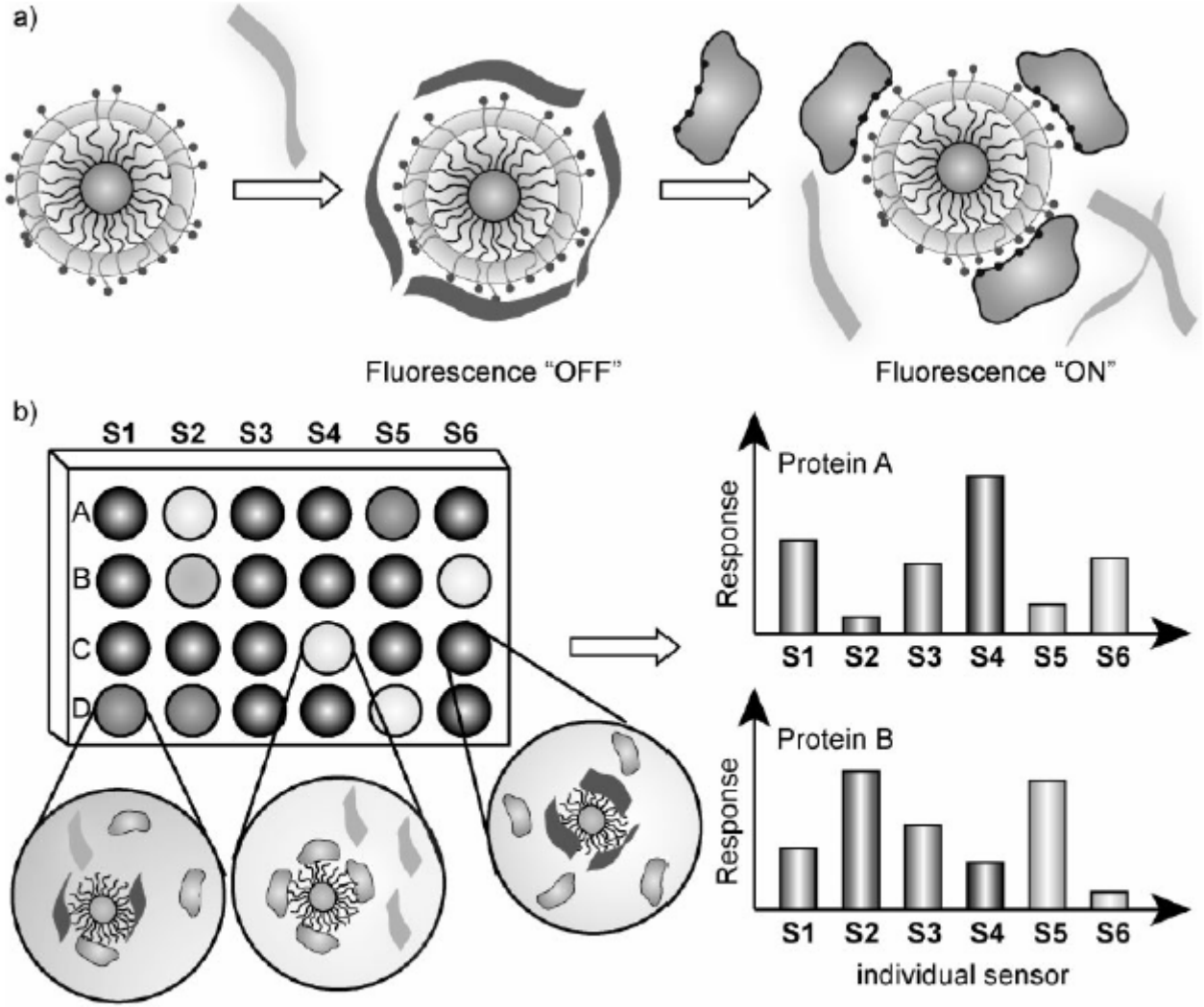


Figure 8. Schematic drawing of a "chemical nose" sensor array based on nanoparticle and fluorescence assay. a) The competitive binding between protein and quenched polymer leads to the fluorescence light-up. b) The combination of an array of sensors generates fingerprint response patterns for individual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

