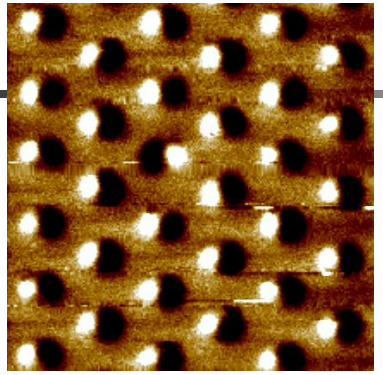
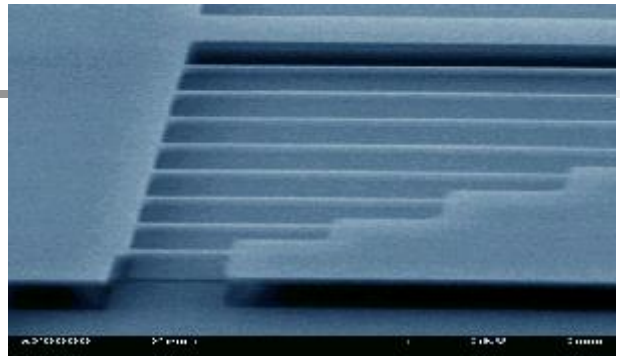
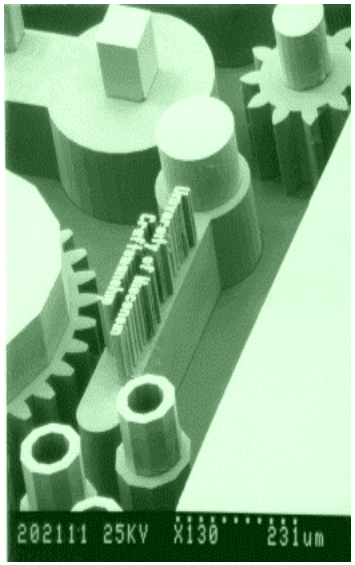
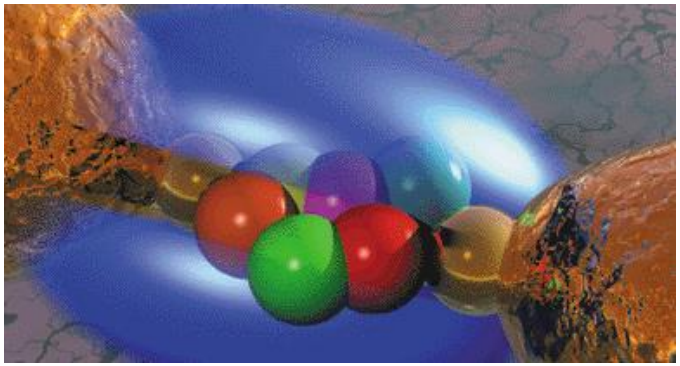
Nanotechnology

