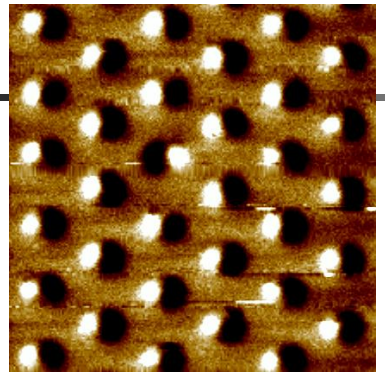
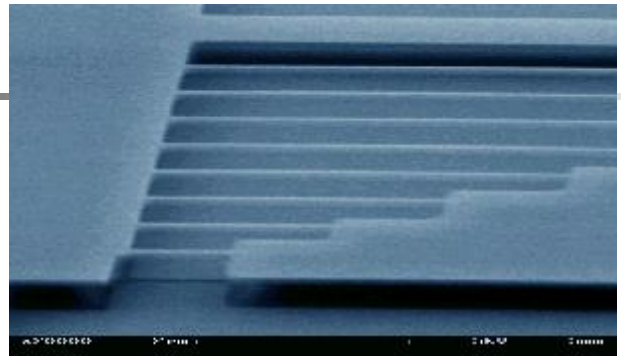
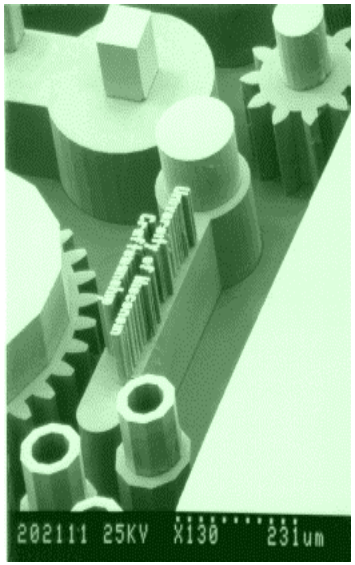
Nanotechnology

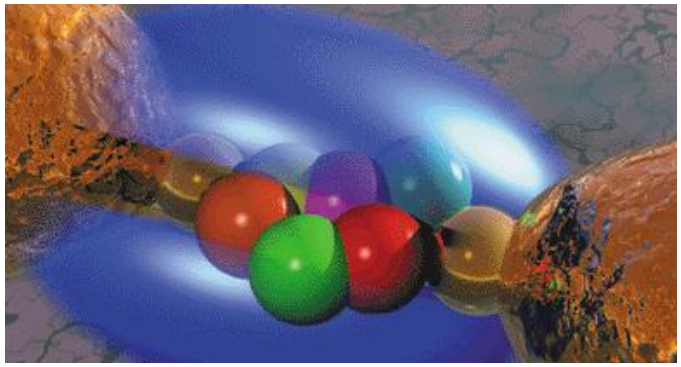
— Introduction

Prof./Dr. Yongqi Fu

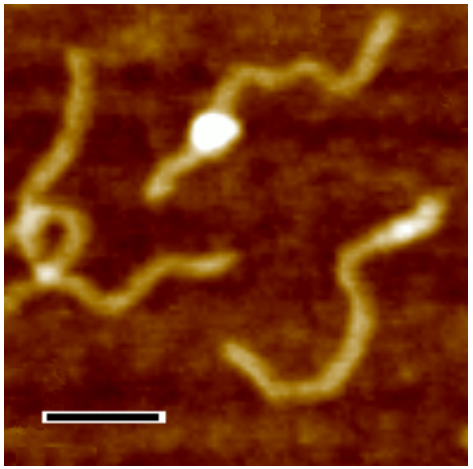


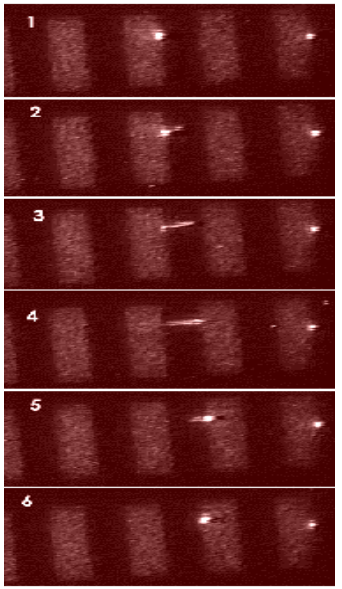






nm





Step into a Nano-world

What is Nanotechnology ?

One definition:

Engineering of materials and devices at scales that allow access to new length-dependent phenomena

In reality:

A collection of research areas with a common, unifying theme:

The control of matter and structures at the nanometer scale

The objective of this class:

To provide a broad and wide-ranging overview of such fields

The Scale of Things – Nanometers and More

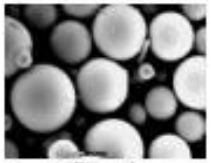
Things Natural

Dust mite

200 µm

Ant

~ 5 mm

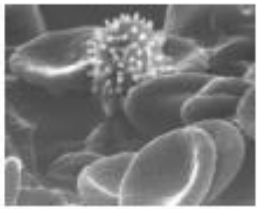


Fly ash

~ 10-20 µm

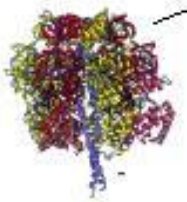
Human hair

~ 60-120 µm wide

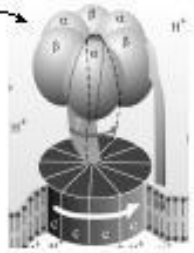


Red blood cells with white cell

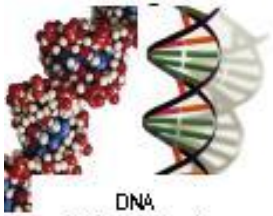
~ 2-5 µm



~10 nm diameter

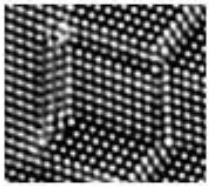


ATPsynthase



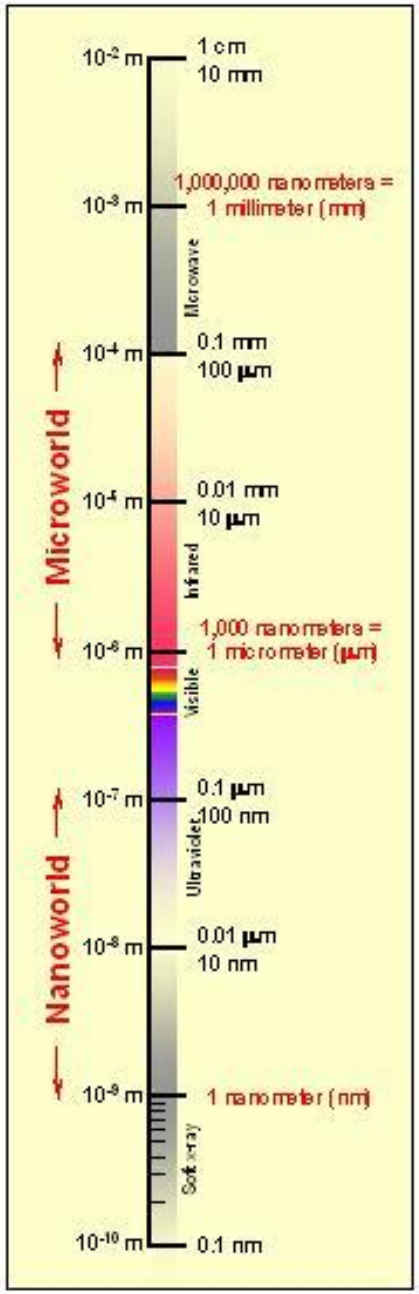
DNA

~2-12 nm diameter

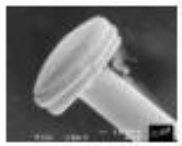


Atoms of silicon

spacing ~tenths of nm

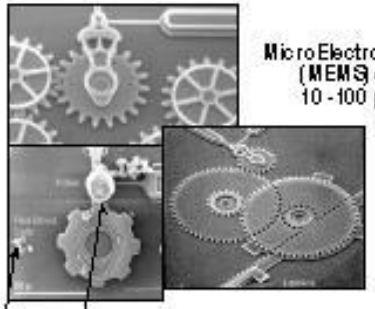


Things Manmade



Head of a pin

1-2 mm

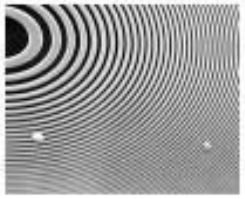


MicroElectroMechanical (MEMS) devices

10 - 100 µm wide

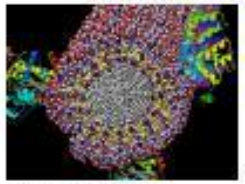
Pollen grain

Red blood cells



Zone plate x-ray "lens"

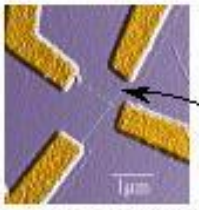
Outer ring spacing ~35 nm



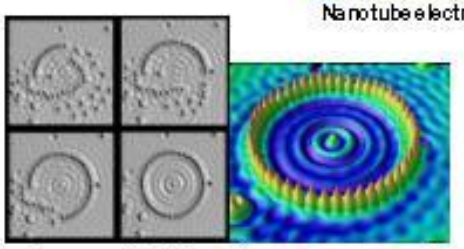
Self-assembled,

Nature-inspired structure

Many 10s of nm

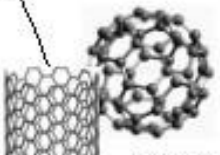


Nanotube electrode



Quantum corral of 48 iron atoms on copper surface positioned one ata time with an STM tip

Corral diameter 14nm



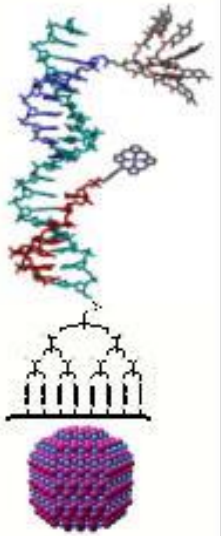
Carbon buckyball

~1 nm diameter

Carbon nanotube

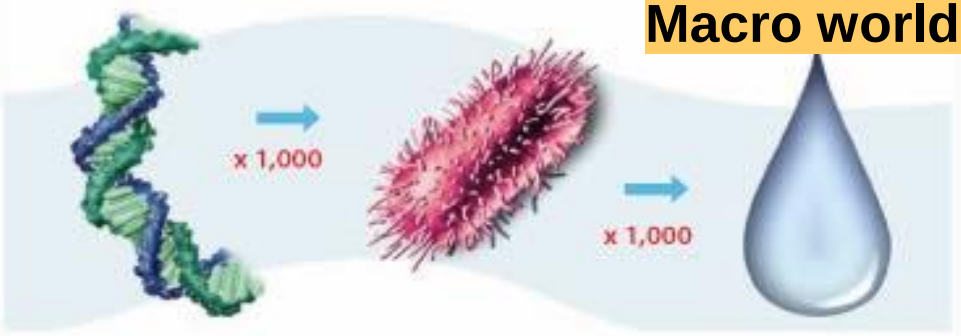
~1.3 nm diameter

The Challenge



Fabricate and combine nanoscale building blocks to make useful devices, e.g., a photosynthetic reaction center with integral semiconductor storage.