Nanoparticles for new therapeutic strategies

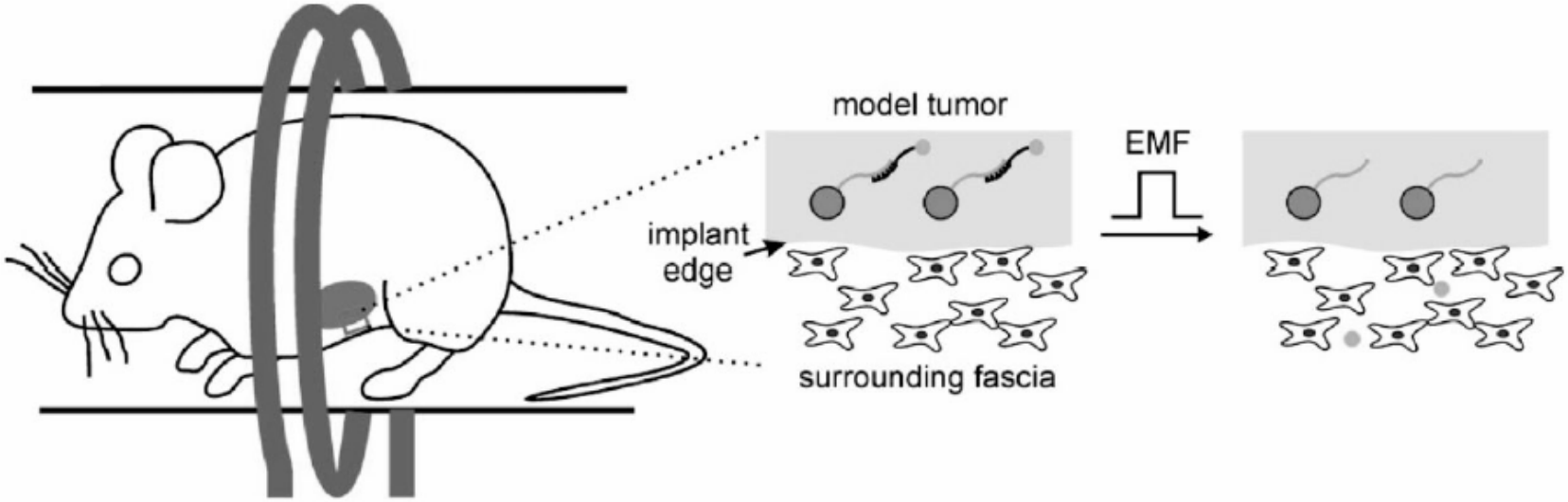
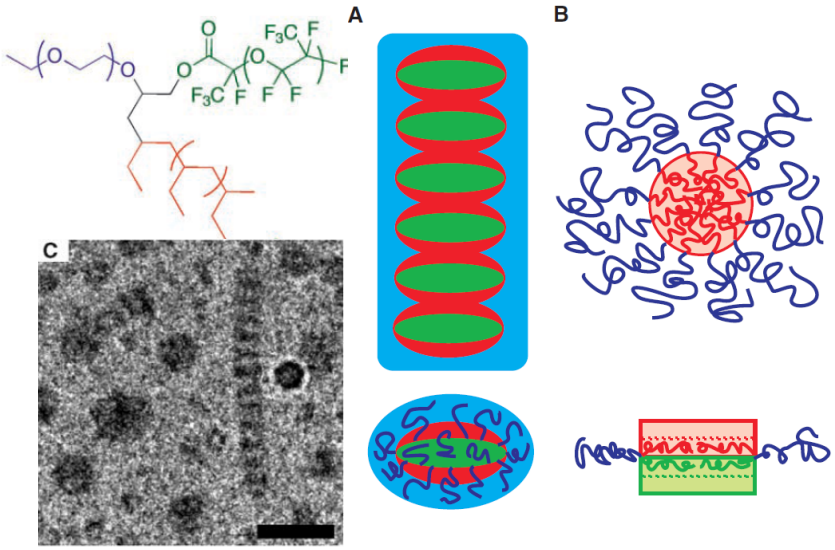


Figure 12. Controlled release of payloads using oligonucleotide-modified iron oxide nanoparticles for drug delivery at a remote location. Adapted with permission from [105].