— Introduction

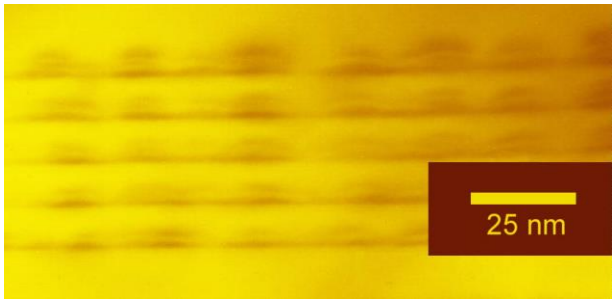


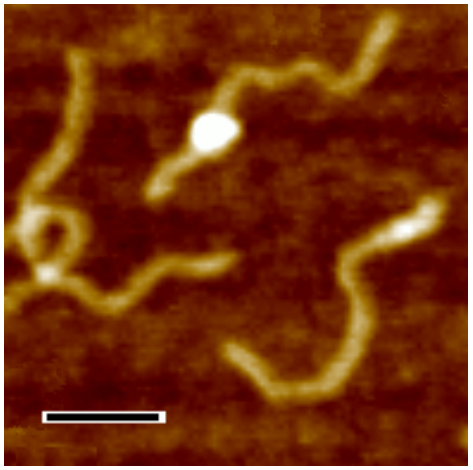


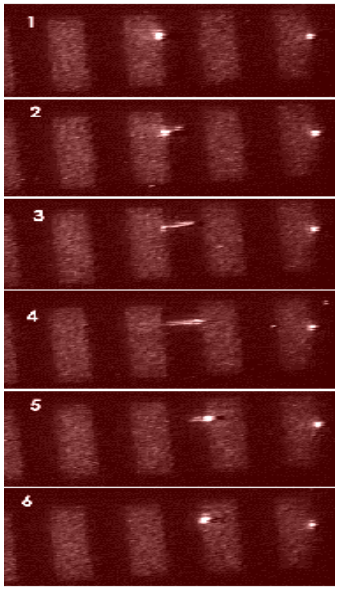




nm







Step into a Nano-world

Step into a Nano-world

物理学院
School of Physics

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

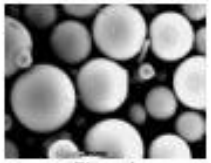
Things Natural

Dust mite

200 µm

Ant

~ 5 mm

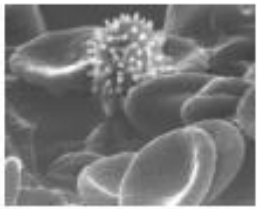


Fly ash

~ 10-20 µm

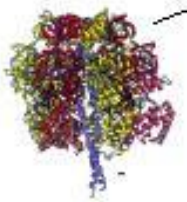
Human hair

~ 60-120 µm wide

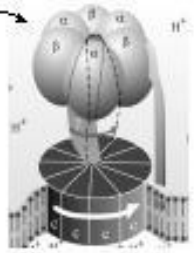


Red blood cells with white cell

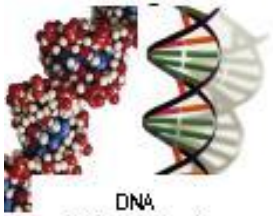
~ 2-5 µm



~10 nm diameter

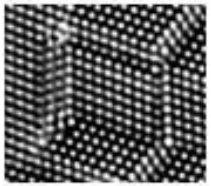


ATPsynthase



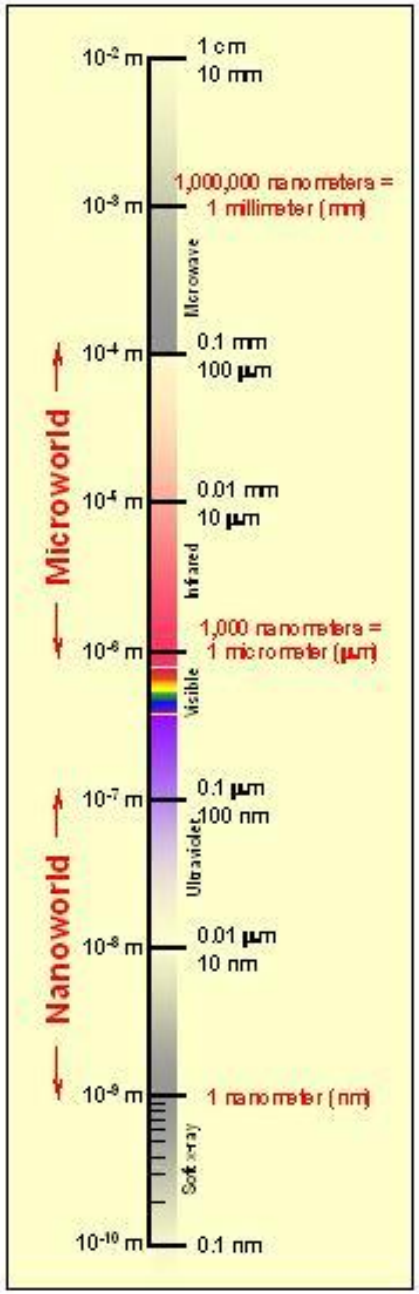
DNA

~2-12 nm diameter

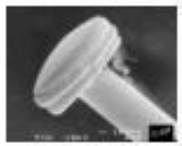


Atoms of silicon

spacing ~tenths of nm

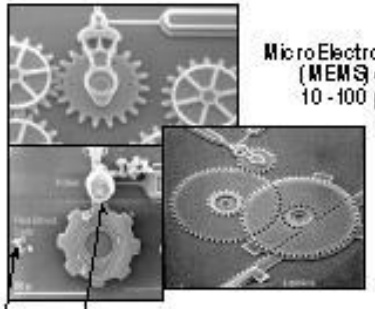


Things Manmade



Head of a pin

1-2 mm

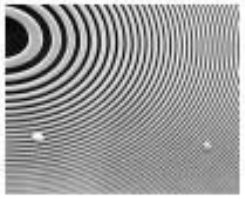


MicroElectroMechanical (MEMS) devices

10 - 100 µm wide

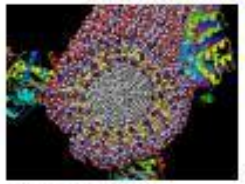
Pollen grain

Red blood cells



Zone plate x-ray "lens"