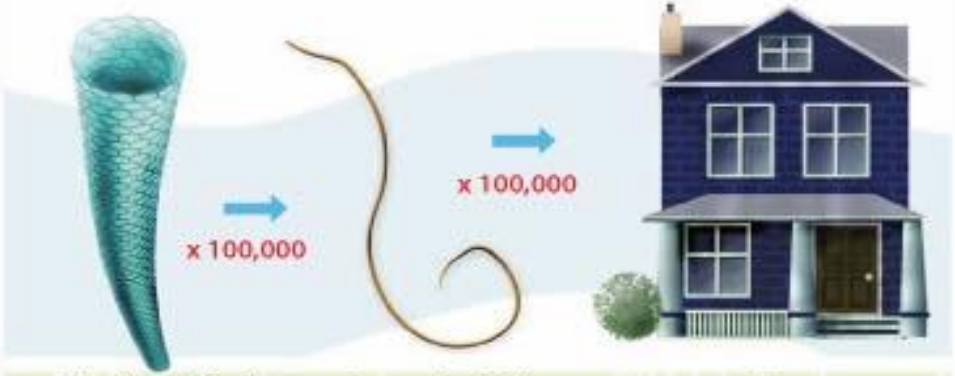
Macro world



DNA
2.5 nanometers
diameter

Bacterium
2.5 micrometers
long

Large Raindrop
2.5 millimeters
diameter



Single-walled Carbon Nanotube
1 nanometer diameter

Strand of Hair
100 micrometers
diameter

House
10 meters
wide

Nanoparticle
4 nanometers
diameter

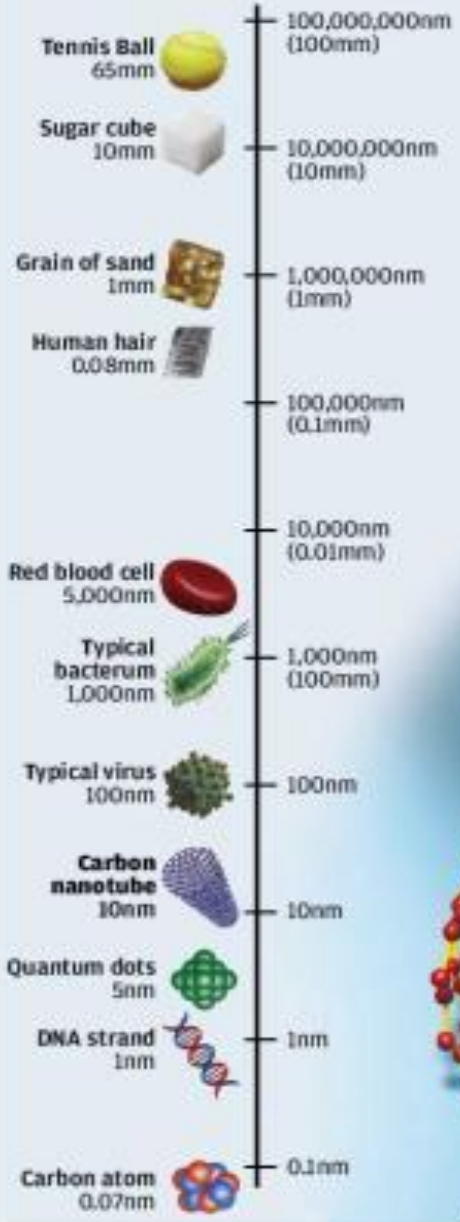
Ant
4 millimeters
long

Indianapolis Motor Speedway
4 kilometers per lap

Small world

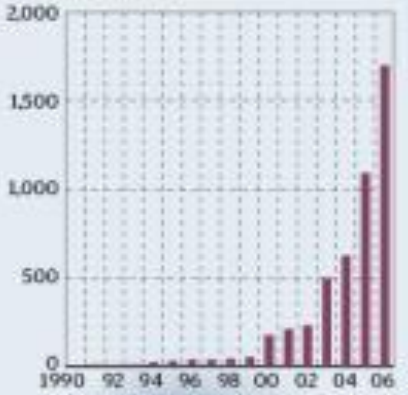
NANOMETRES IN CONTEXT

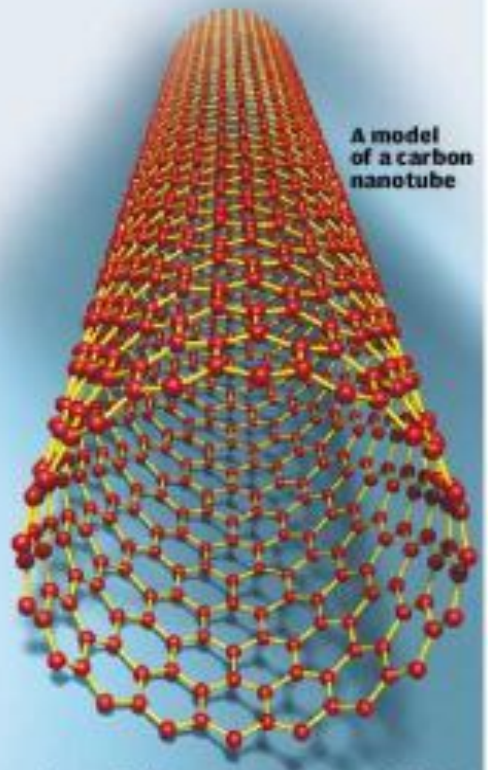
DIAMETERS



PATENTS ON NANOMATERIALS

NUMBER OF PATENTS

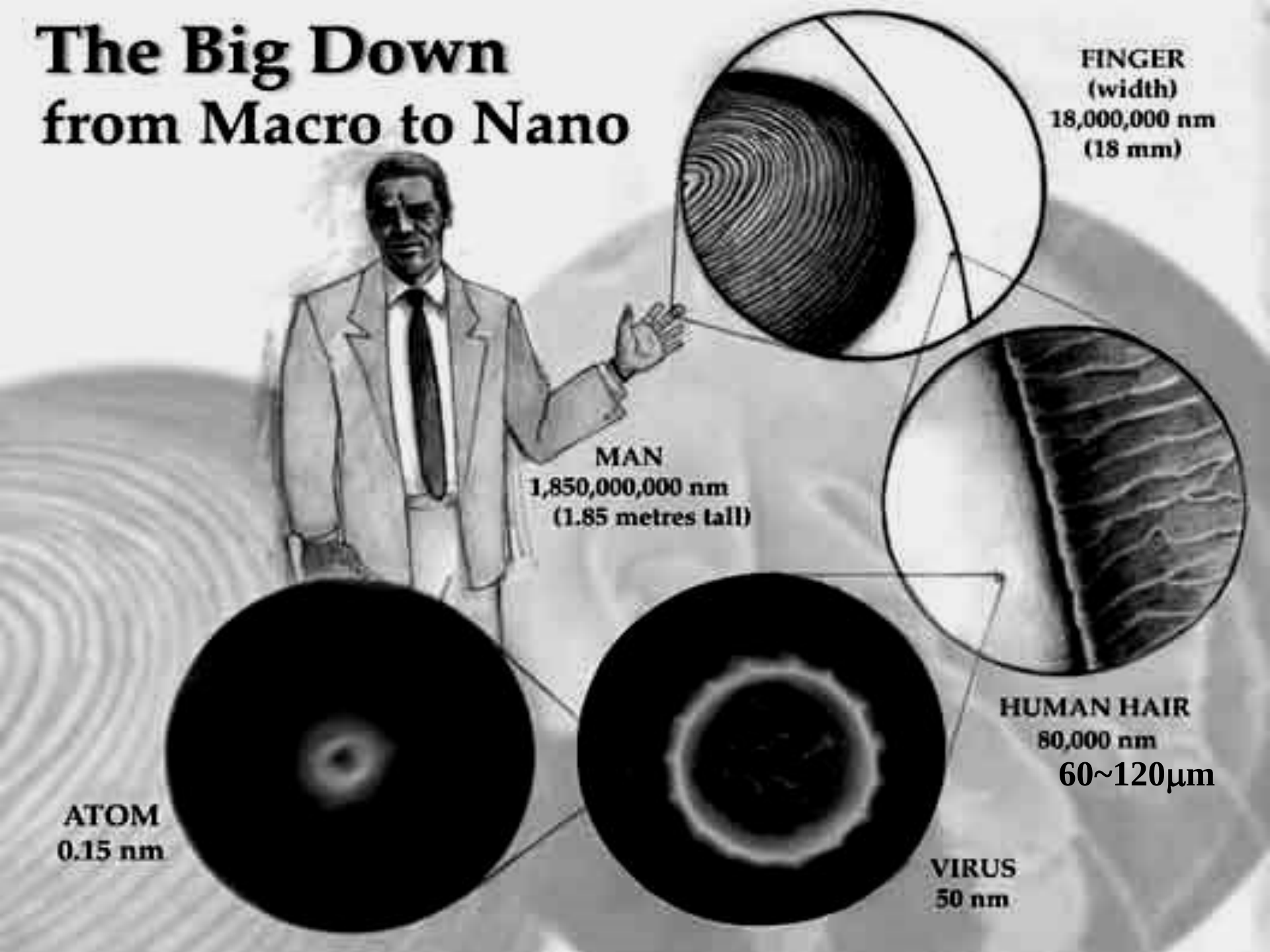


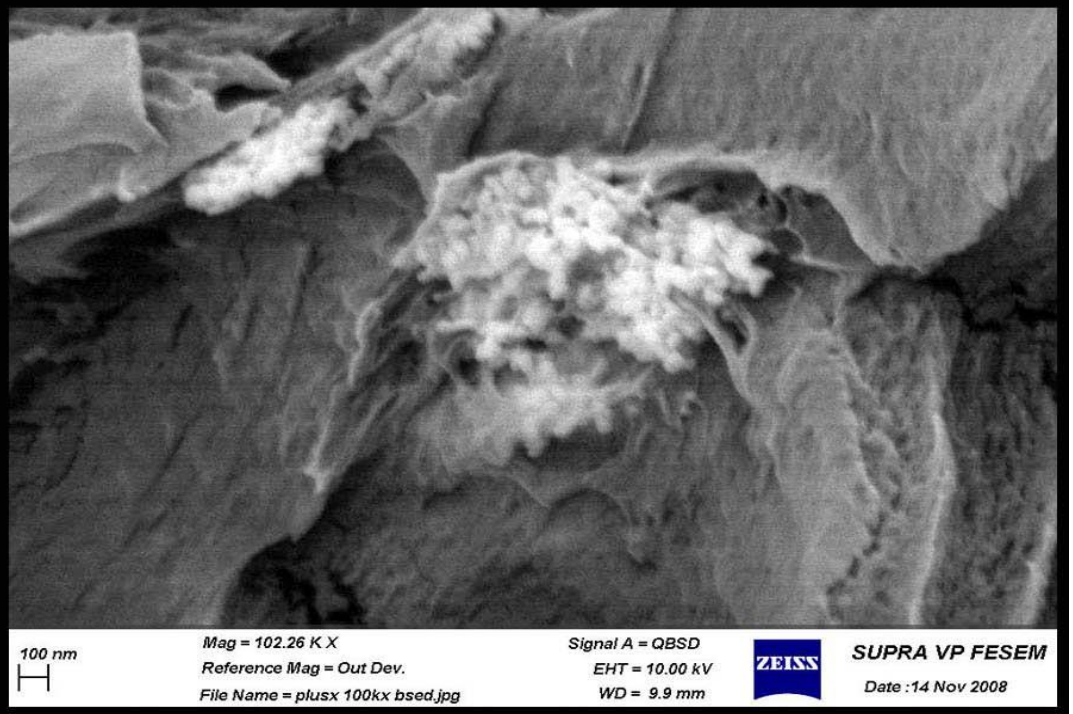


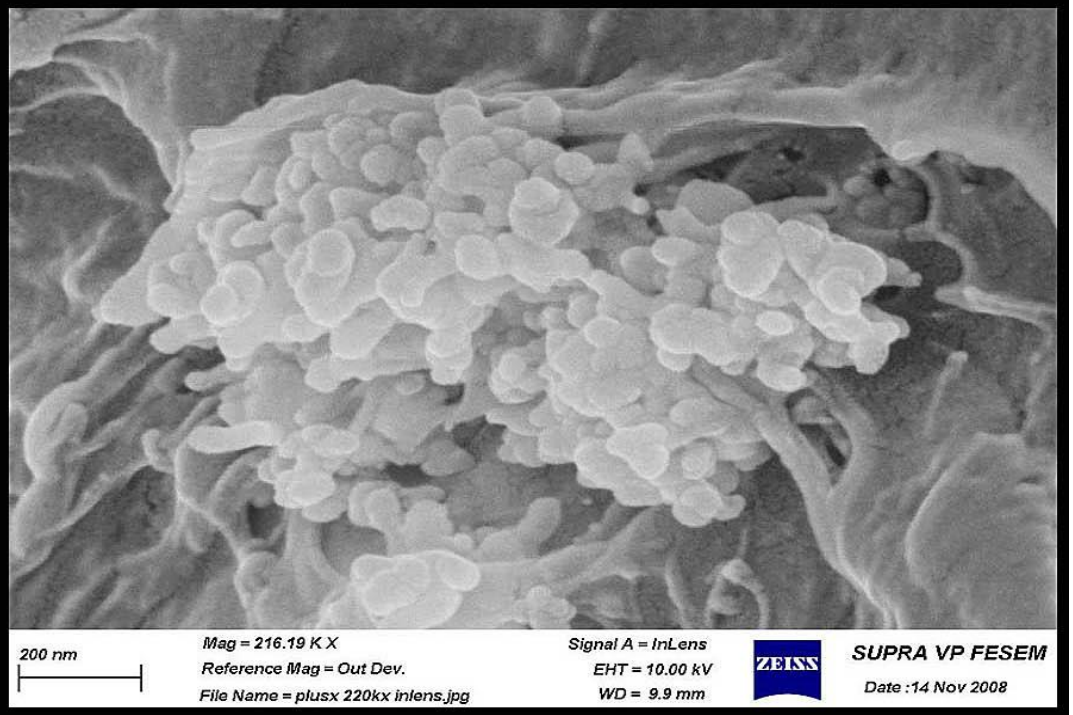
A model of a carbon nanotube

Source: Royal Commission on Environmental Pollution


NANOTECHNOLOGY
WINDSHIELD SEALANT

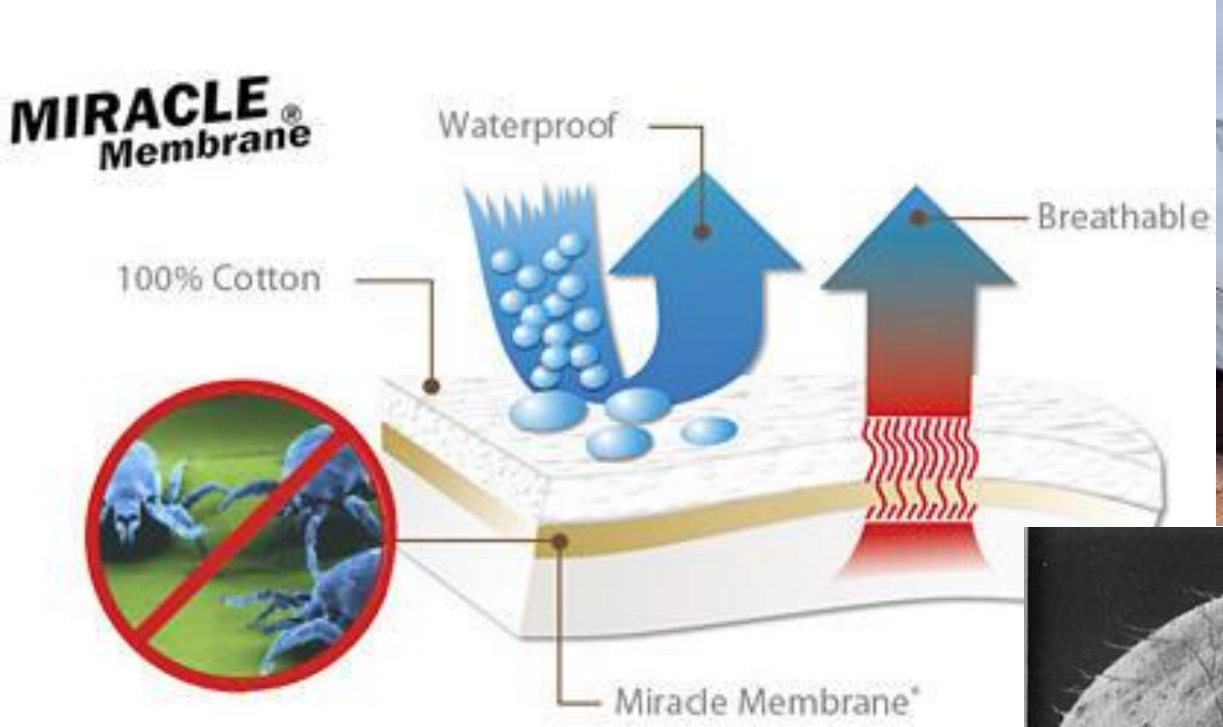

The Big Down
from Macro to Nano
FINGER
(width)
18,000,000 nm
(18 mm)
MAN
1,850,000,000 nm
(1.85 metres tall)
HUMAN HAIR
80,000 nm
60~120μm
ATOM
0.15 nm
VIRUS
50 nm



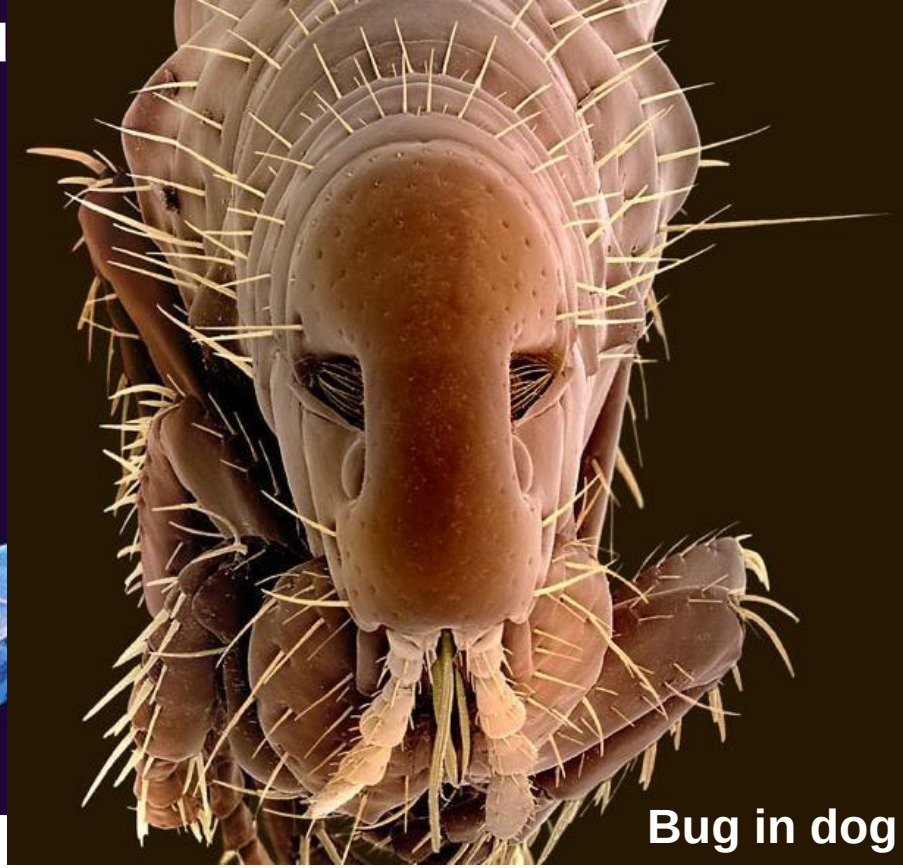


SEM image of a grain of sand

It is infinite in the tiny world!


MIRACLE Membrane
Waterproof
Breathable
100% Cotton
Miracle Membrane*


a



mosquito

SEM images of insects
zoom in with 1 million times

Main Topics in Nanotechnology

Contents of Nanotechnology

I. Nanofabrication and Characterization

II. Nanomaterials and Nanostructures

III. Nanoscale and Molecular Electronics

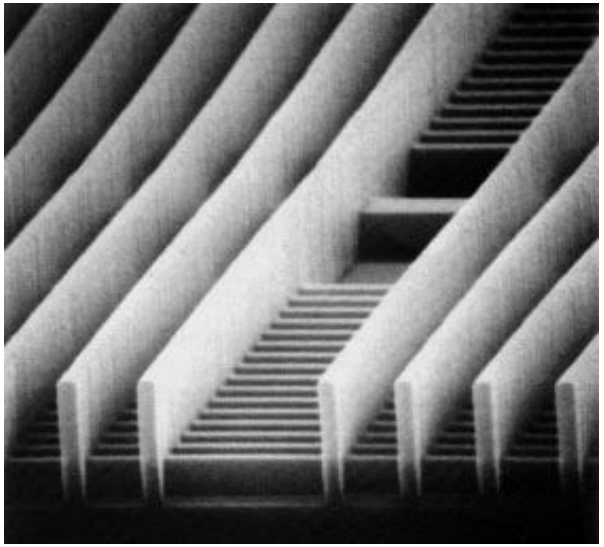
IV. Nanotechnology in Integrative System

V. Nanoscale Optoelectronics

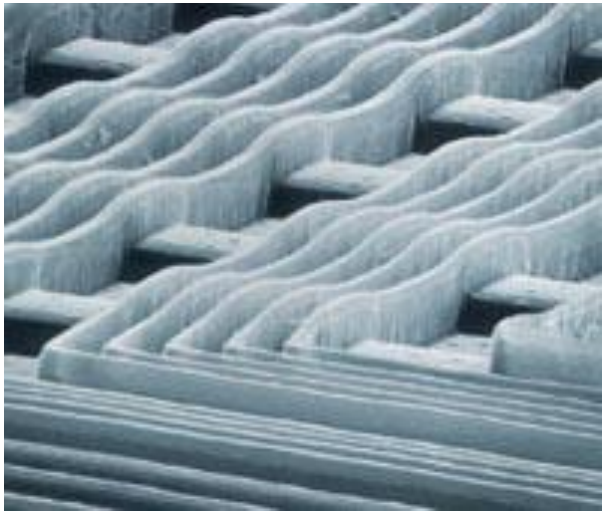
VI. Nanobiotechnology (time permitting)

VII. Nano-electronic-mechanical system (NEMS)

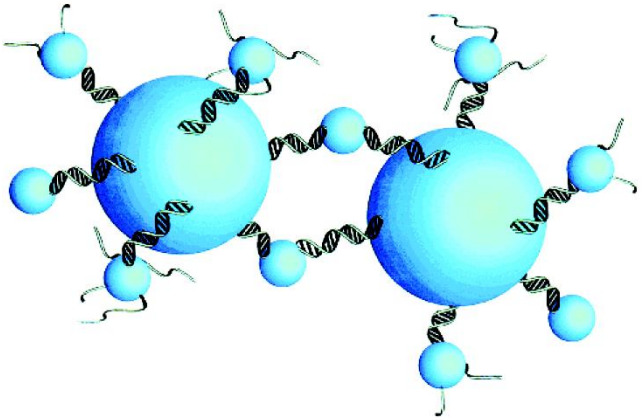
I. Nanofabrication/Characterization



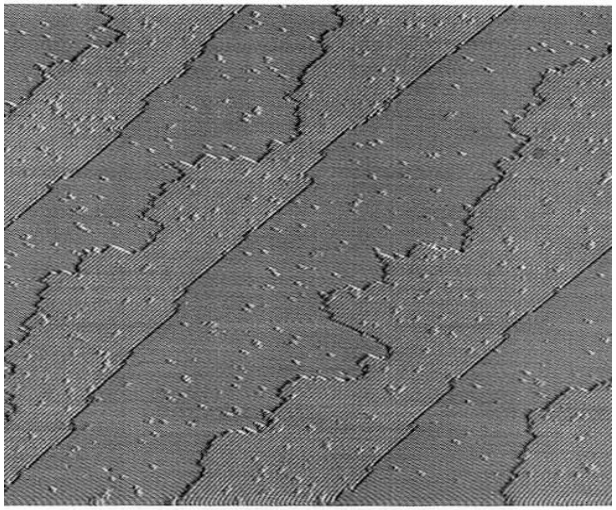
Will provide an overview of technologies that enable nanoscale research



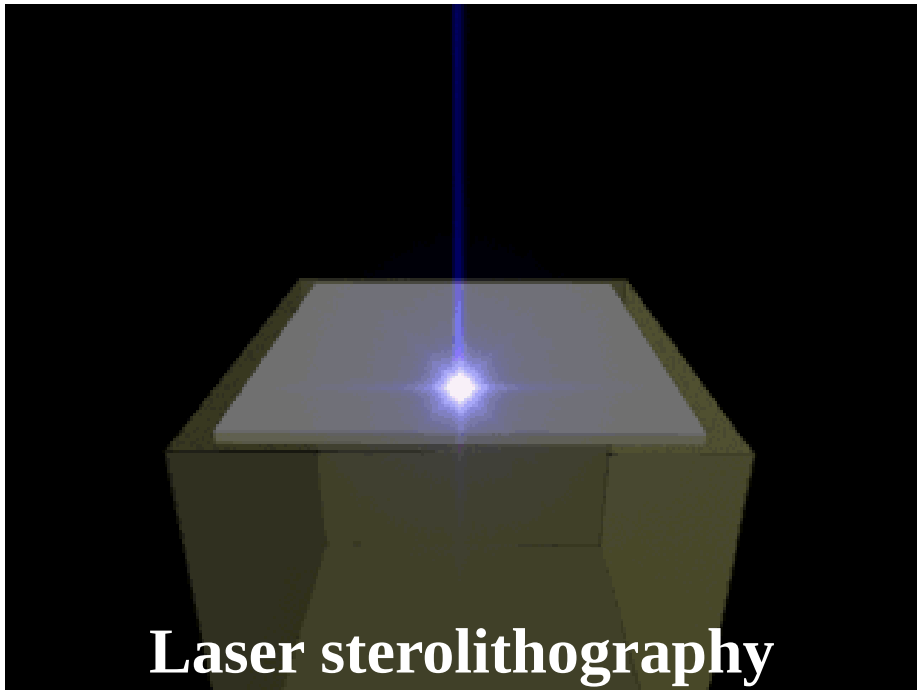
Nanophotolithography

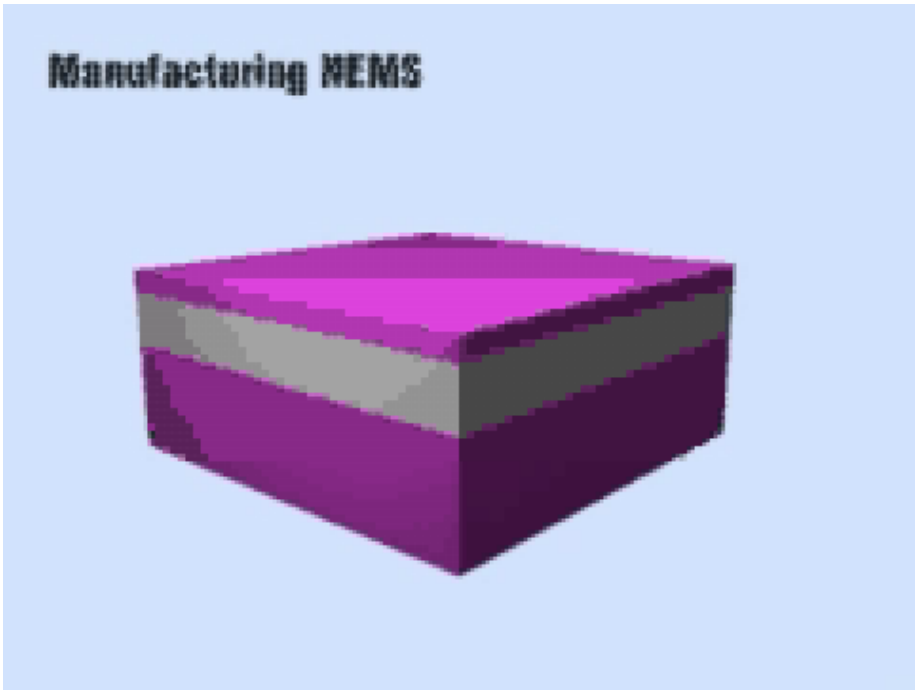


Self-Assembly



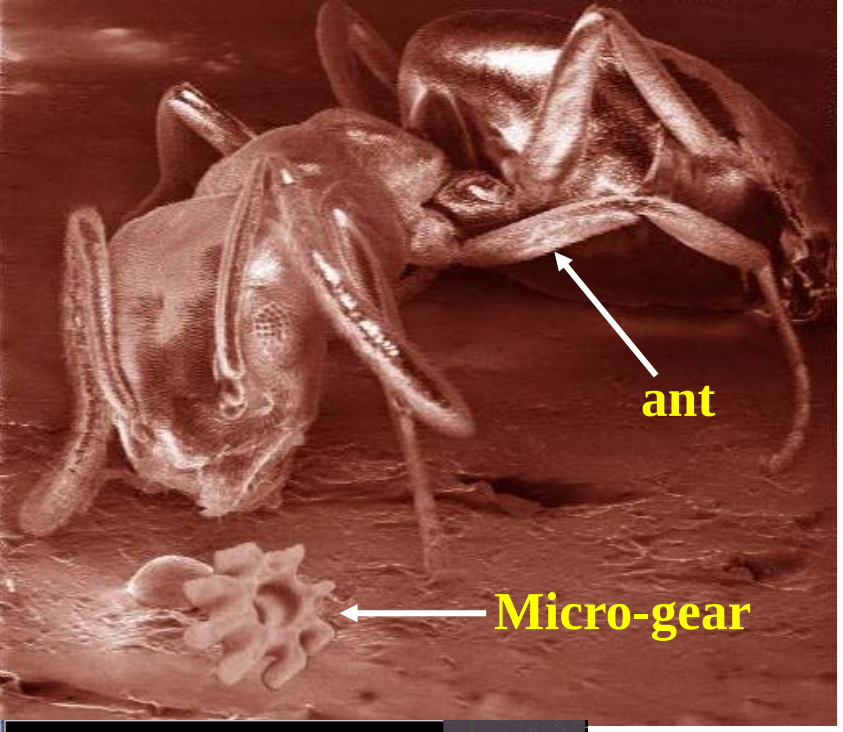
Probe Microscopy

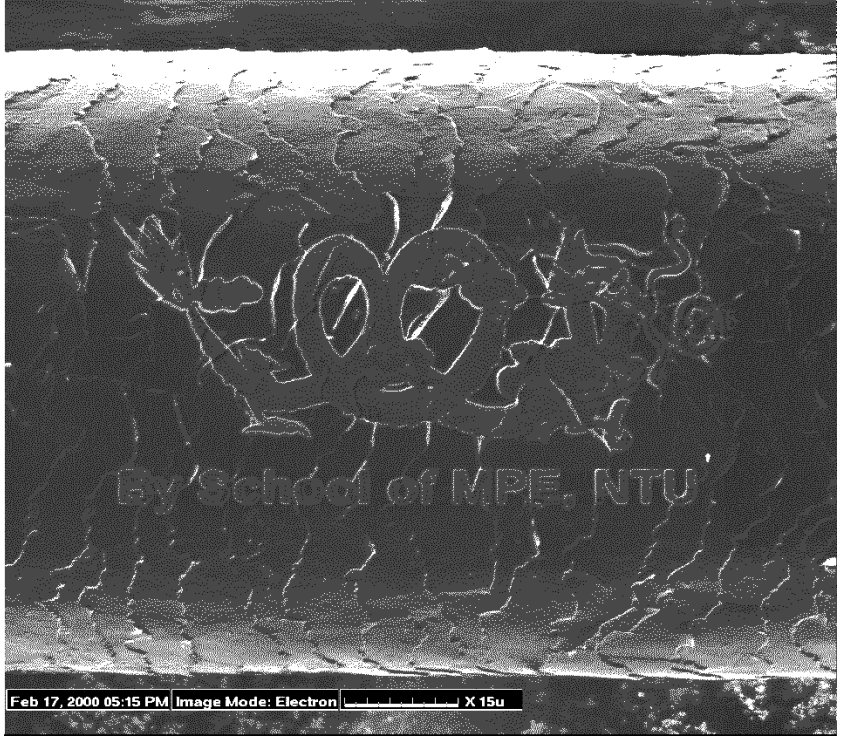




E-beam lithography

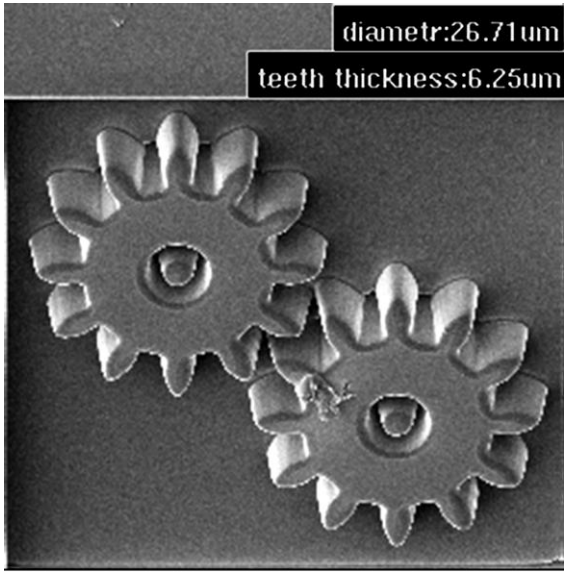
Atomic force microscope



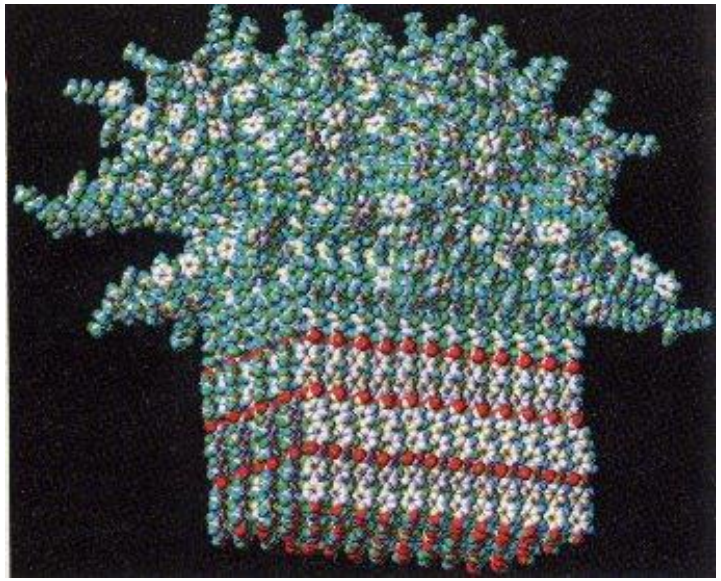


Dragon pattern milled on human hair with diameter of **60 micron** by FIB technology