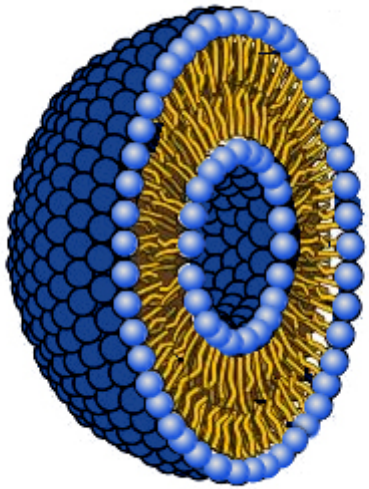
SOFT MATERIALS

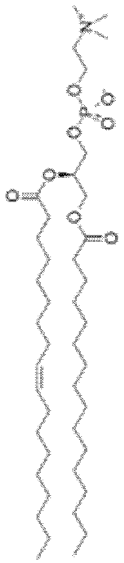
polymers/block copolymers

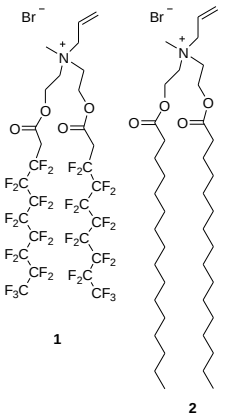
block terpolymer



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







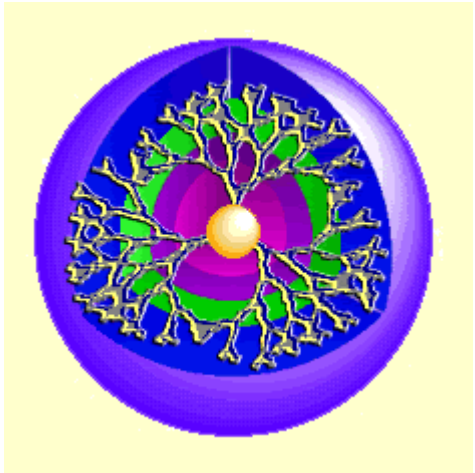
liposomes

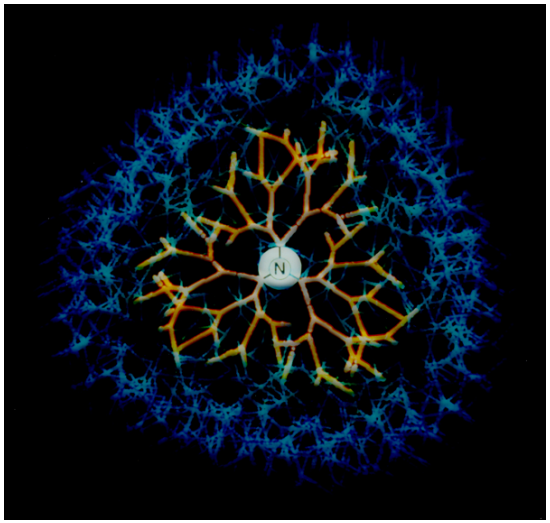
A **liposome** is an artificially-prepared vesicle composed of a lipid bilayer.
The liposome can be used as a vehicle for administration of nutrients and pharmaceutical drugs.
Liposomes are often composed of phosphatidylcholine-enriched phospholipids and may also contain mixed lipid chains with surfactant properties such as egg phosphatidylethanolamine