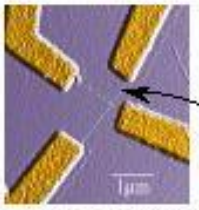
Outer ring spacing ~35 nm



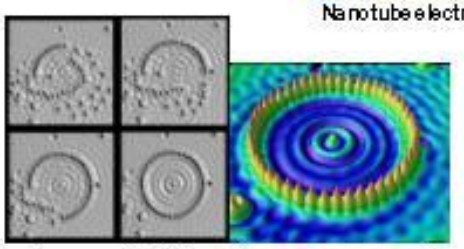
Self-assembled,

Nature-inspired structure

Many 10s of nm

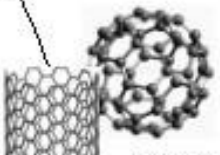


Nanotube electrode



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

Corral diameter 14nm



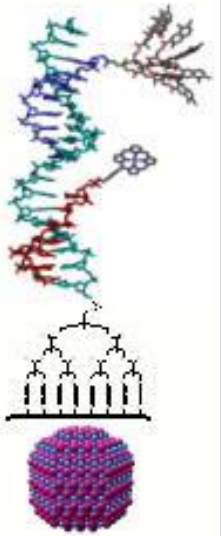
Carbon buckyball

~1 nm diameter

Carbon nanotube

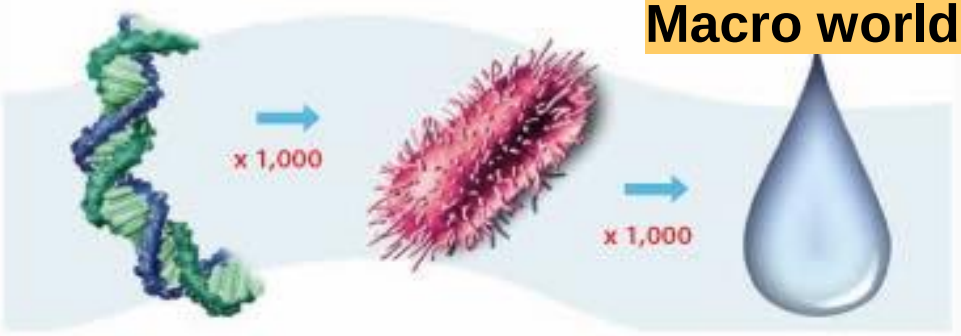
~1.3 nm diameter

The Challenge



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

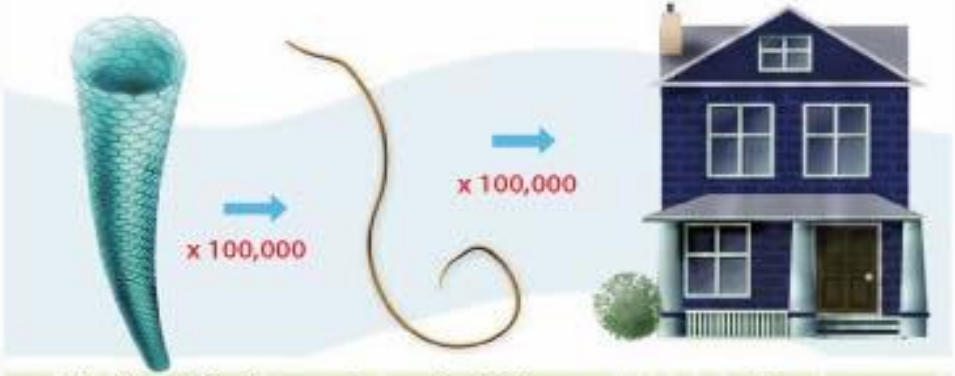
Macro world



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