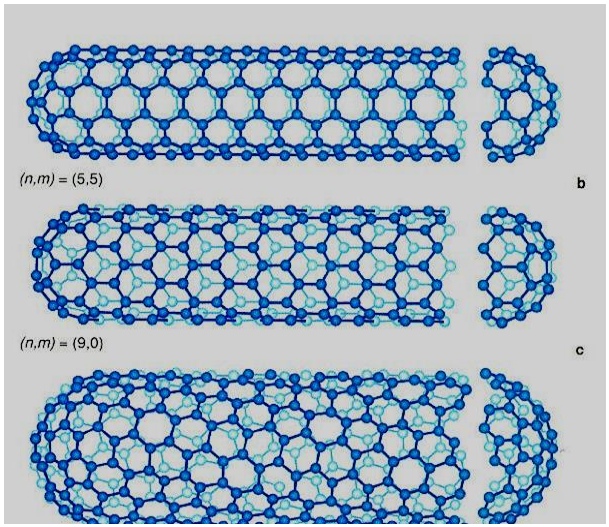
Gear with **26.71μm** pitch diameter



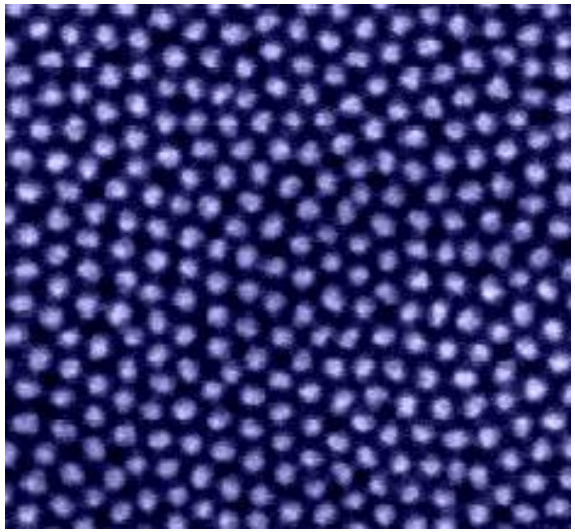
II. Nanomaterials and Nanostructures



Will provide an overview of nanomaterials and nanoscale synthesis techniques

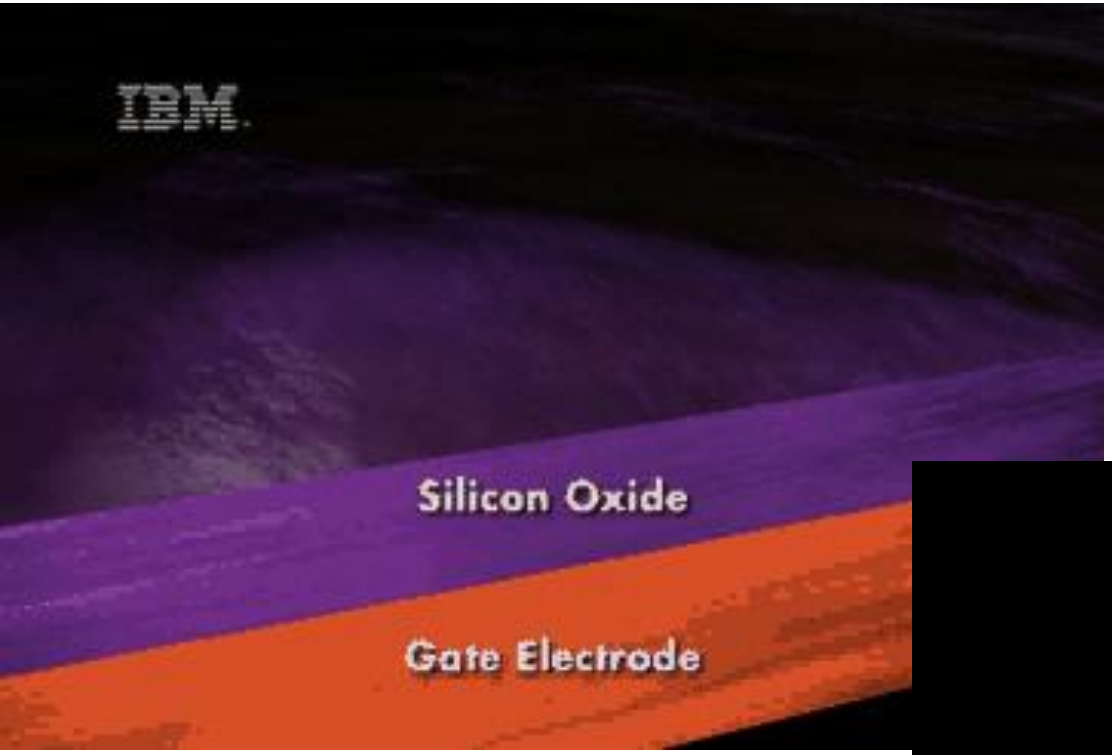


Fullerenes and Nanotubes



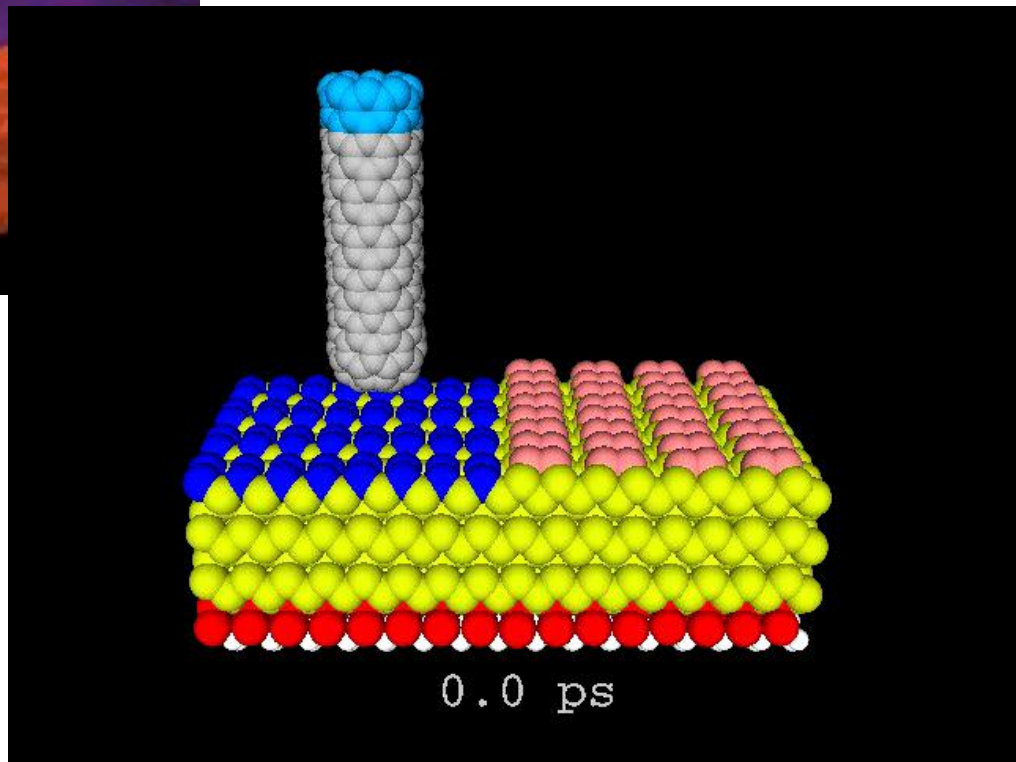
Quantum Dots

Nanotube movies



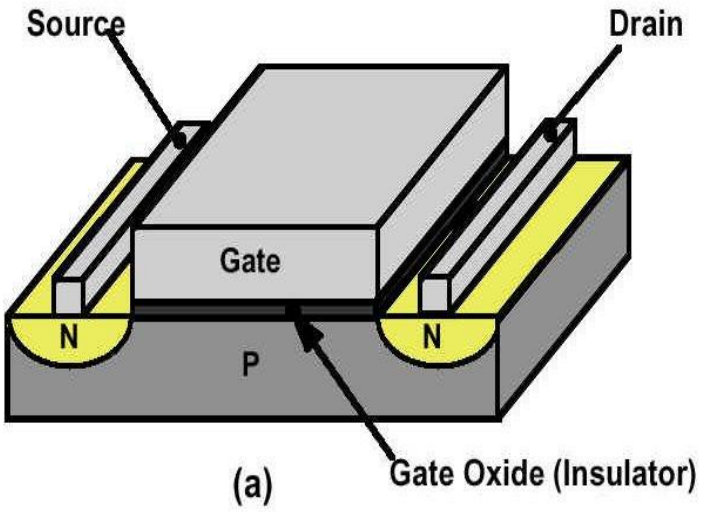
Carbon nanotube-based nanoelectronic circuits

Carbon nanotube-based nanoprobe



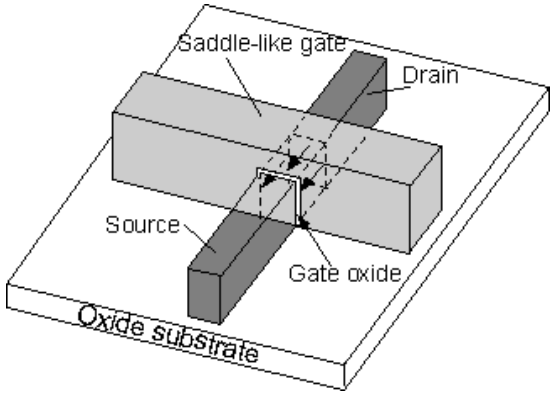
Nanofactory

III. Nanoscale Molecular Electronics

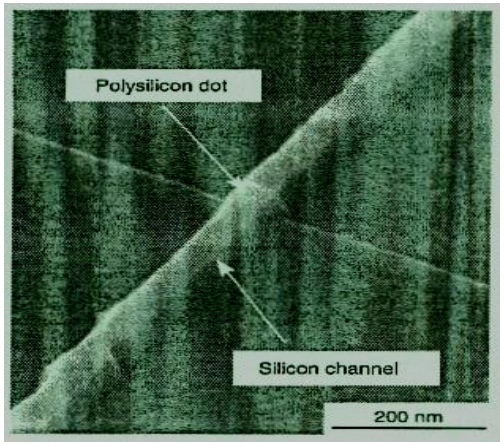


Challenges in electronic devices

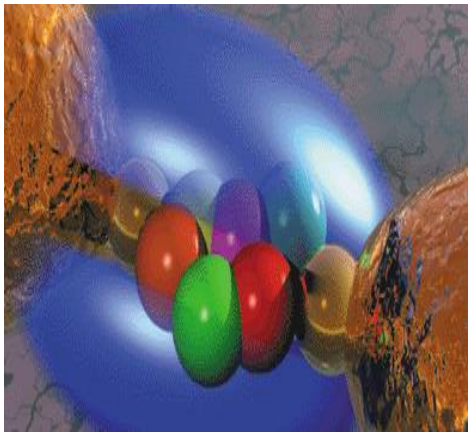
Sustained need of smaller and faster electronics may require revolutionary approaches to device manufacturing



Nanoscale CMOS

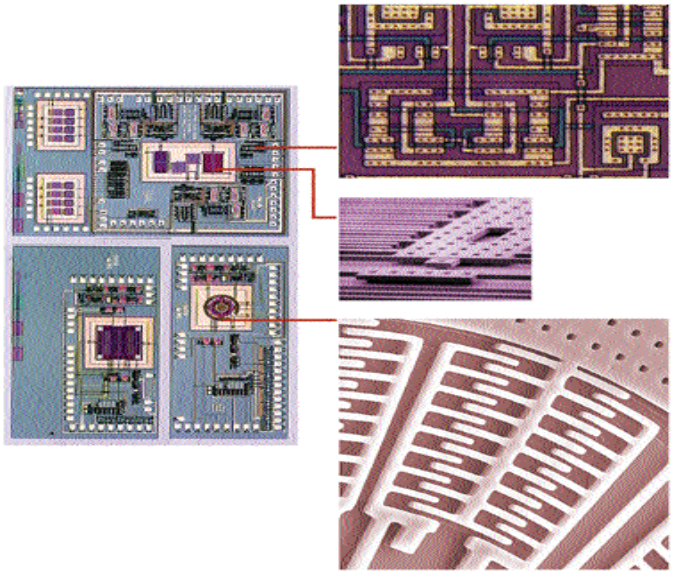


Single-Electron Systems



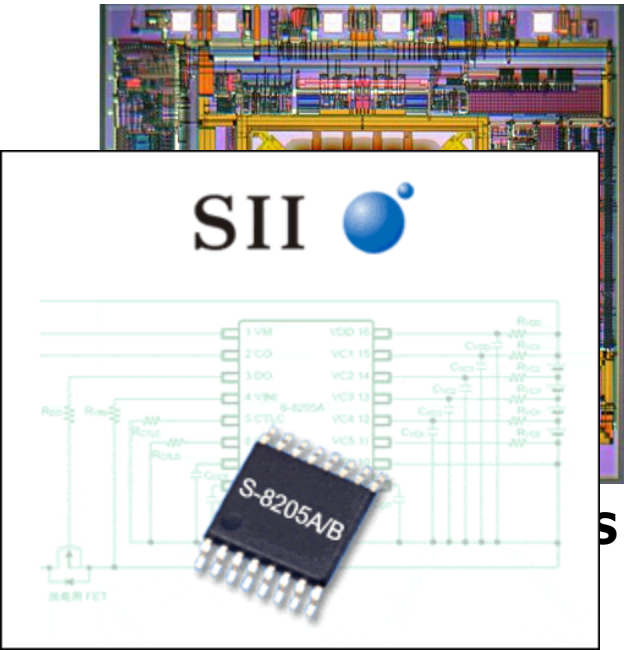
Molecular Electronics

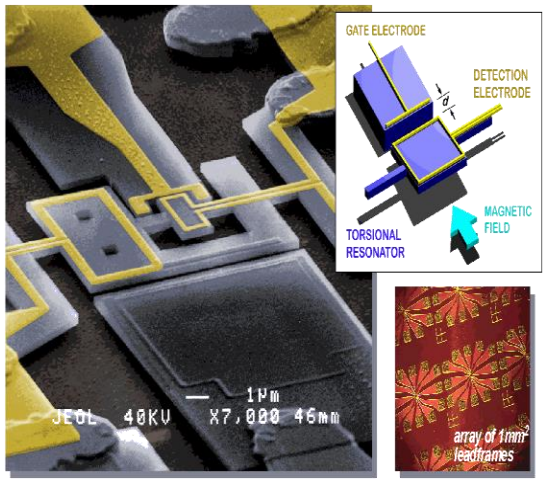
IV. Nanotechnology in Integrative Systems



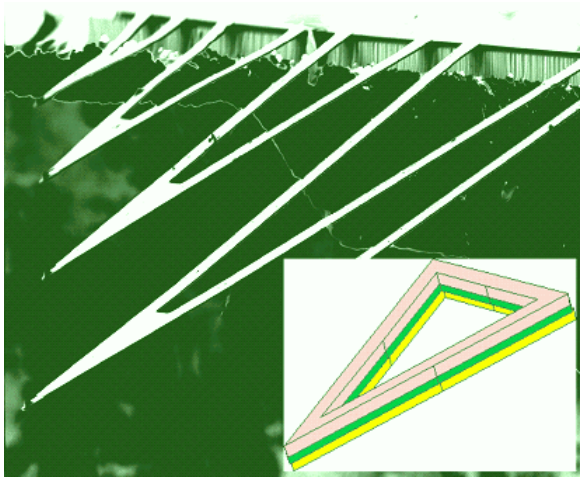
Challenges in microsystems

- complex architectures
- reduction of system size
- lower power consumption
- requires new "success" stories





Nanoelectromechanical Systems（NEMS）



Micromechanical Sensors

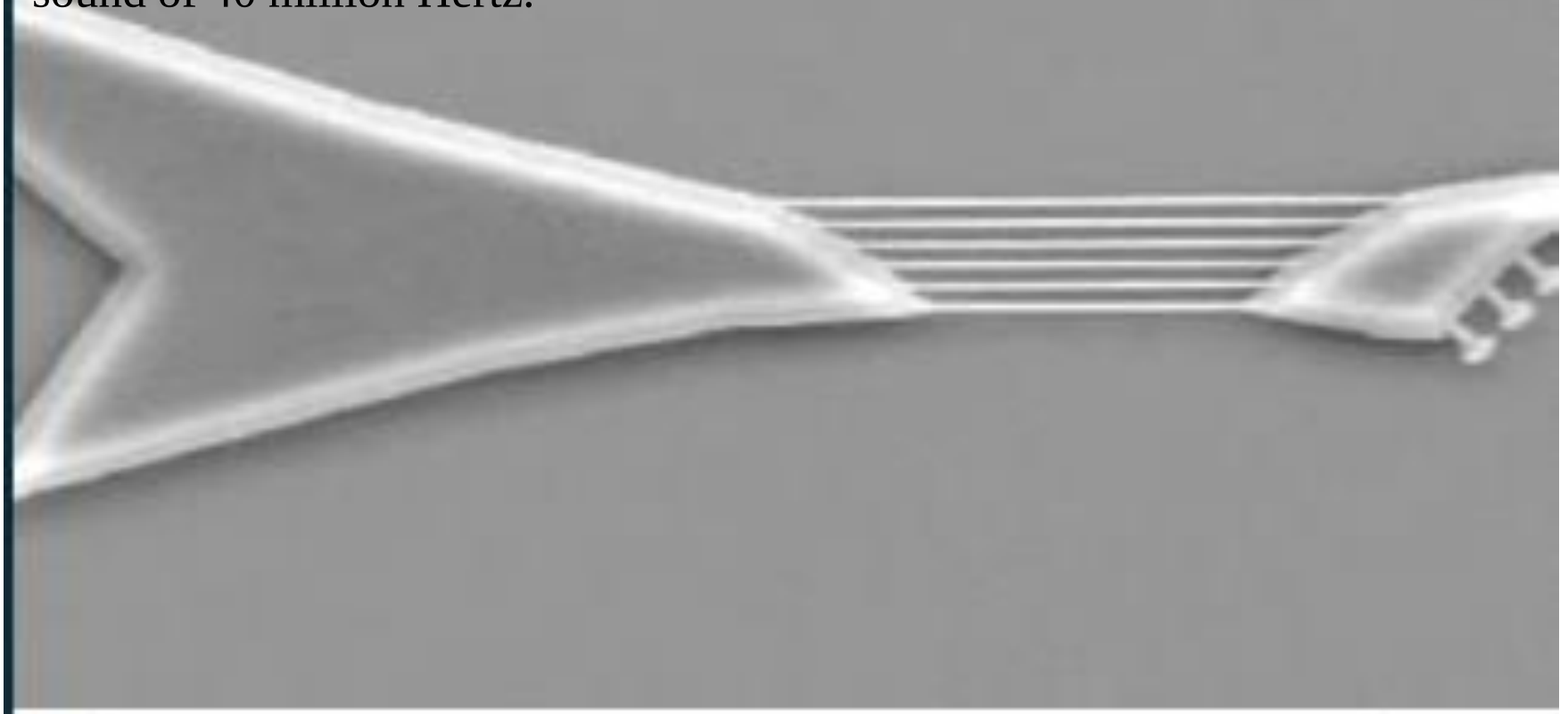
Application of micro-accelerator：

Safety air bag in automobile

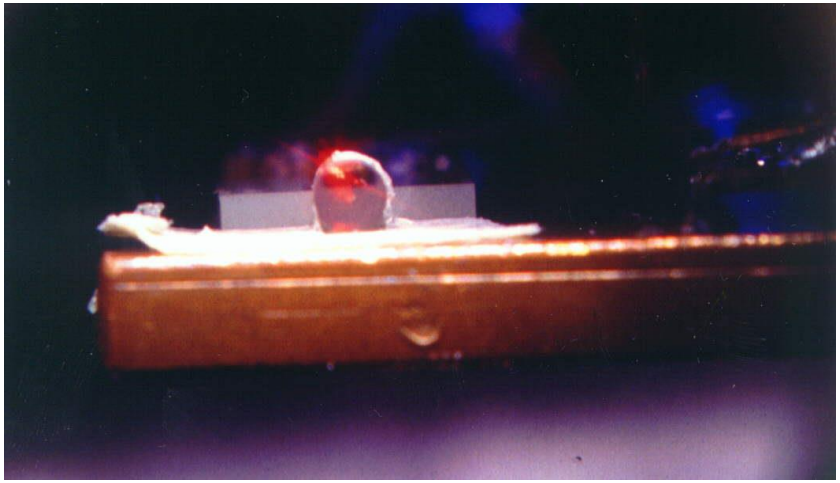
MANUFACTURING NANO-OBJECT

NANOGUITARS

This micro-instrument was made from silicon. Each of its strings measures about 50 nanometres, while the thickness is 100 atoms. Despite its tiny size, it was manufactured using the top-down technique. Physicists at Cornell University (New York) have used a laser beam to pluck the strings of the smallest guitar in the world and managed to produce a particularly high-pitched sound of 40 million Hertz.