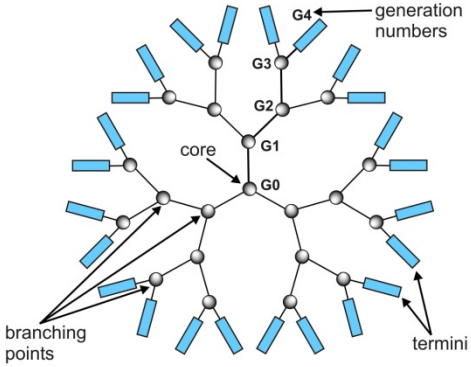
DENDRIMERS

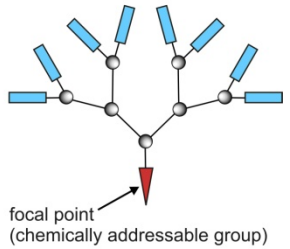
Dendrimers are repetitively branched molecules. The name comes from the Greek word δένδρον (**dendron**), which translates to "tree".

they are monodisperse and usually higly symmetric compounds

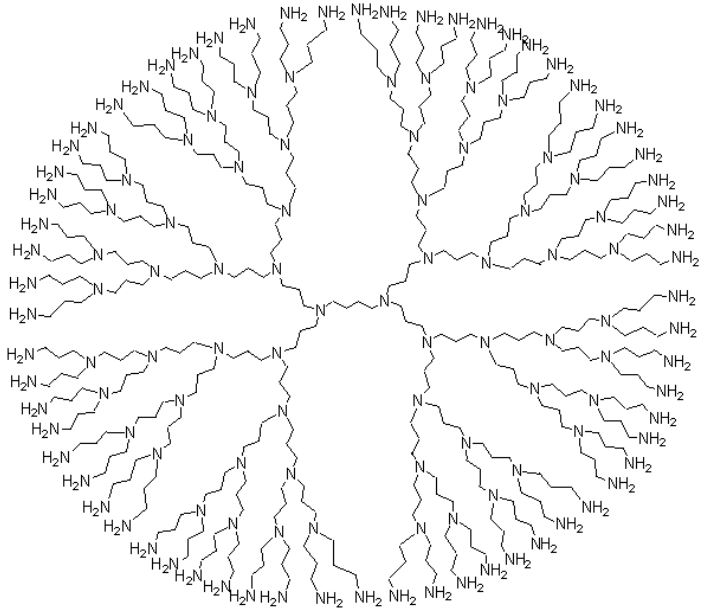




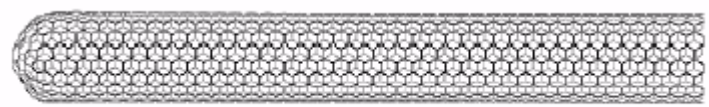




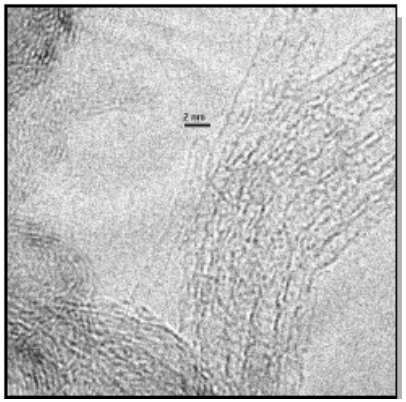
DENDRIMER **DENDRON**



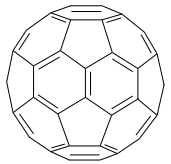
materiali organici



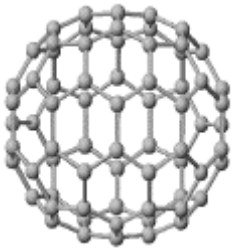
SWCNT
MWCNT
T = 1 (trasparenza elettronica)



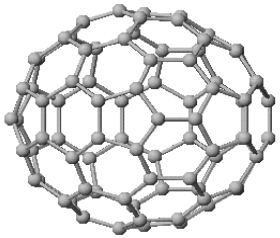
FULLERENI



C60



C70



C84

GRAPHENE