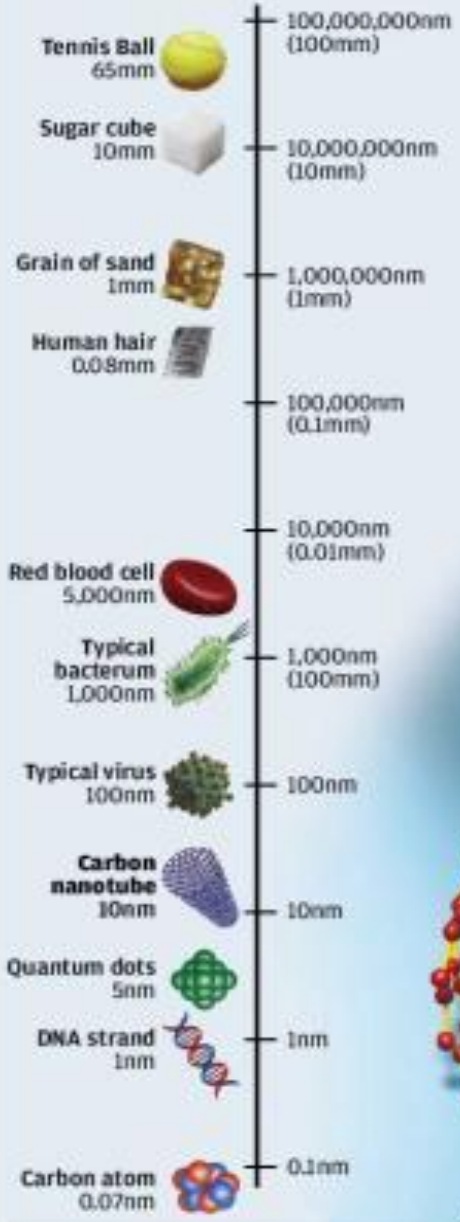
Ant
4 millimeters
long

Indianapolis Motor Speedway
4 kilometers per lap

Small world

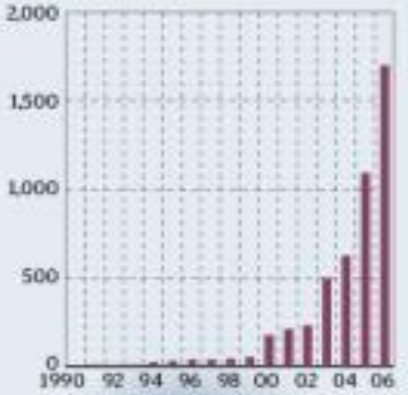
NANOMETRES IN CONTEXT

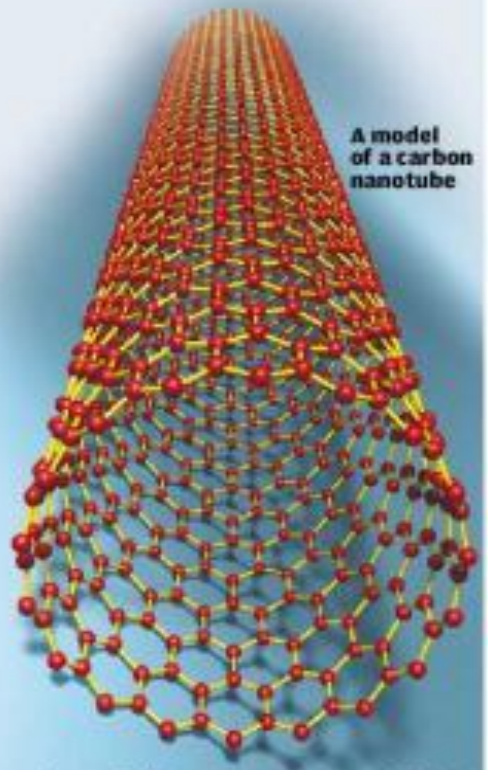
DIAMETERS



PATENTS ON NANOMATERIALS

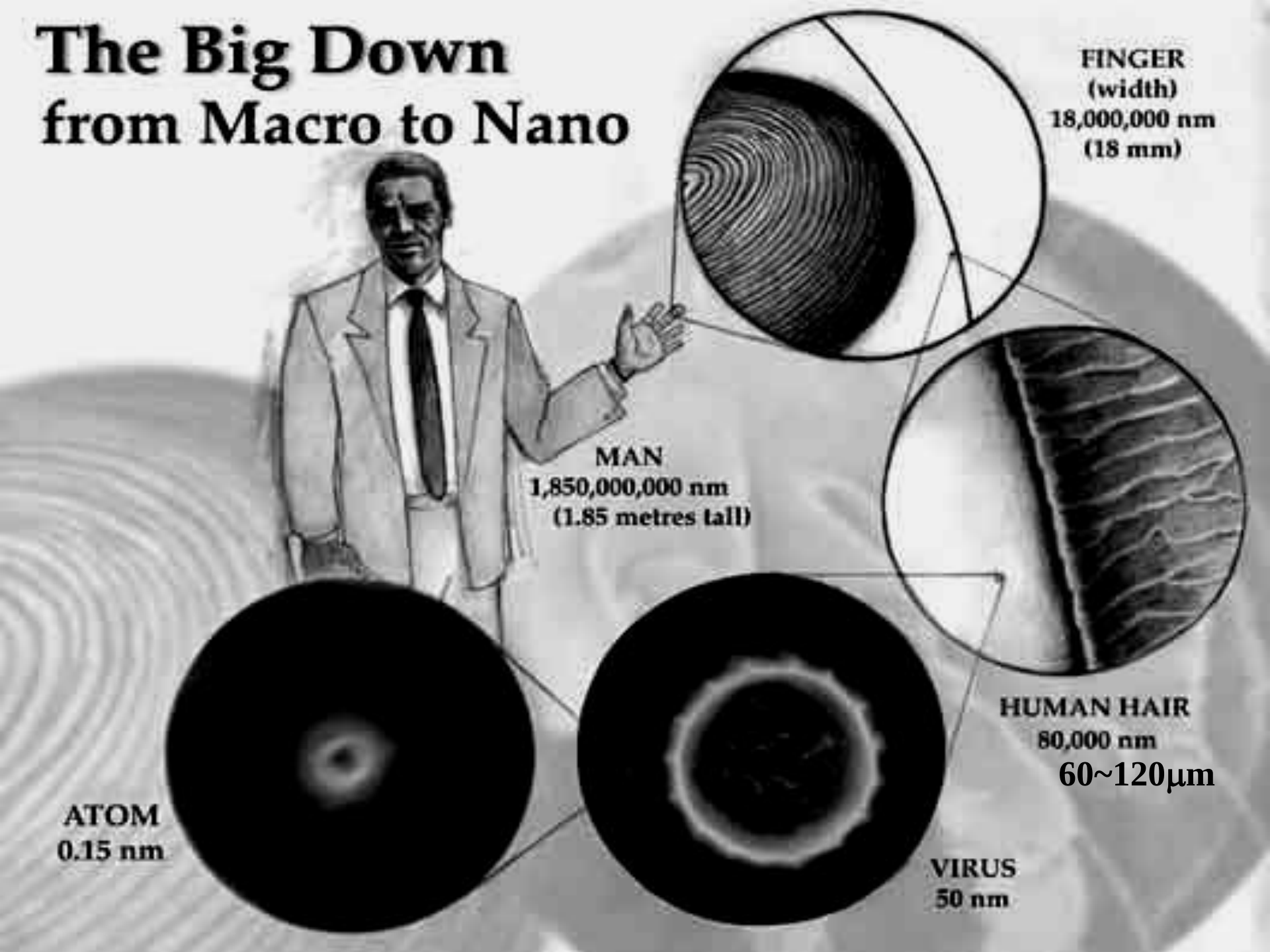