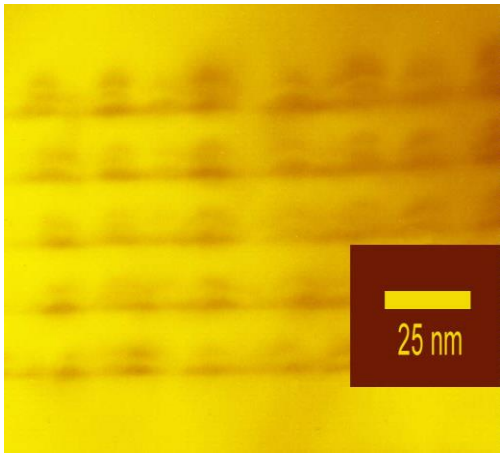


V. Nanoscale Optoelectronics

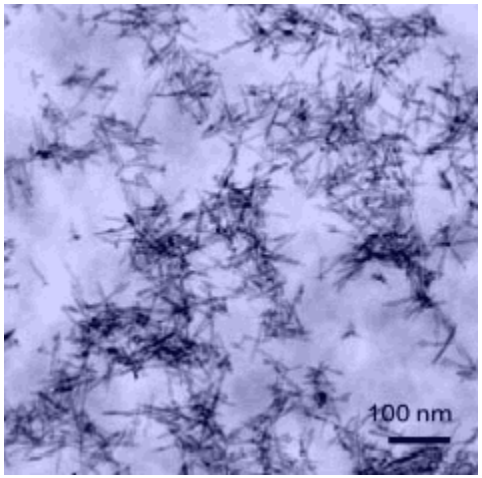


Challenges in optoelectronics

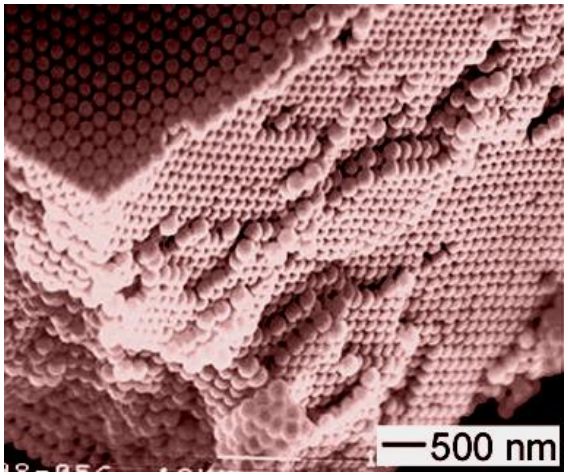
- device efficiency
- device tunability
- device integration
- novel materials for new applications



Quantum devices



Organic Assemblies

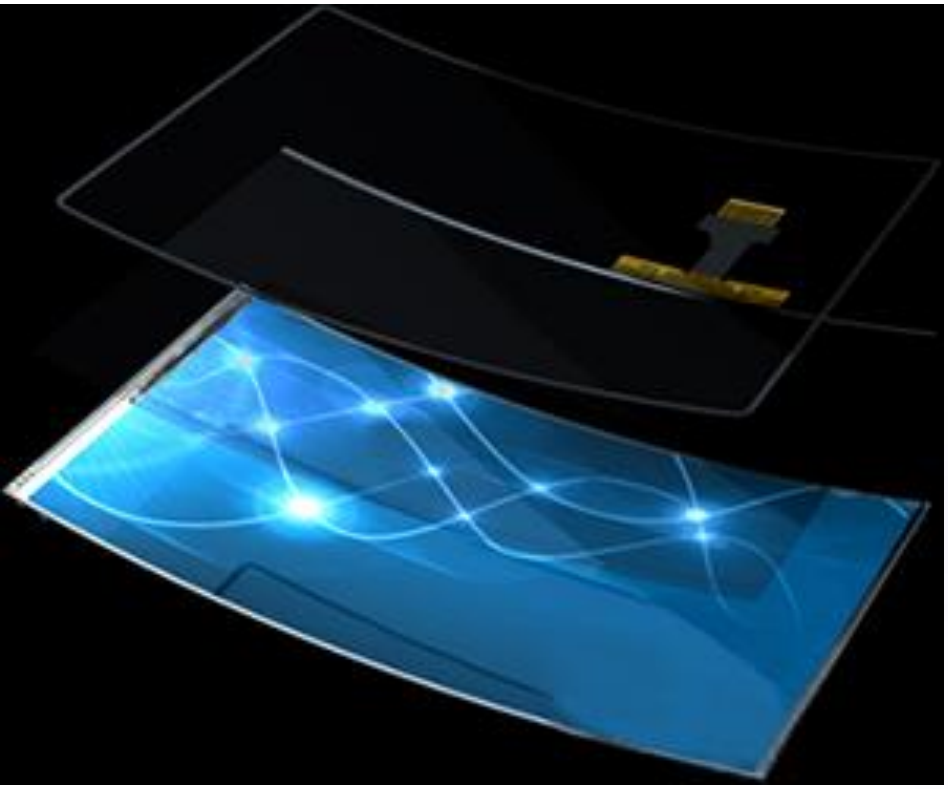


Photonic Crystals


8:15 PM AIR SKY
On TV
The Gadget Show
Food Unwrapped
Grand Designs
Agatha Christie's P...
Coronation Street
Ben Fogle: New Liv...
My Mad Fat Diary
in 45min
Guide
Timeline View
Trending
Recorded TV

iPhone7

基于石墨烯材料的柔性显示屏



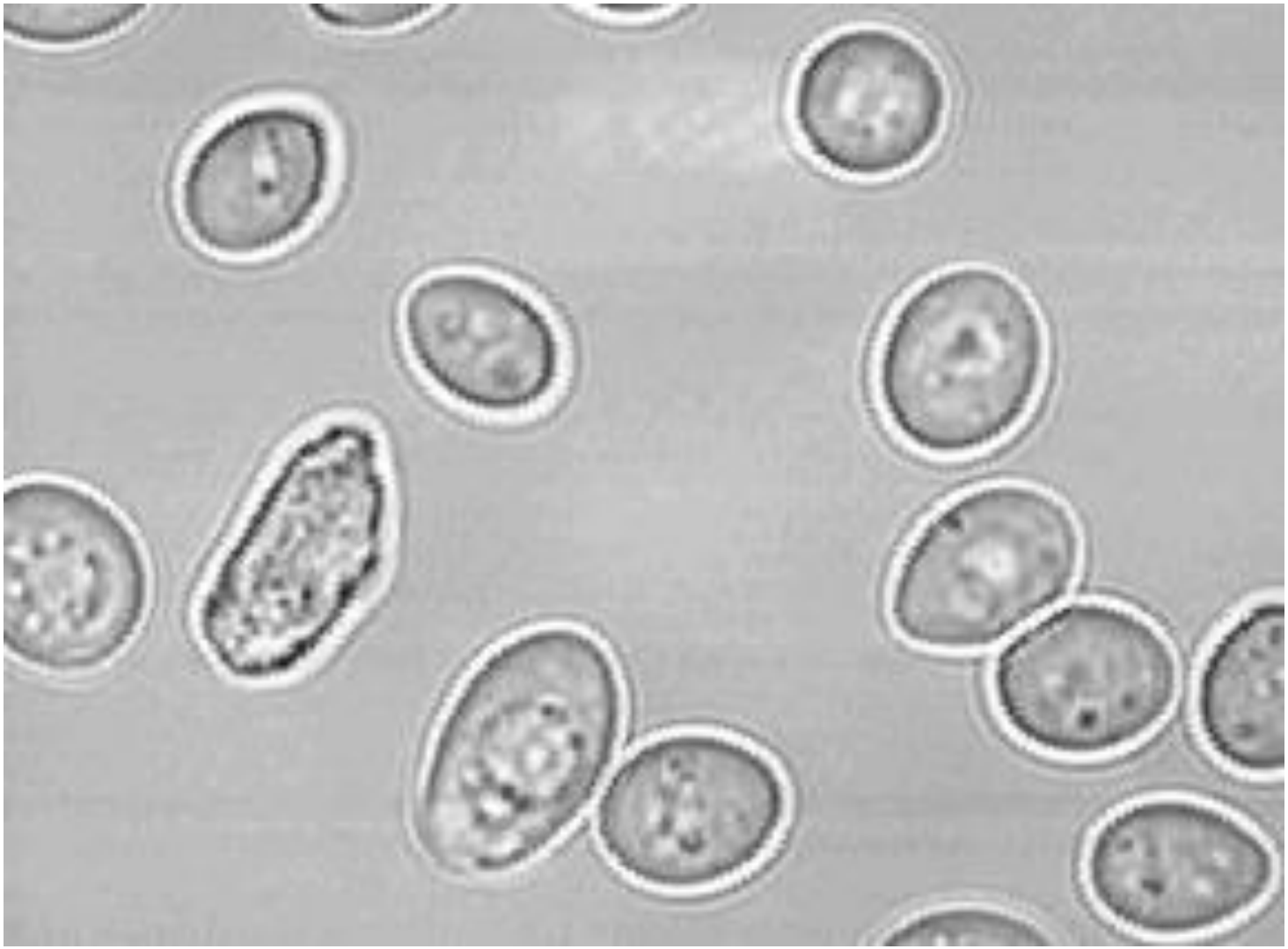
Huawei foldable

cellphone

Price：17500RMB

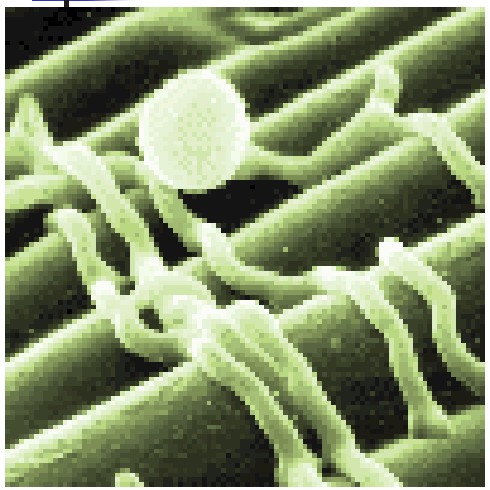
Li-Fi technique

Movies



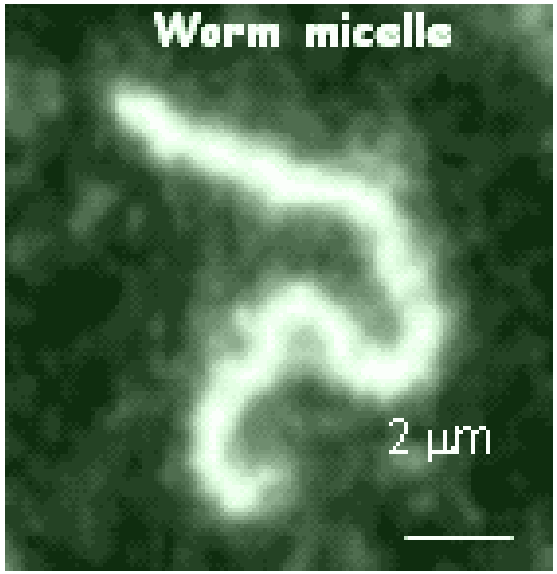
Optical tweezers

VI. Nanobiotechnology

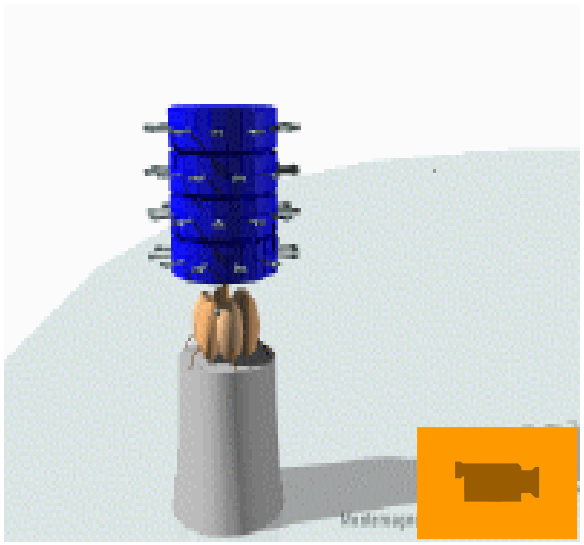


Challenges in biotechnology

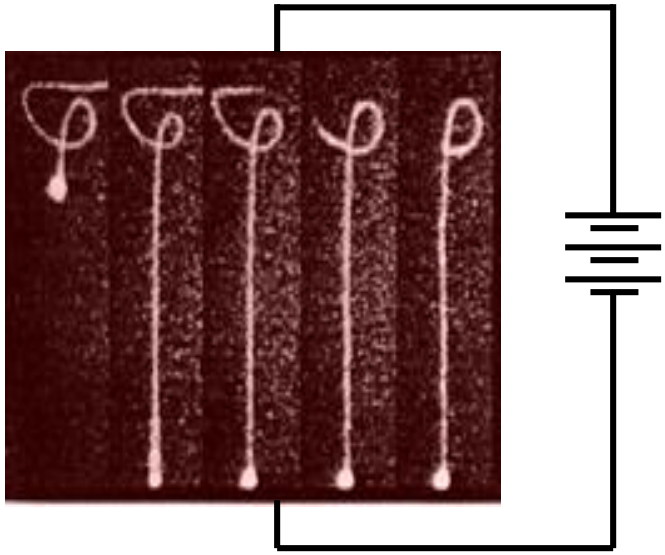
- understanding of natural nanosystems
- replication of nanosystems for novel device design



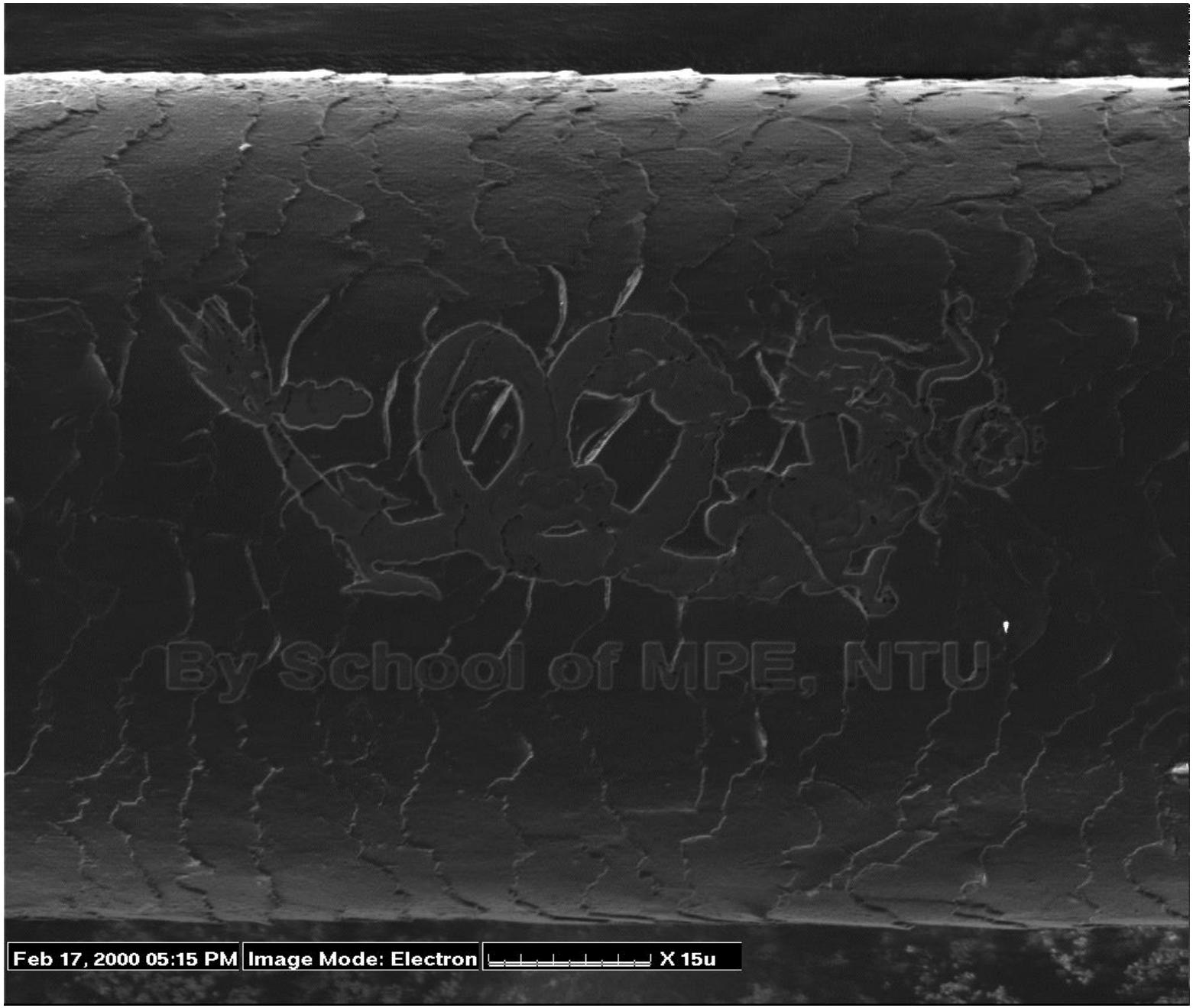
Biomimetic Nanostructures



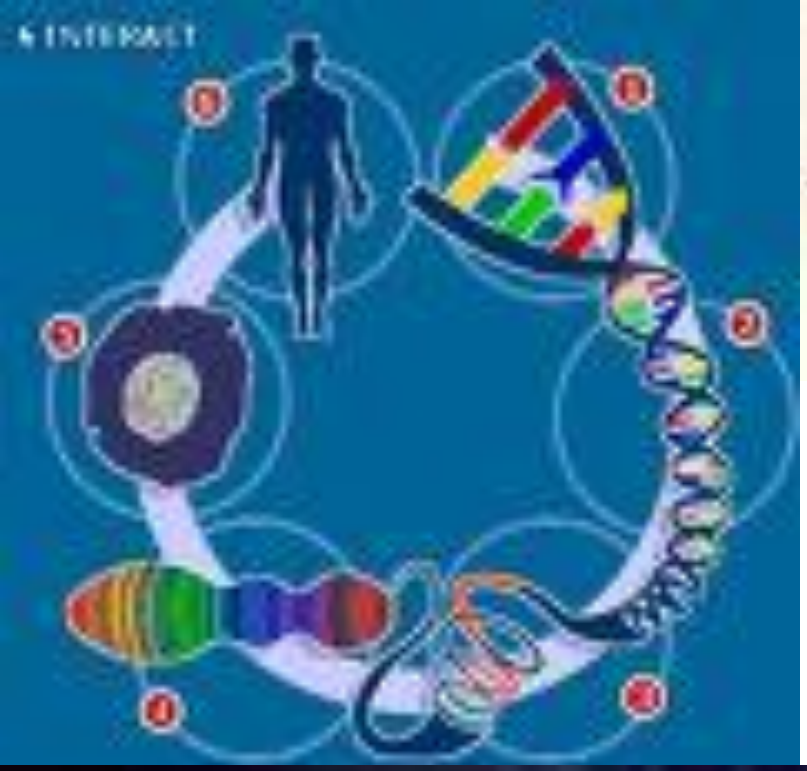
Molecular Motors



Nanofluidics



Dragon pattern milled on human hair with diameter of **60 μm** by FIB technology



Macro？ Micro？ Relativity！

VII. Nano-electronic-mechanical system (NEMS)

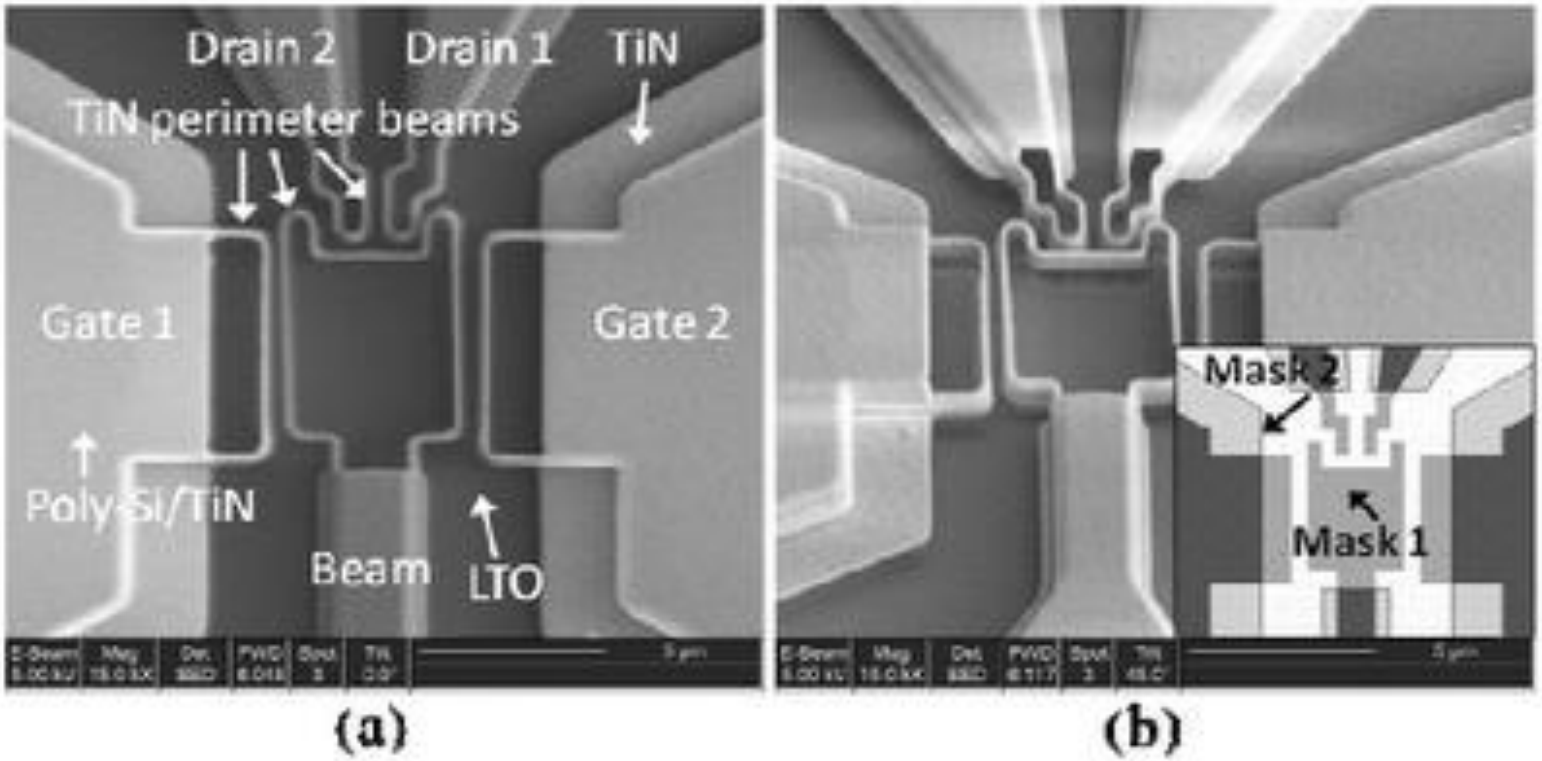
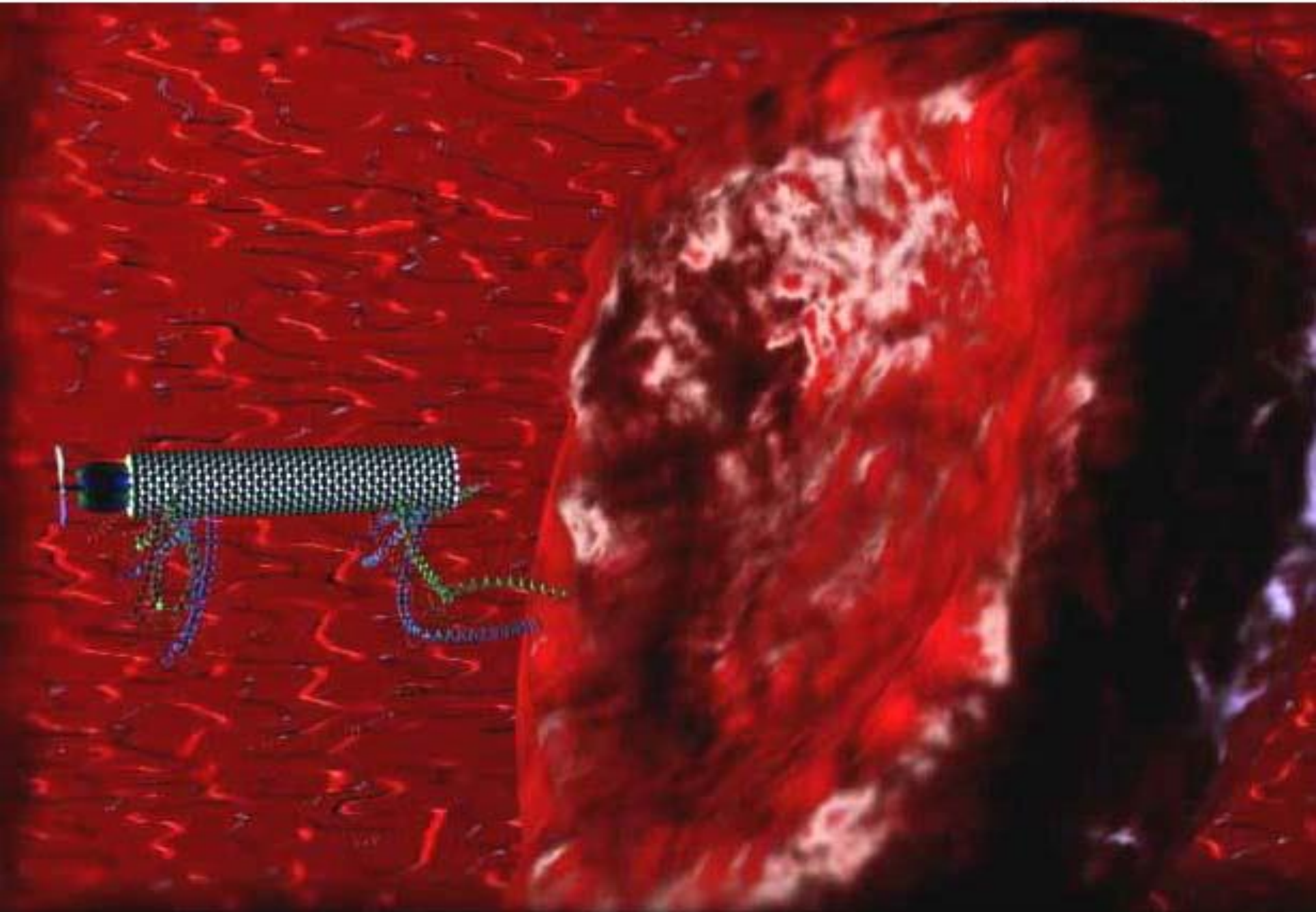
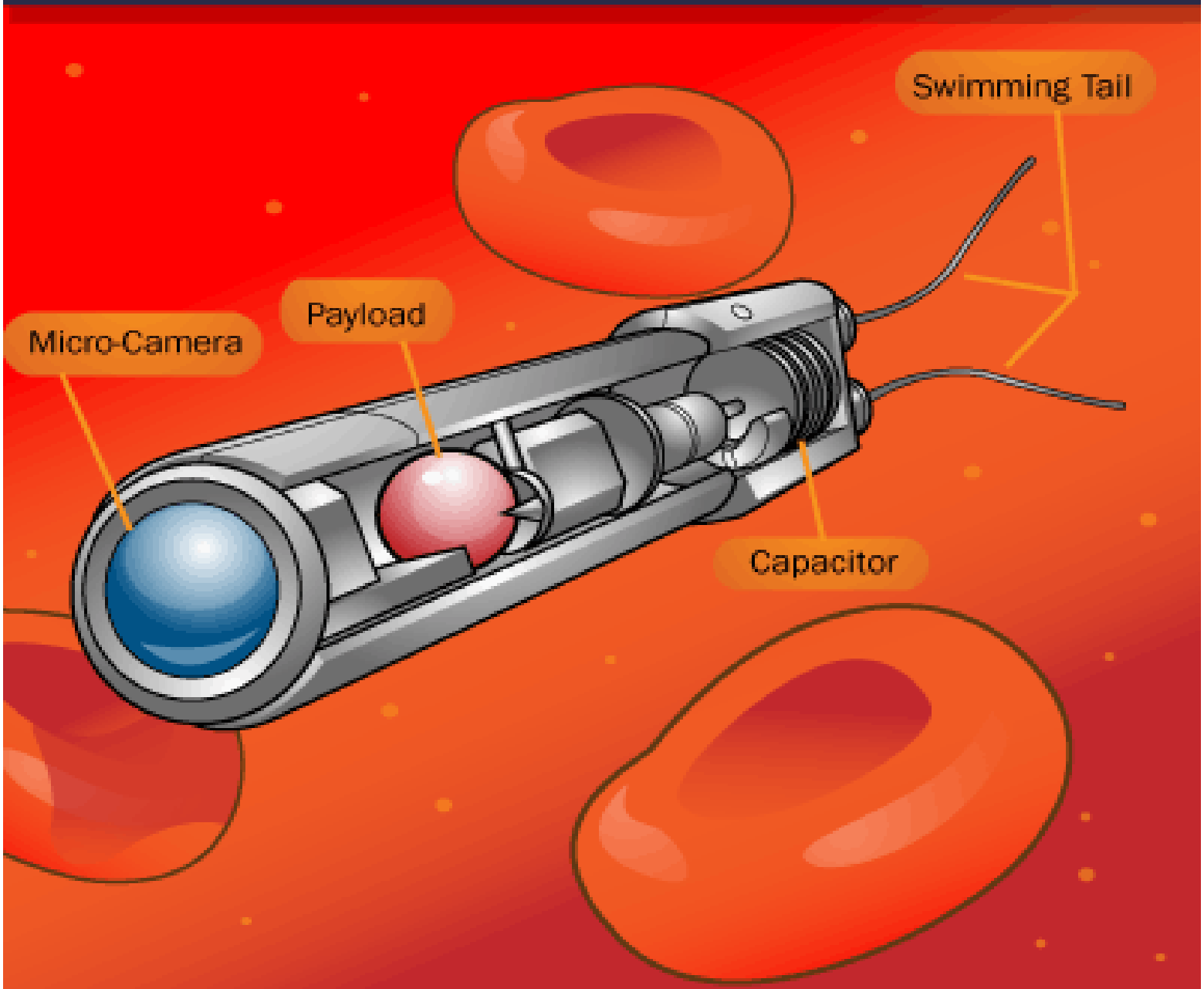


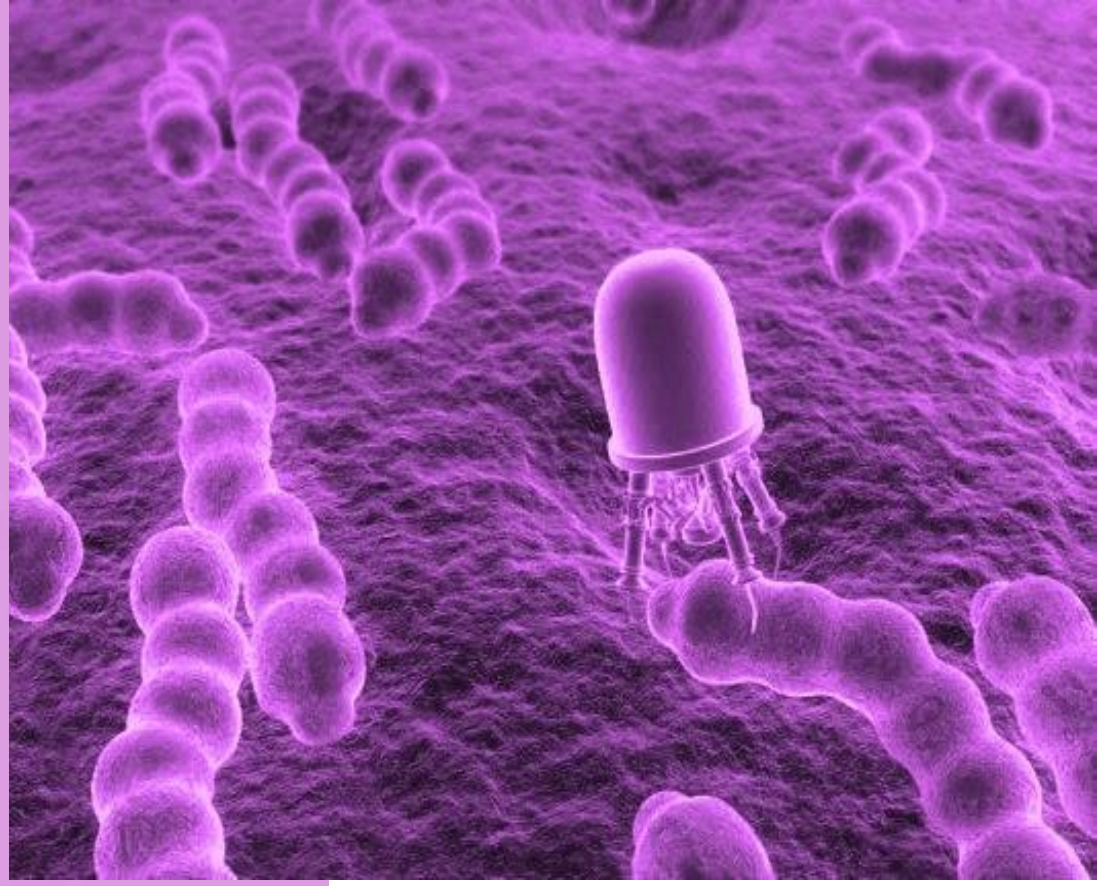
Figure 2. SEMs and mask layout of a fabricated lateral five-terminal NEM relay actuated in an SEM using the process in Fig. 1: (a) Top view, (b) 45 degree oblique view (Inset: Mask layout). The beam-to-gate and beam-to-drain spacing is 350nm and 200nm, respectively. The drains functions as a mechanical stop.



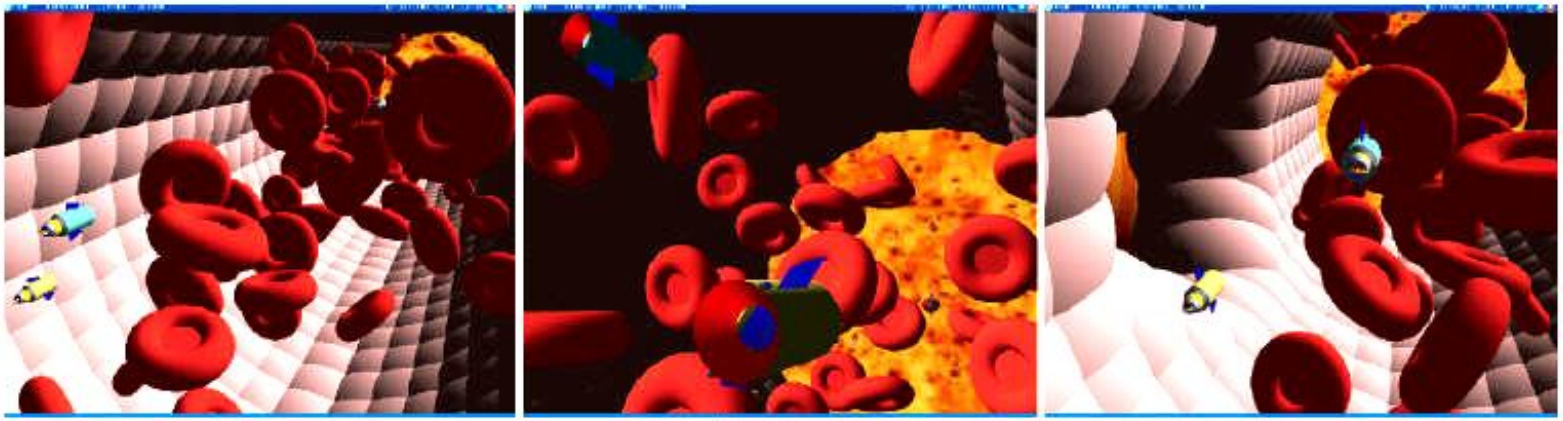
Powering nano-robotics

How Blood Swimming Robots Work





Nanorobots can be injected into human body by this way!!

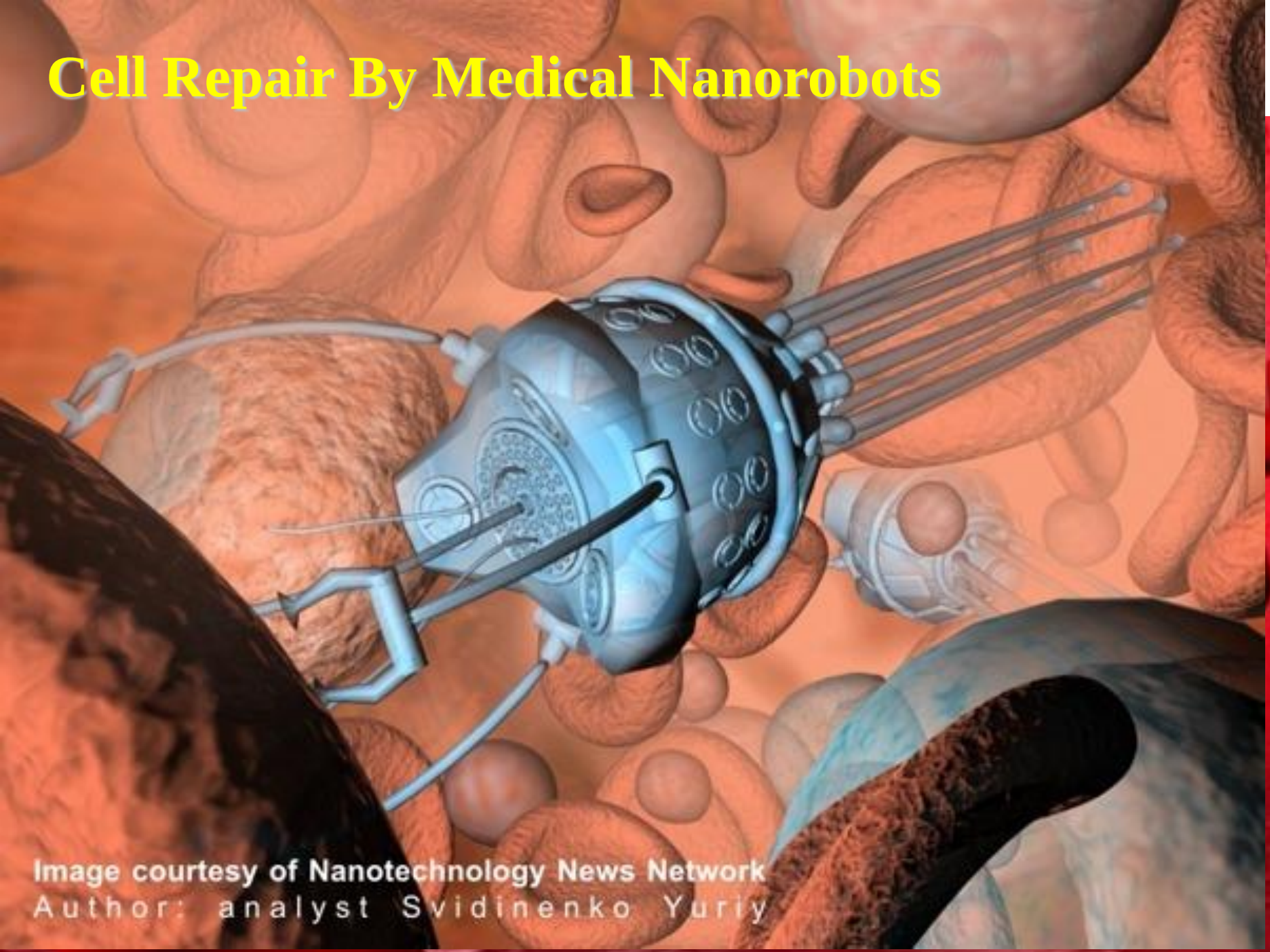


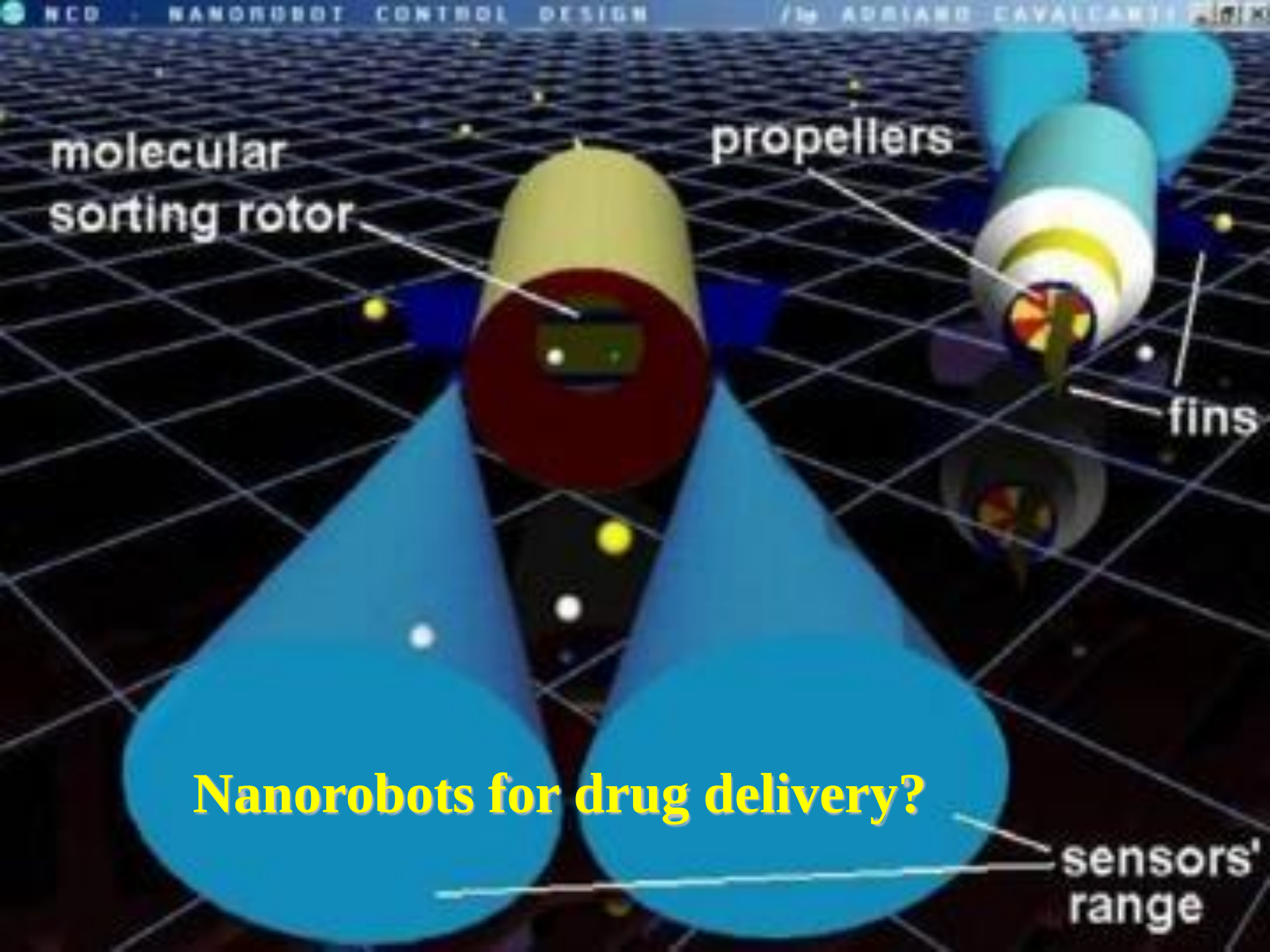
(a) (b) (c)

(d) (e) (f)

(g) (h) (i)

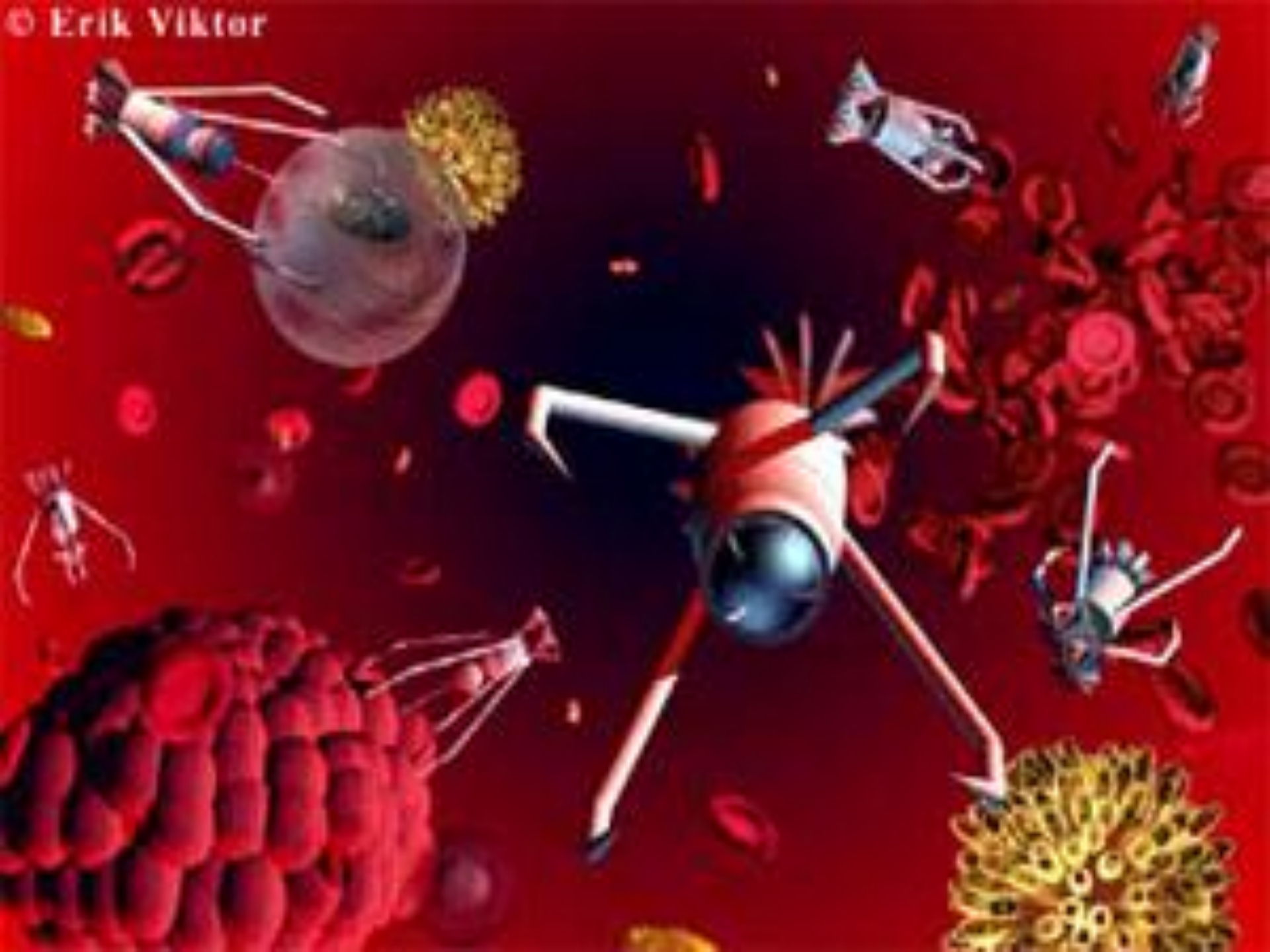
Cell Repair By Medical Nanorobots



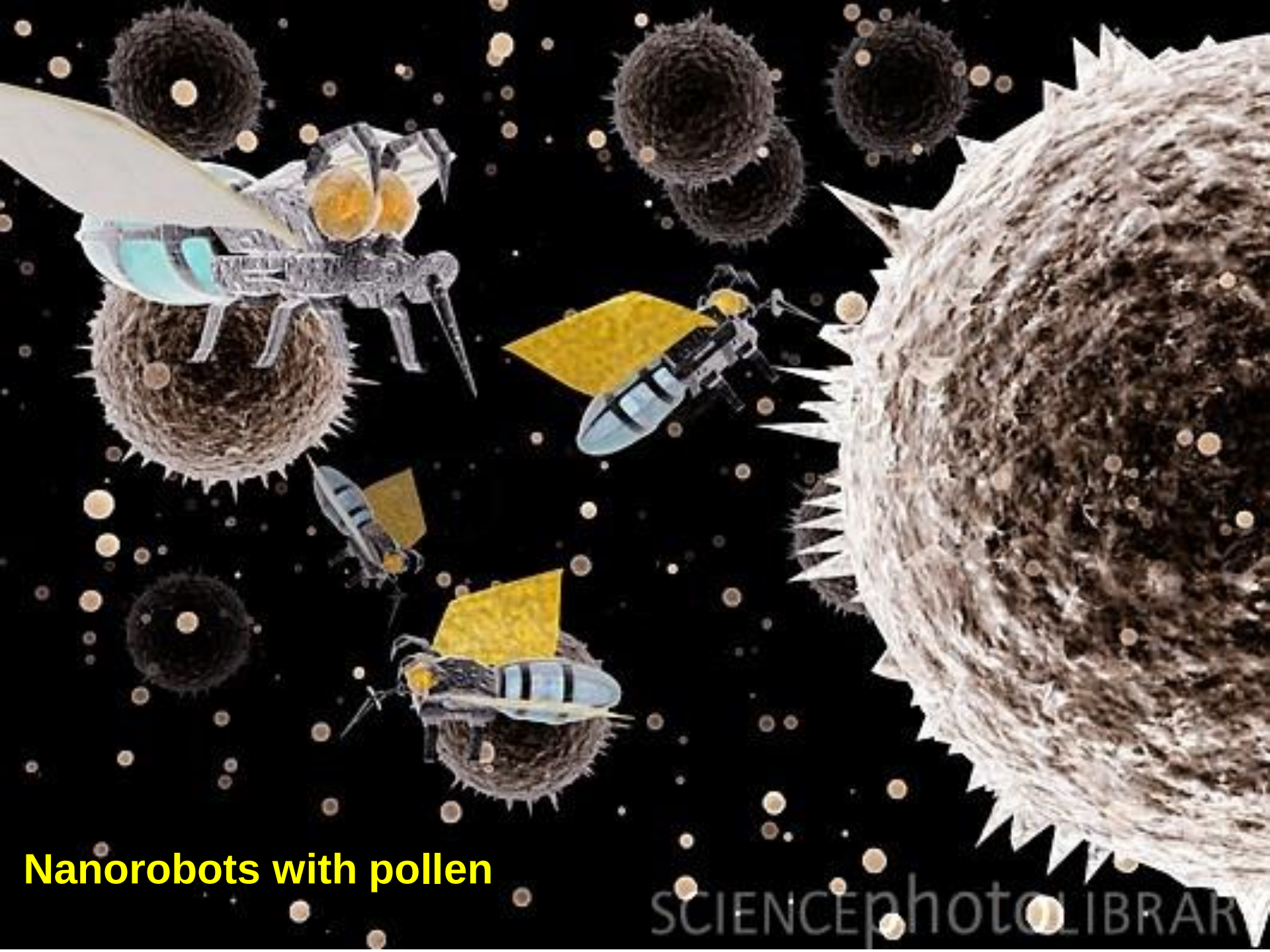


Nanorobots for drug delivery?

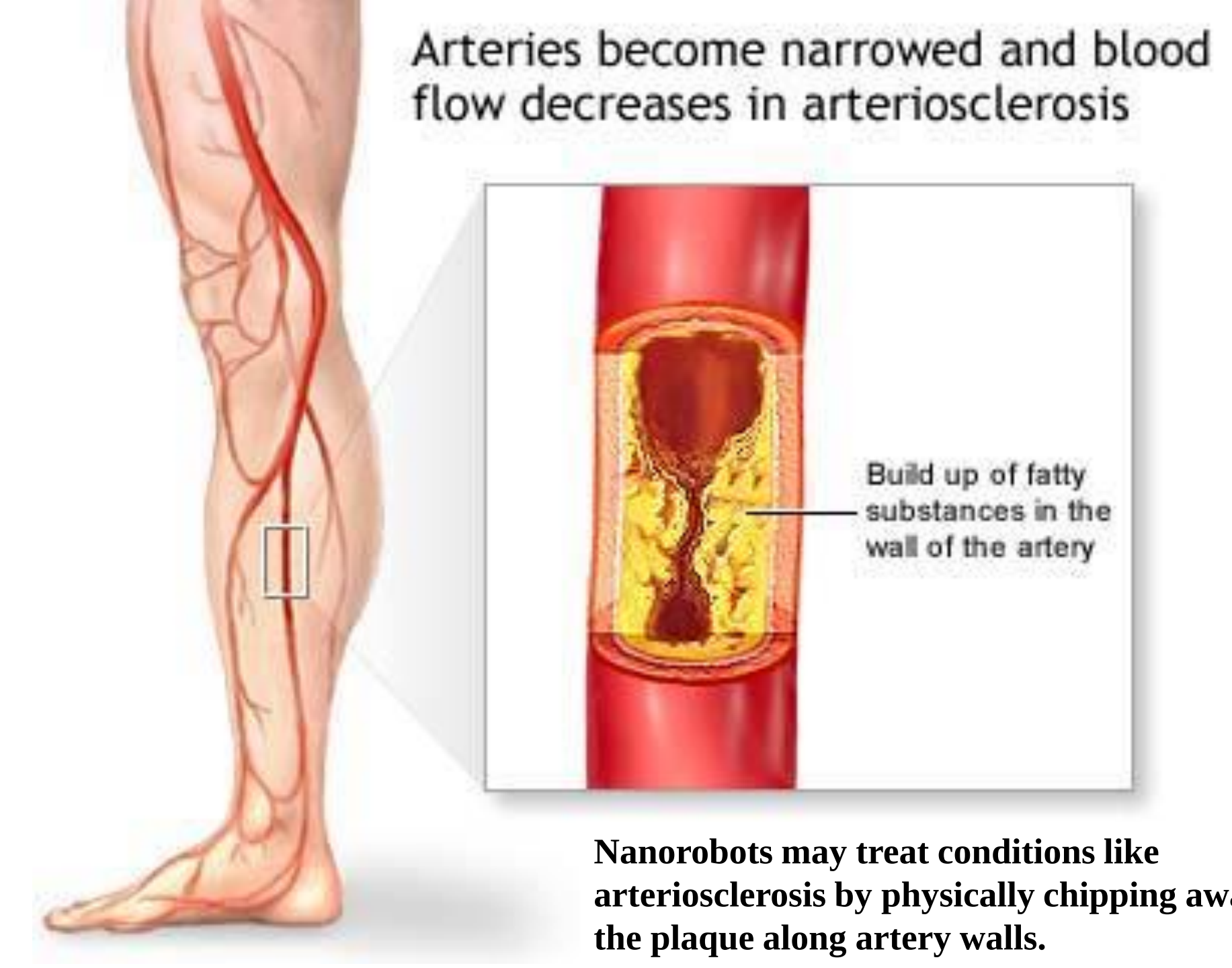

SCIENCEphotoLIBRARY


© Erik Viktor


hybrid

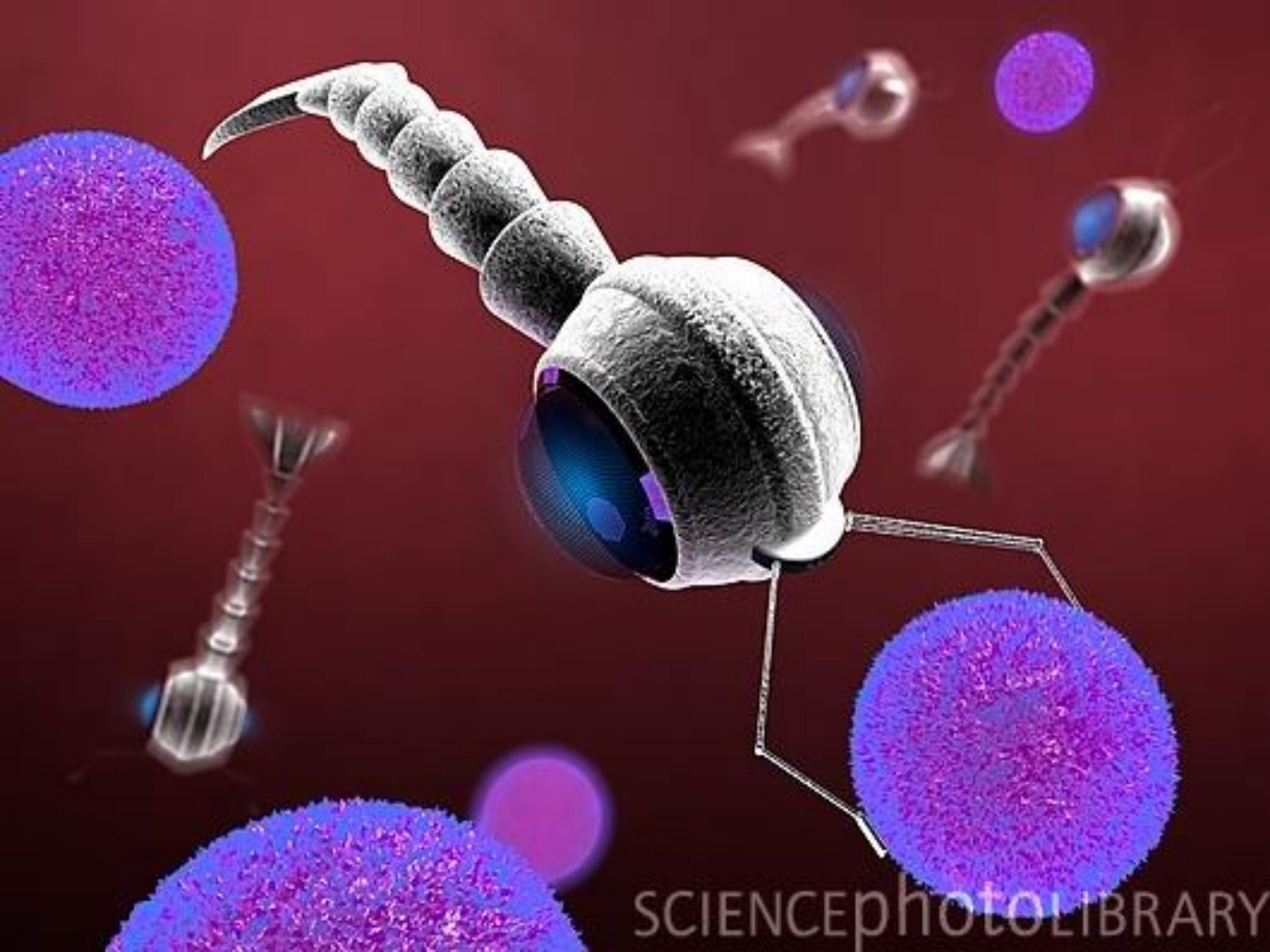


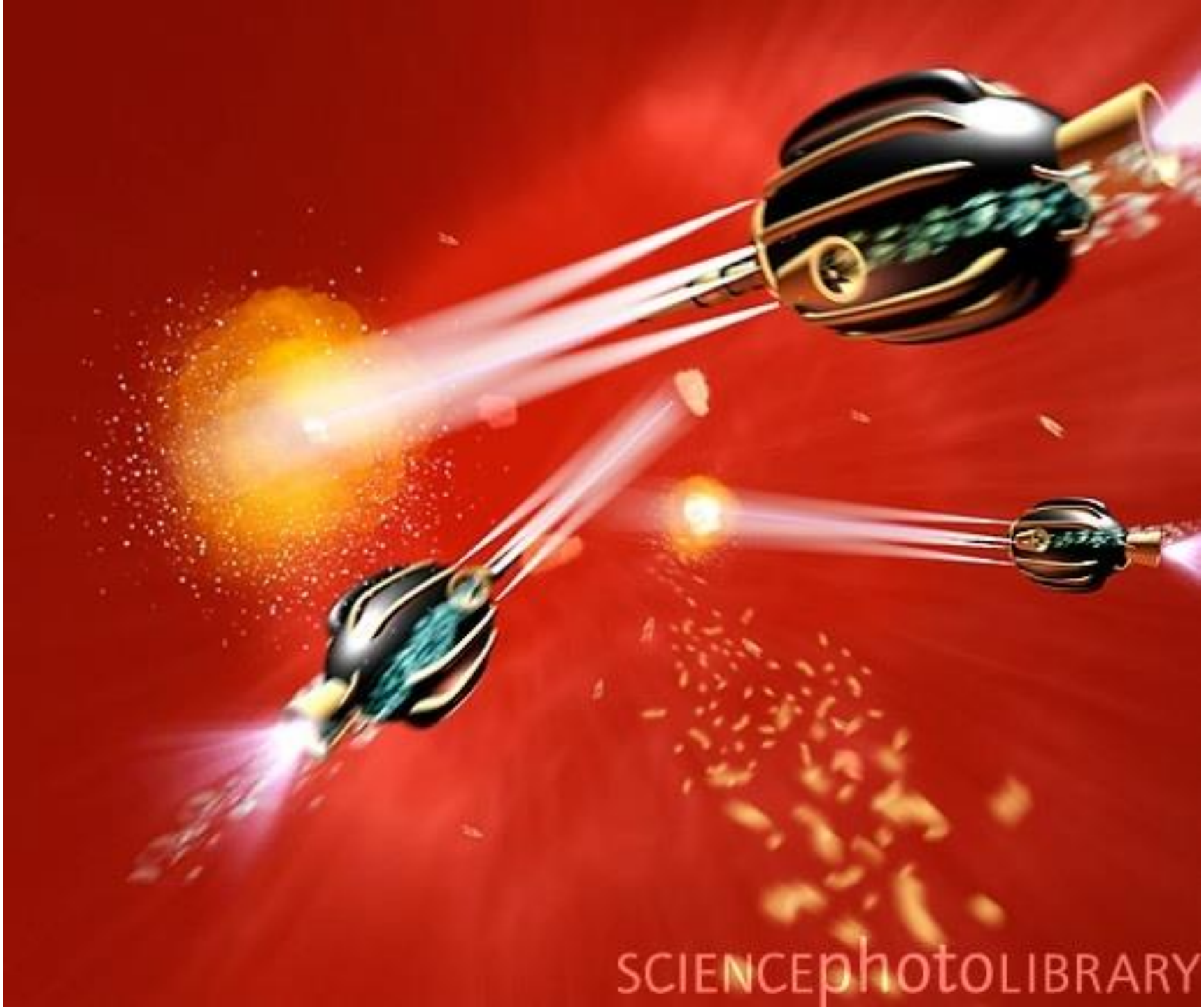
Nanorobots with pollen



Nanorobots may treat conditions like arteriosclerosis by physically chipping away the plaque along artery walls.

Tiny nanorobots the size of cells are programmed to travel through the bloodstream, finding and repairing defects in the body's organs and tissues.


SCIENCEphotoLIBRARY


SCIENCEphotoLIBRARY

A Robot So Tiny it Can Alter DNA Code

Future Dreams

of Human Being

Stem cell utilization: regenereation

Reproductive cloning technique using stem cell

乳腺细胞

1. Scientists remove the nucleus of an egg cell from a female sheep.

nucleus

egg cell

2. A mammary gland cell is removed from an adult female sheep. This cell and the egg cell are placed next to each other in a bath of chemicals.

egg cell

mammary gland cell

3. A jolt of electricity causes the two cells to fuse.

egg cell

mammary gland cell

fused cell

4. The fused cell begins dividing to form an embryo.

dividing cell

embryo

5. The embryo is then inserted into the uterus of a surrogate mother to complete its development. The resulting lamb is a clone of the sheep that donated the mammary gland cell.

Figure 5.32 The reproductive cloning process

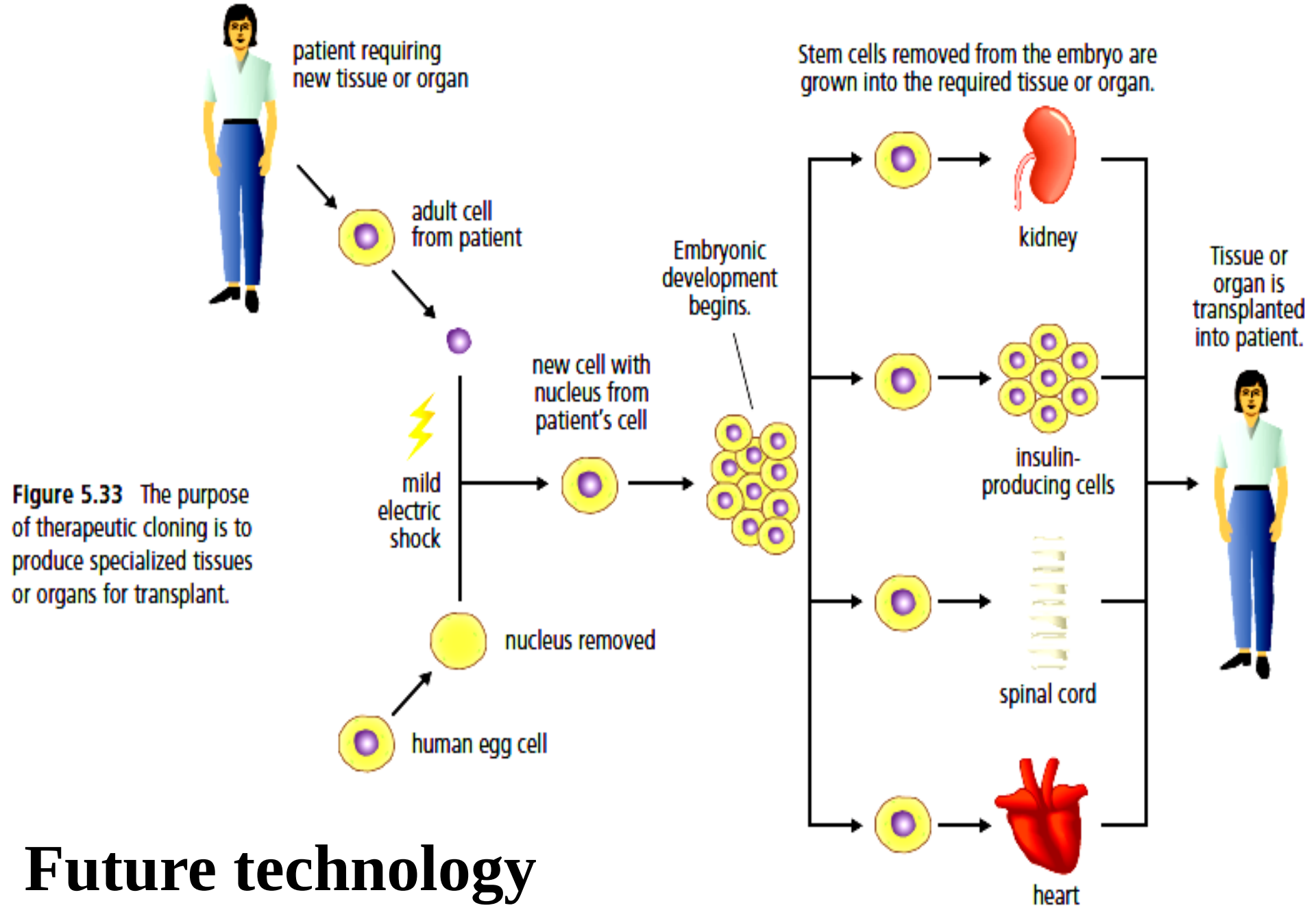
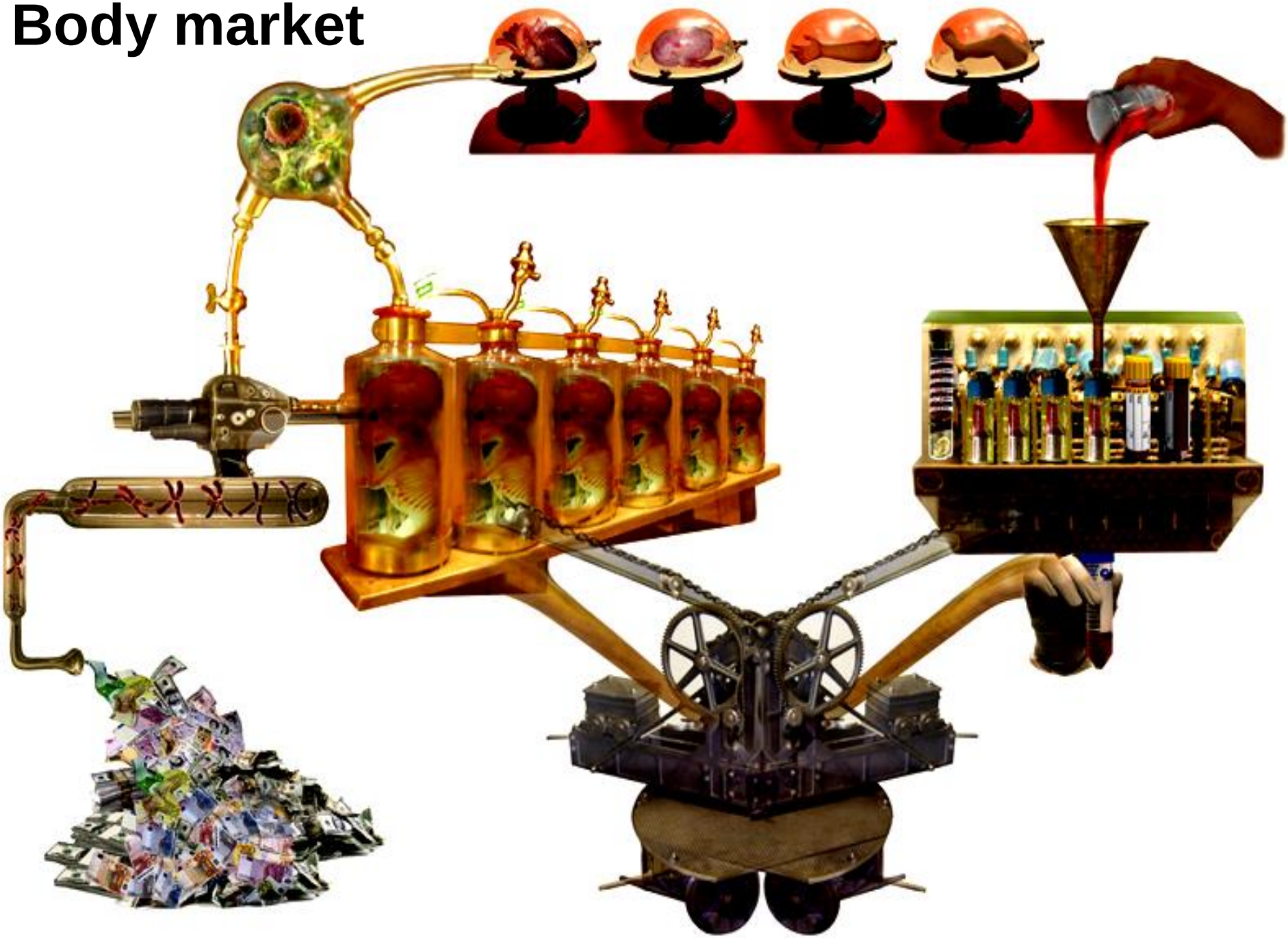


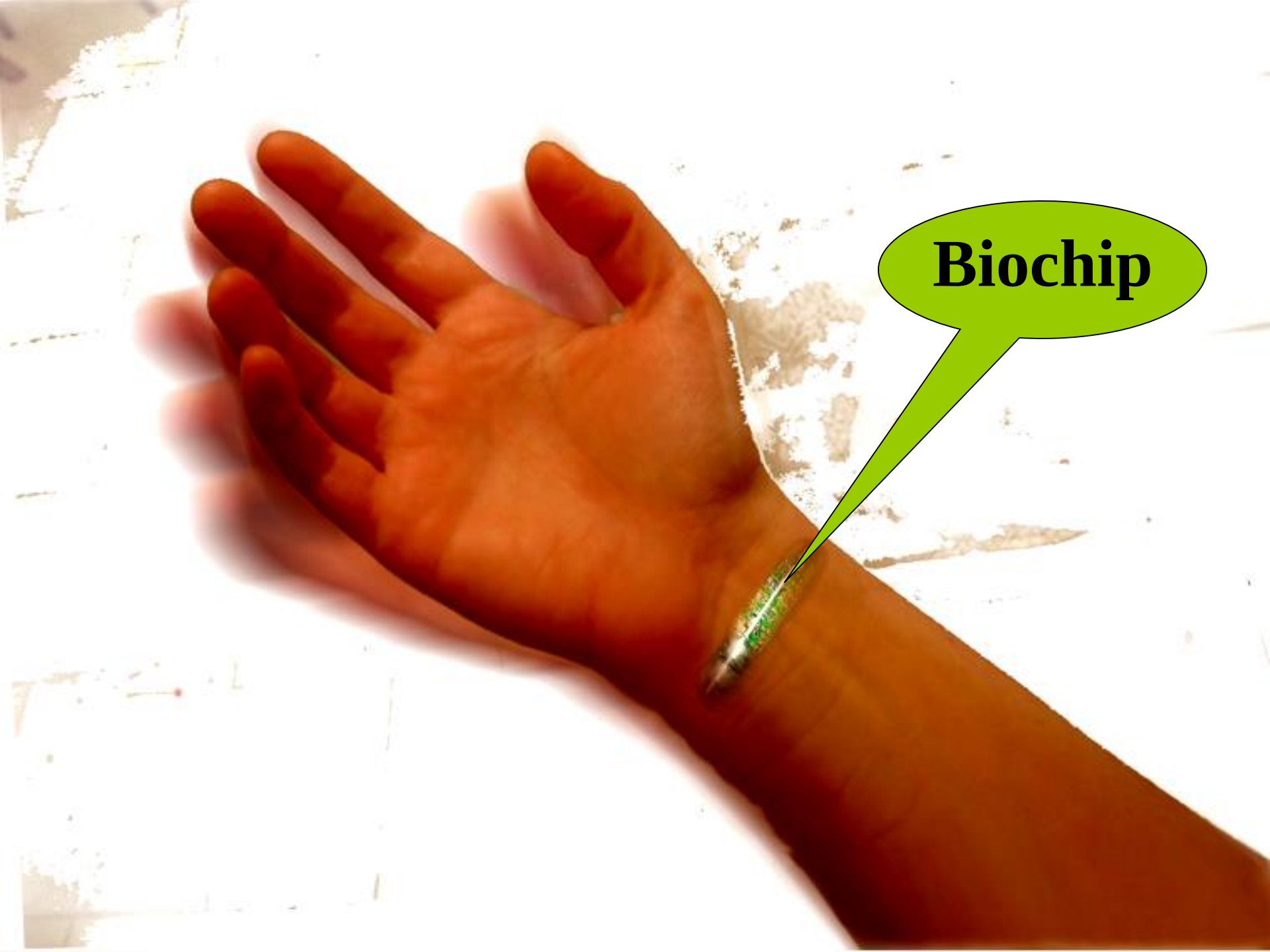
Figure 5.33 The purpose of therapeutic cloning is to produce specialized tissues or organs for transplant.

Future technology

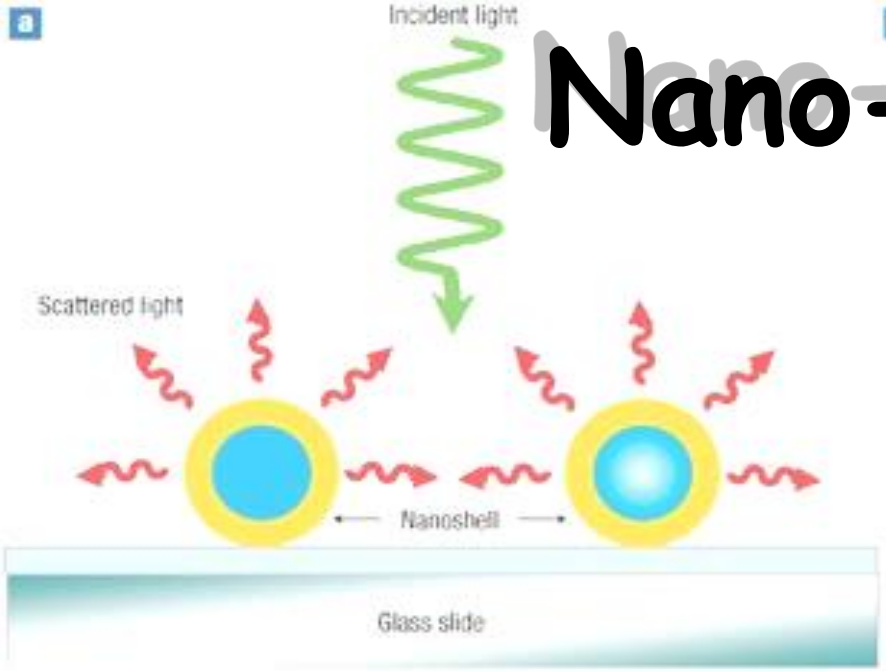
Body market

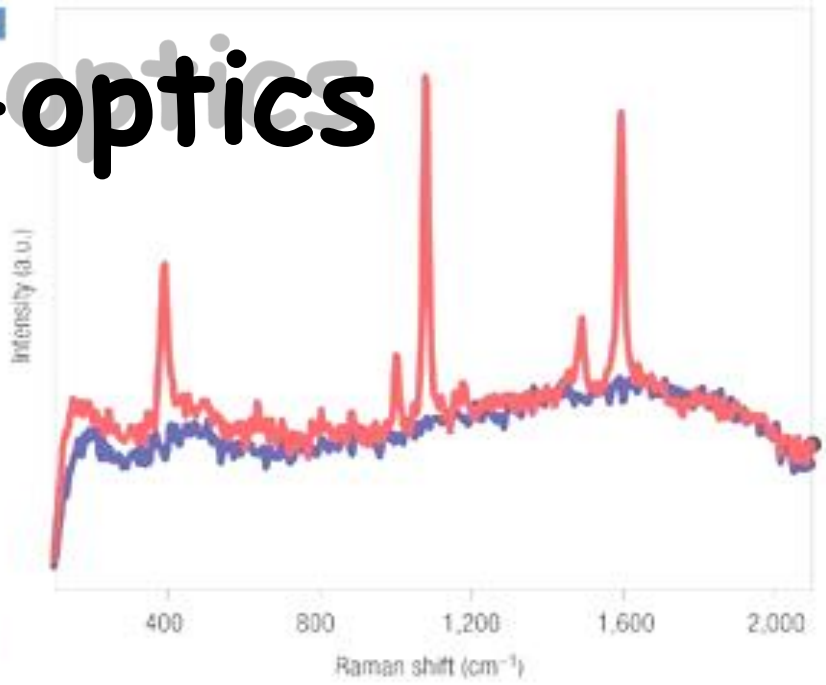


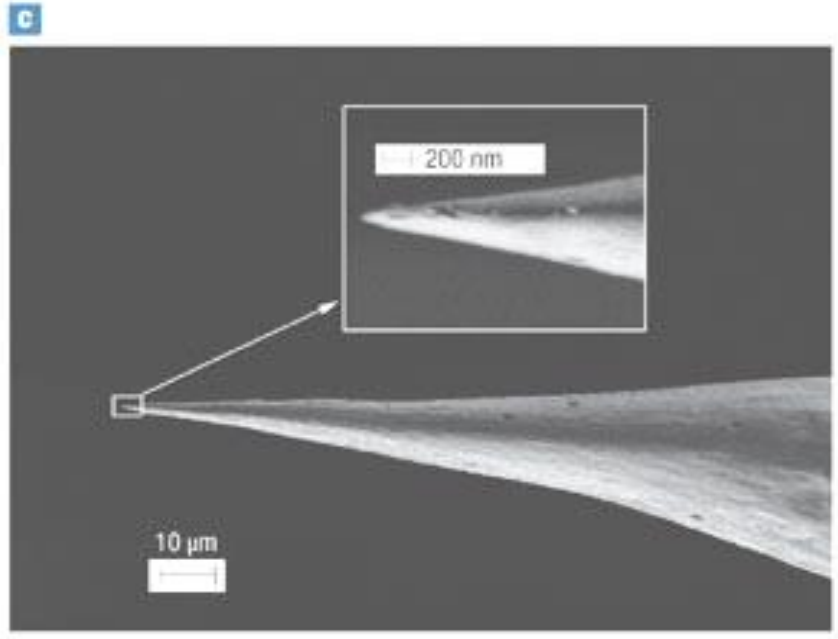
Fresh fruit

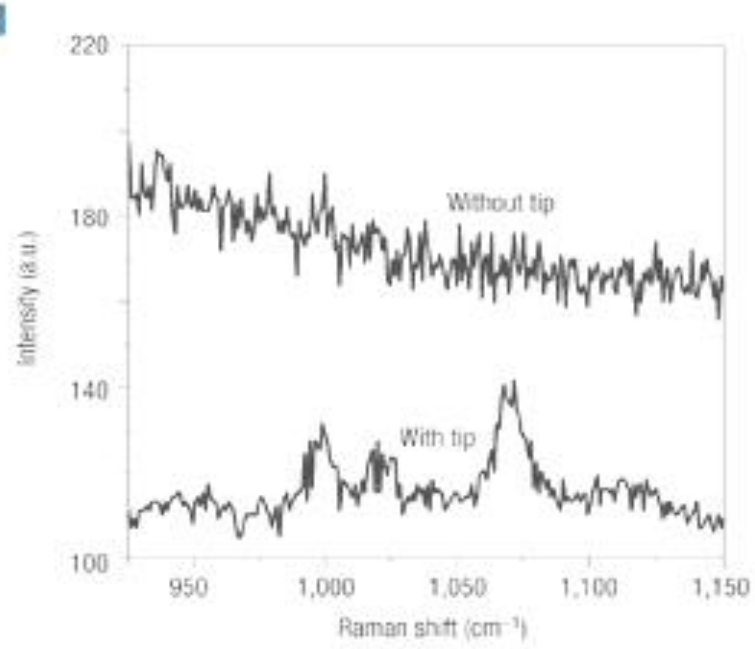

Biochip

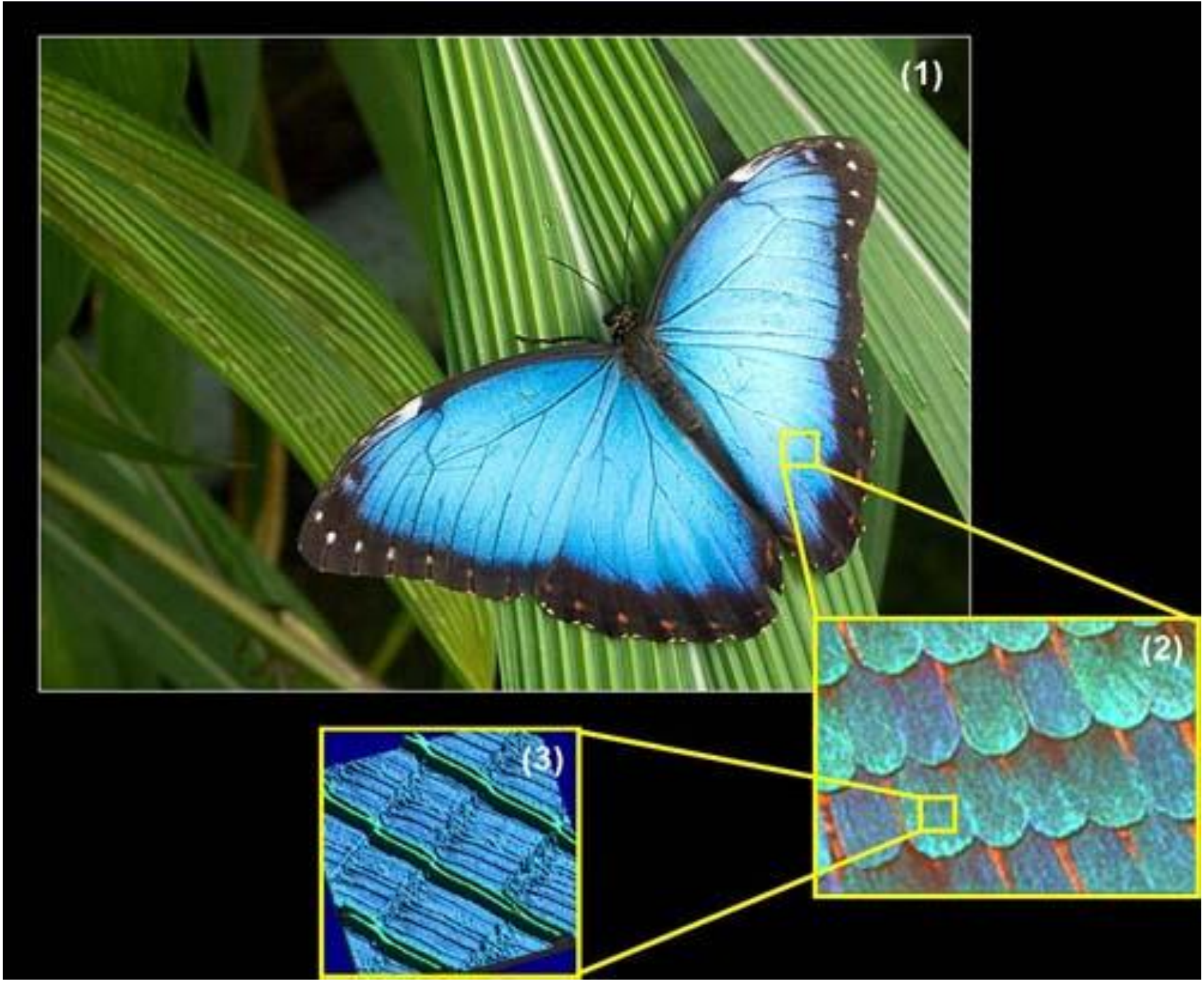
Nano-optics


a
Incident light
Scattered light
Nanoshell
Glass slide

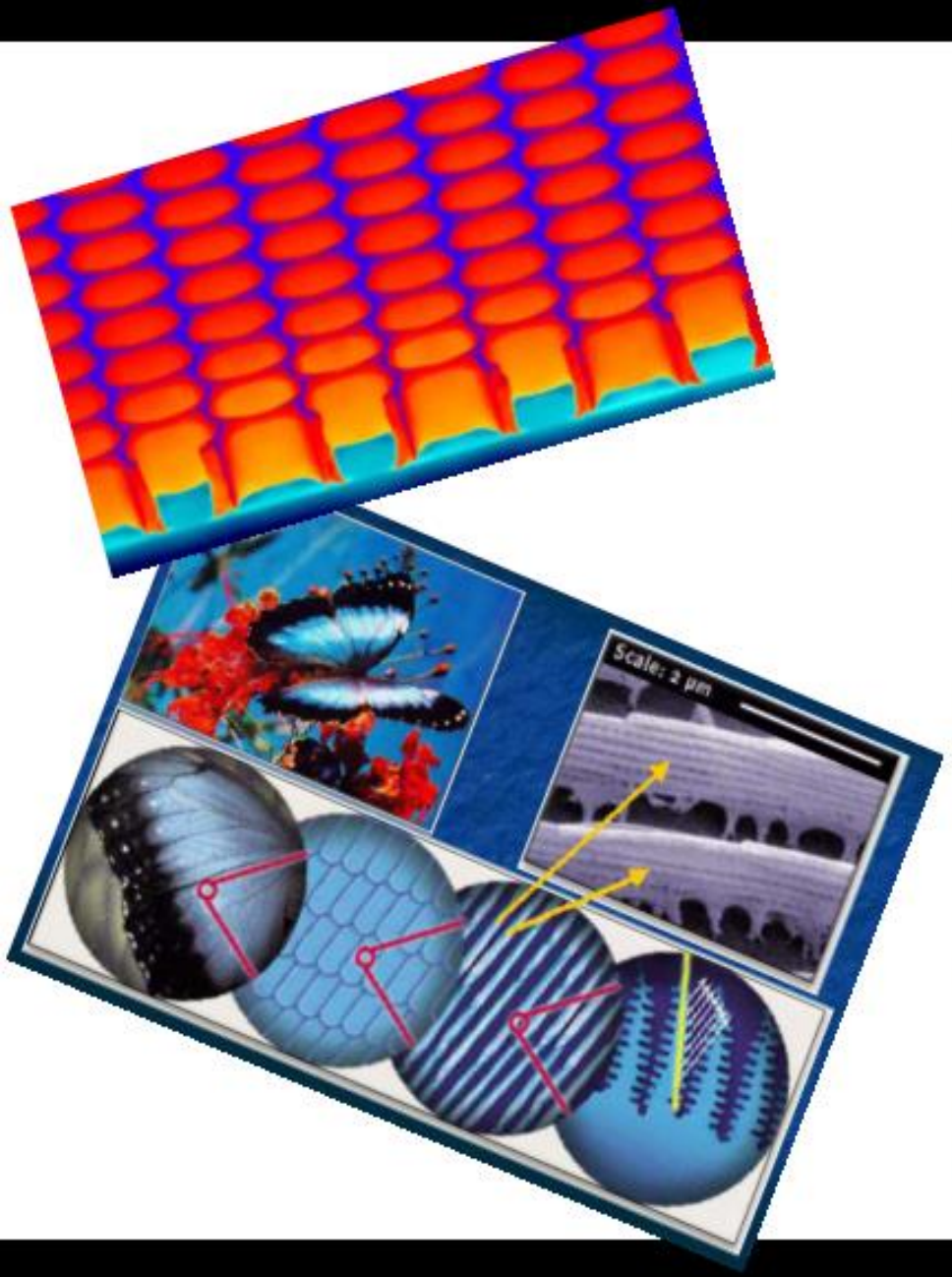

b
Intensity (a.u.)
400
800
1,200
1,600
2,000
Raman shift (cm⁻¹)


c
200 nm
10 μm


d
220
180
140
100
Intensity (a.u.)
Without tip
With tip
950
1,000
1,050
1,100
1,150
Raman shift (cm⁻¹)


(1)
(2)
(3)

Photonic crystals



... have lattice constants comparable to light wavelengths: $a \sim \lambda$

... can be artificial or natural

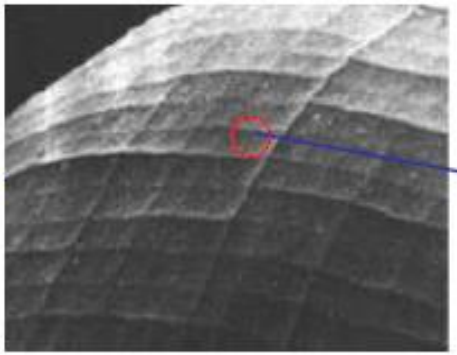
... have properties governed by the diffraction of the periodic structures

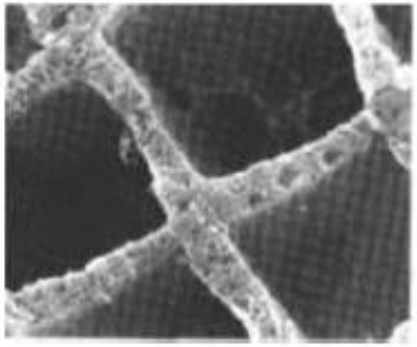
... may exhibit a bandgap for photons

... typically are ***not*** well described using effective parameters ε, μ, n, Z

... often behave like but they are ***not*** true metamaterials

Metamaterials: Properties not found in nature?

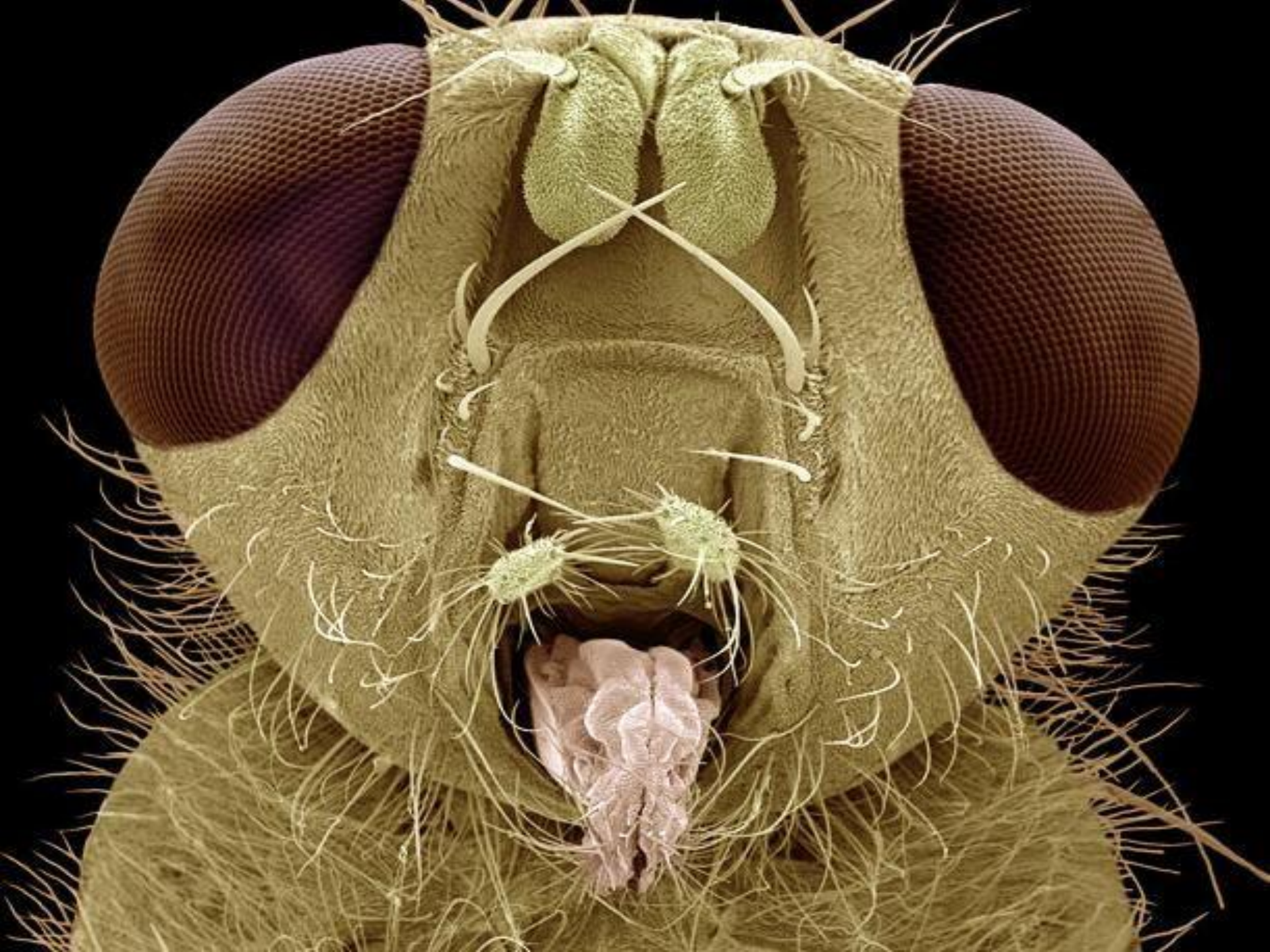


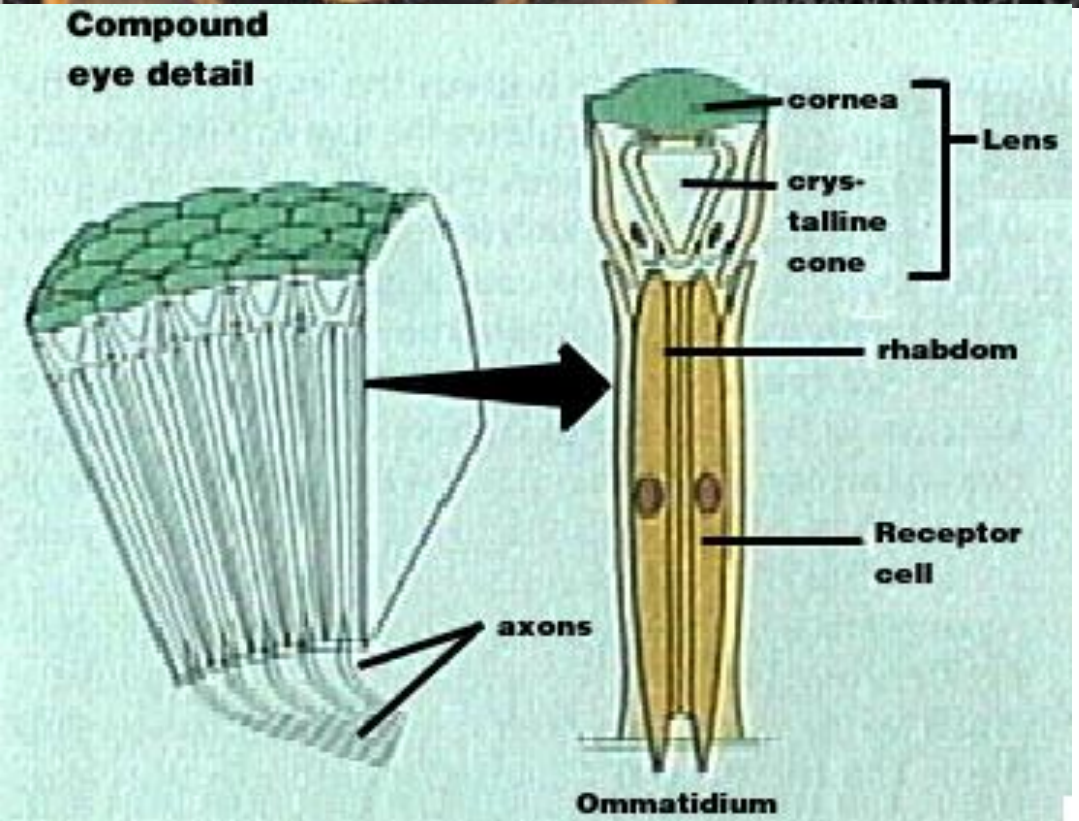


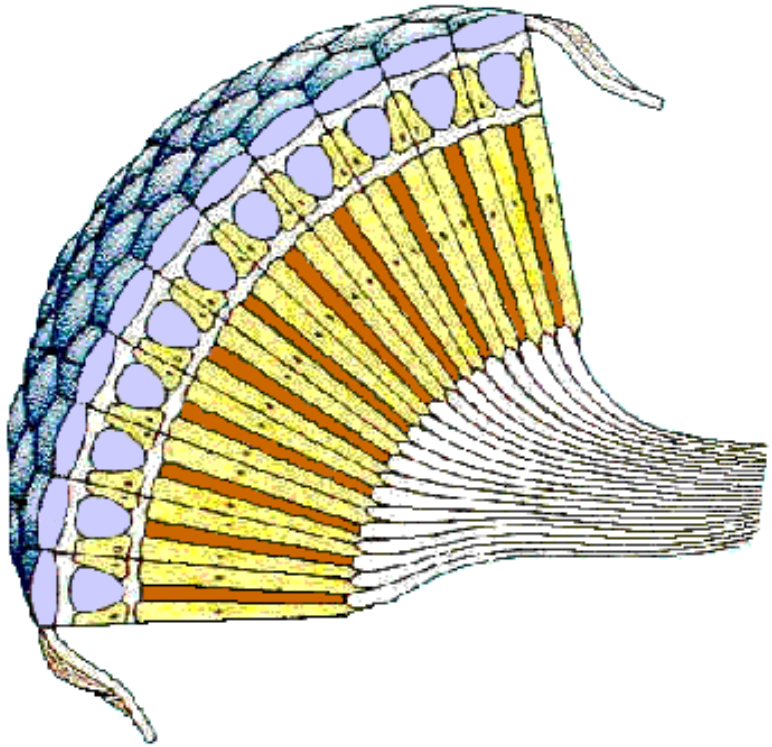
Journal of the European Optical Society - Rapid Publications 1, 06010 (2006) www.jeos.org

Invertebrate superposition eyes-structures that behave like metamaterial with negative ~~refractive index~~ *(refraction!)*

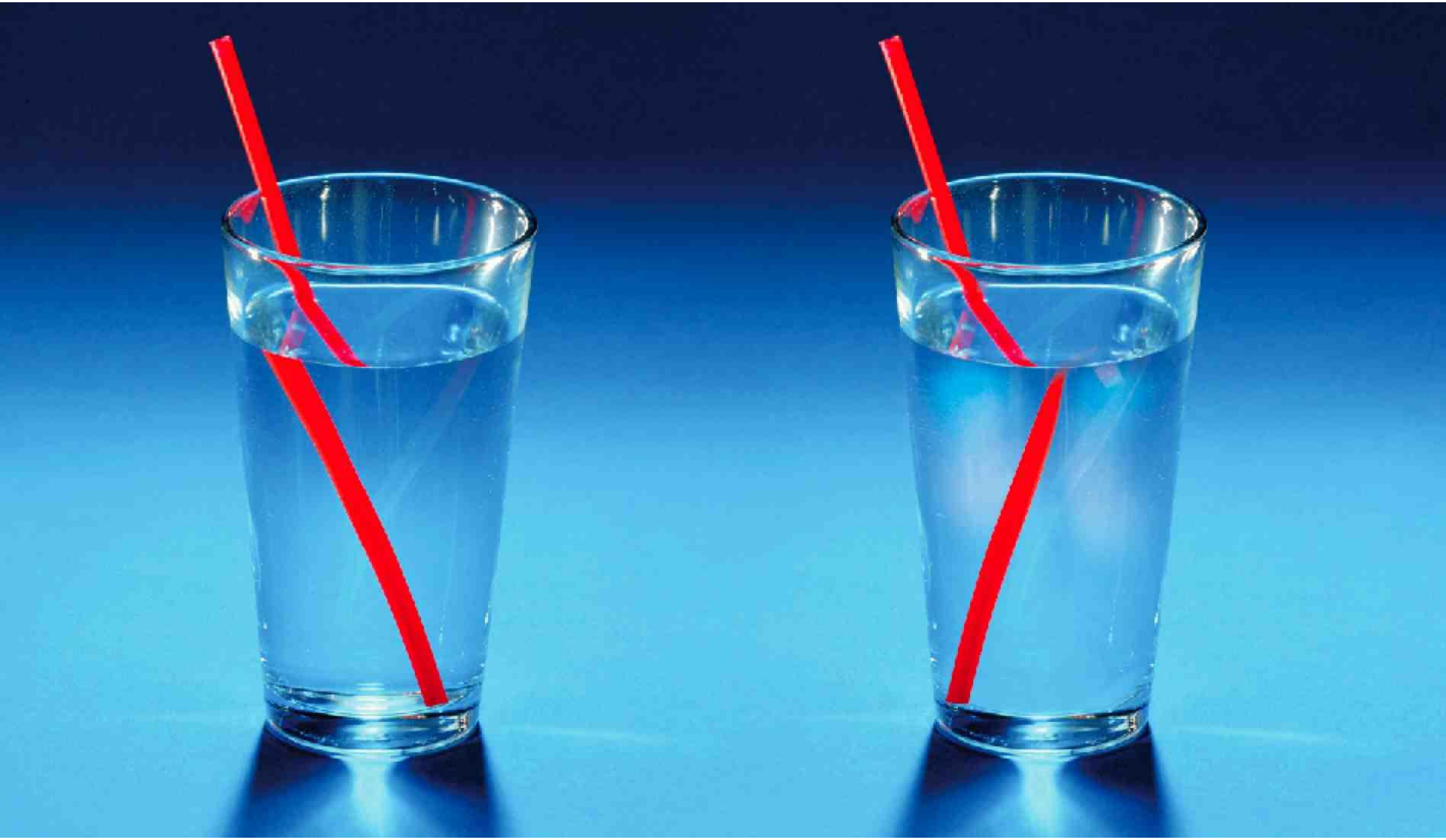
D.G. Stavenga
D.G.Stavenga@rug.nl
Department of Neurobiophysics, University of Groningen, NL 9747 AG Groningen, the Netherlands



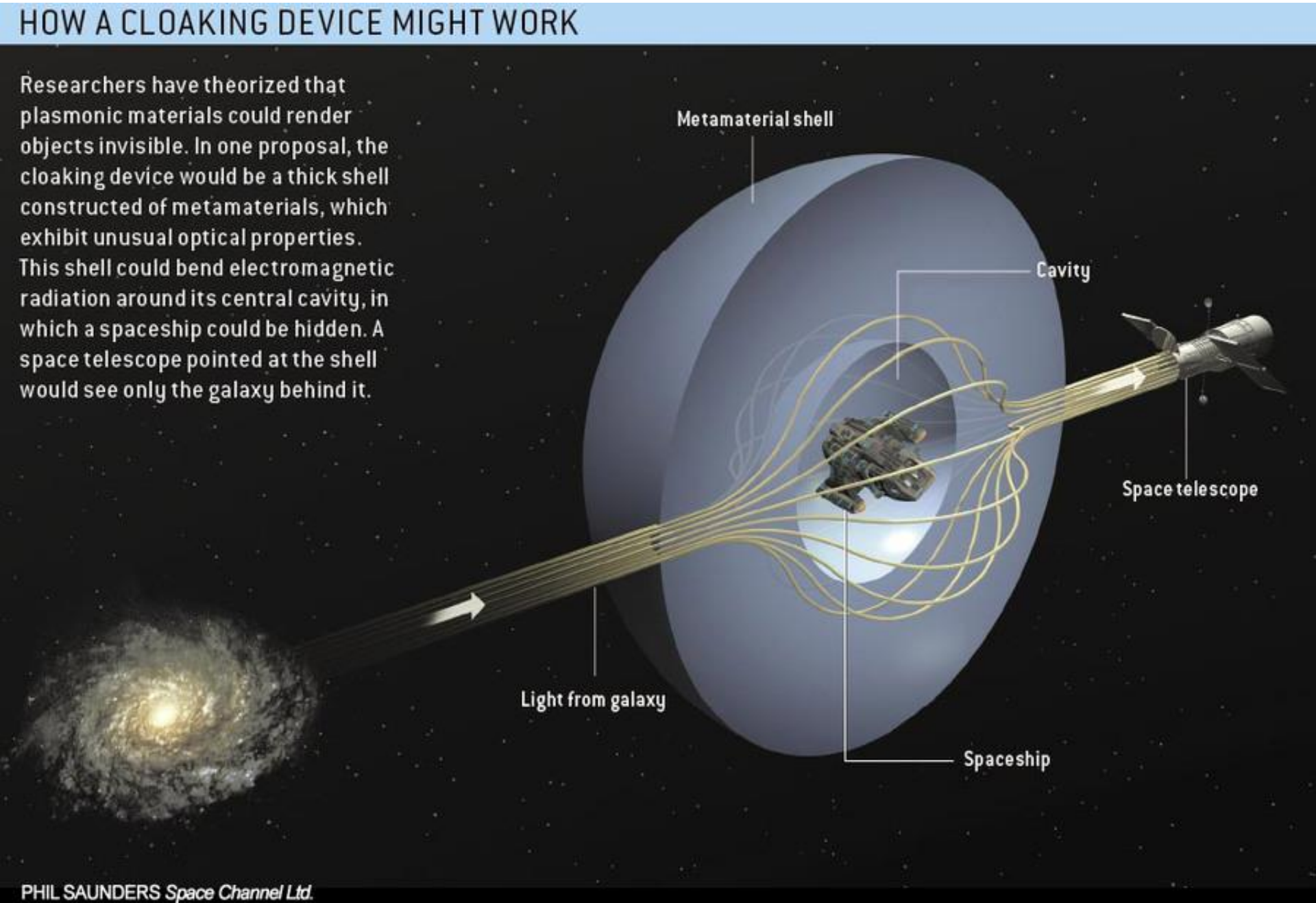

Compound eye detail
cornea
Lens
crys-talline cone
rhabdom
Receptor cell
axons
Ommatidium



Any special with negative refraction?

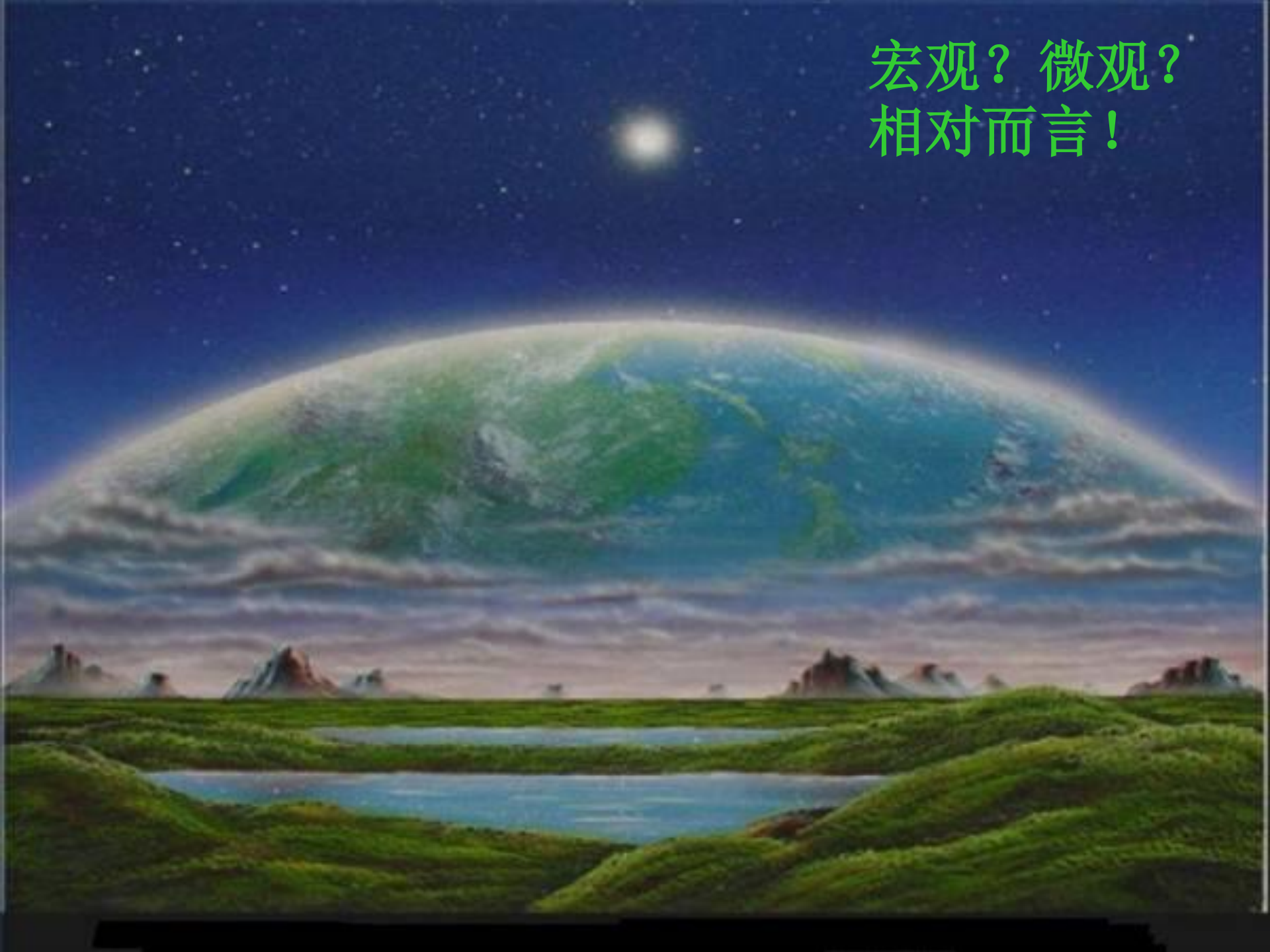


Metamaterials for invisible effect



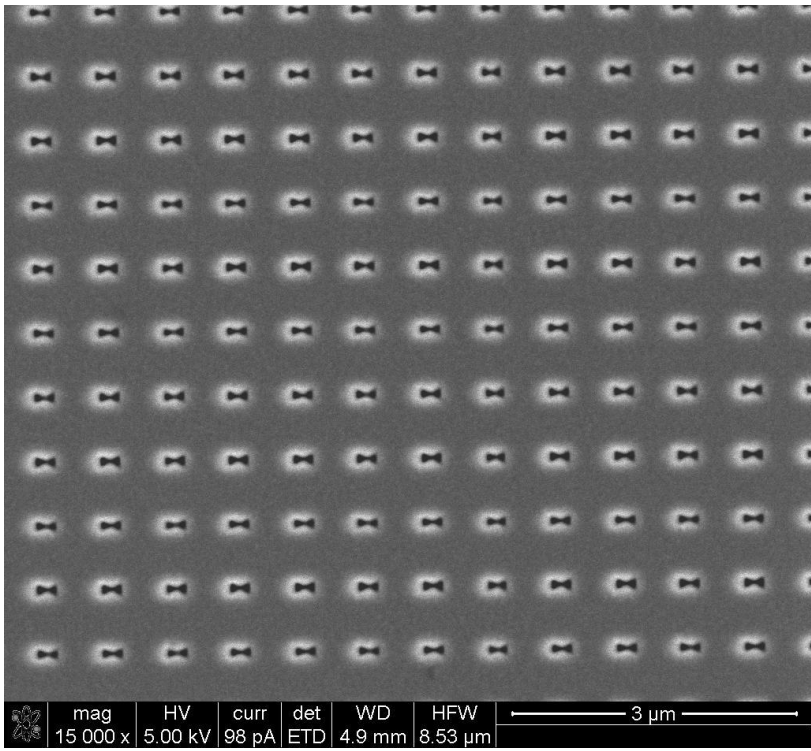
The Lycurgus Cup (glass; British Museum; 4th century A. D.)

When illuminated from outside, it appears green. However, when illuminated from within the cup, it glows red. Red color is due to very small amounts of **gold powder** (about 40 parts per million).


宏观？微观？
相对而言！


HSBC

HSBC


mag
15 000 x
HV
5.00 kV
curr
98 pA
det
ETD
WD
4.9 mm
HFW
8.53 µm
3 µm


THE END