NUMBER OF PATENTS

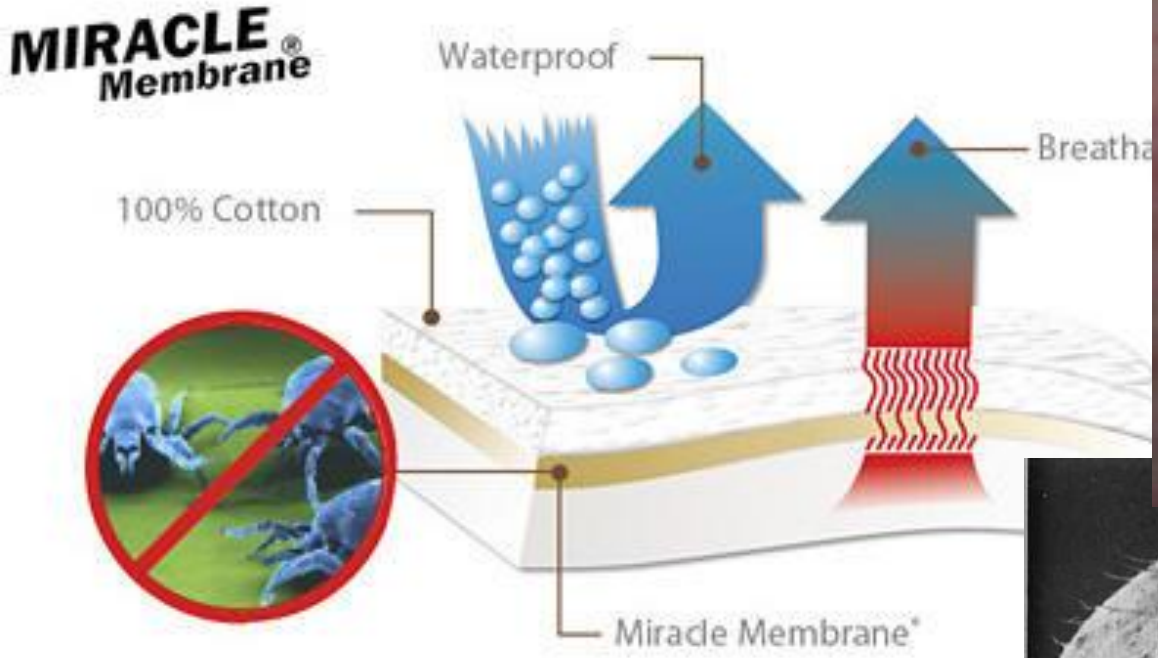


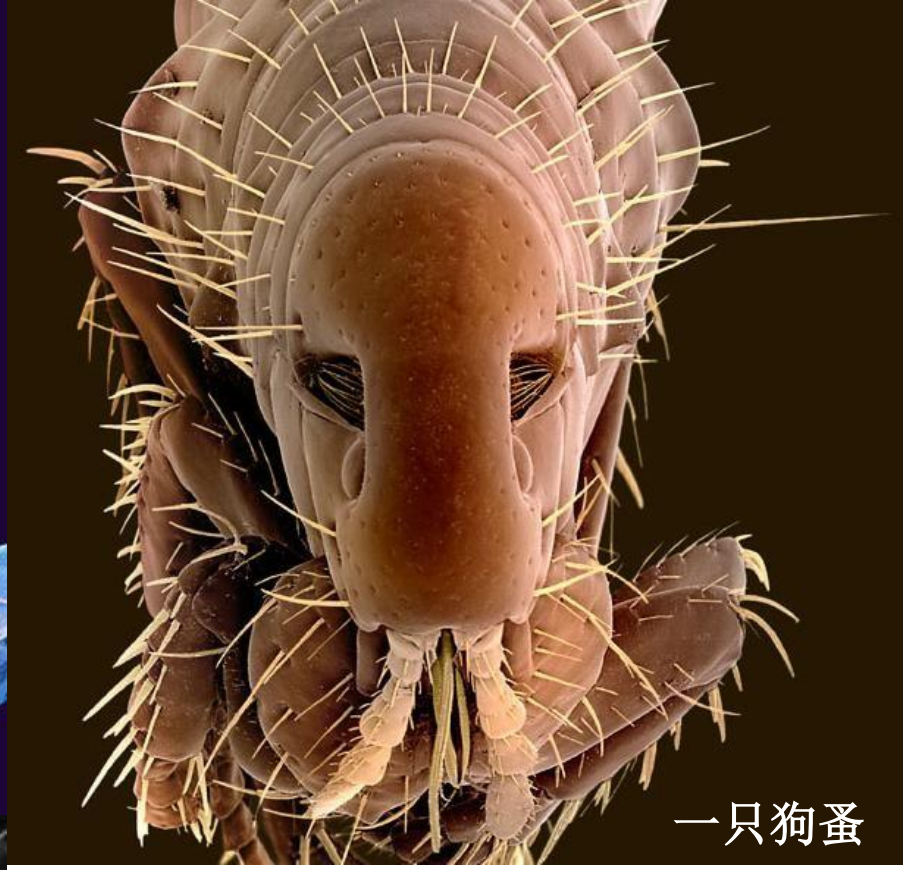


A model of a carbon nanotube

Source: Royal Commission on Environmental Pollution


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


MIRACLE Membrane
Waterproof
Breatha
100% Cotton
Miracle Membrane*



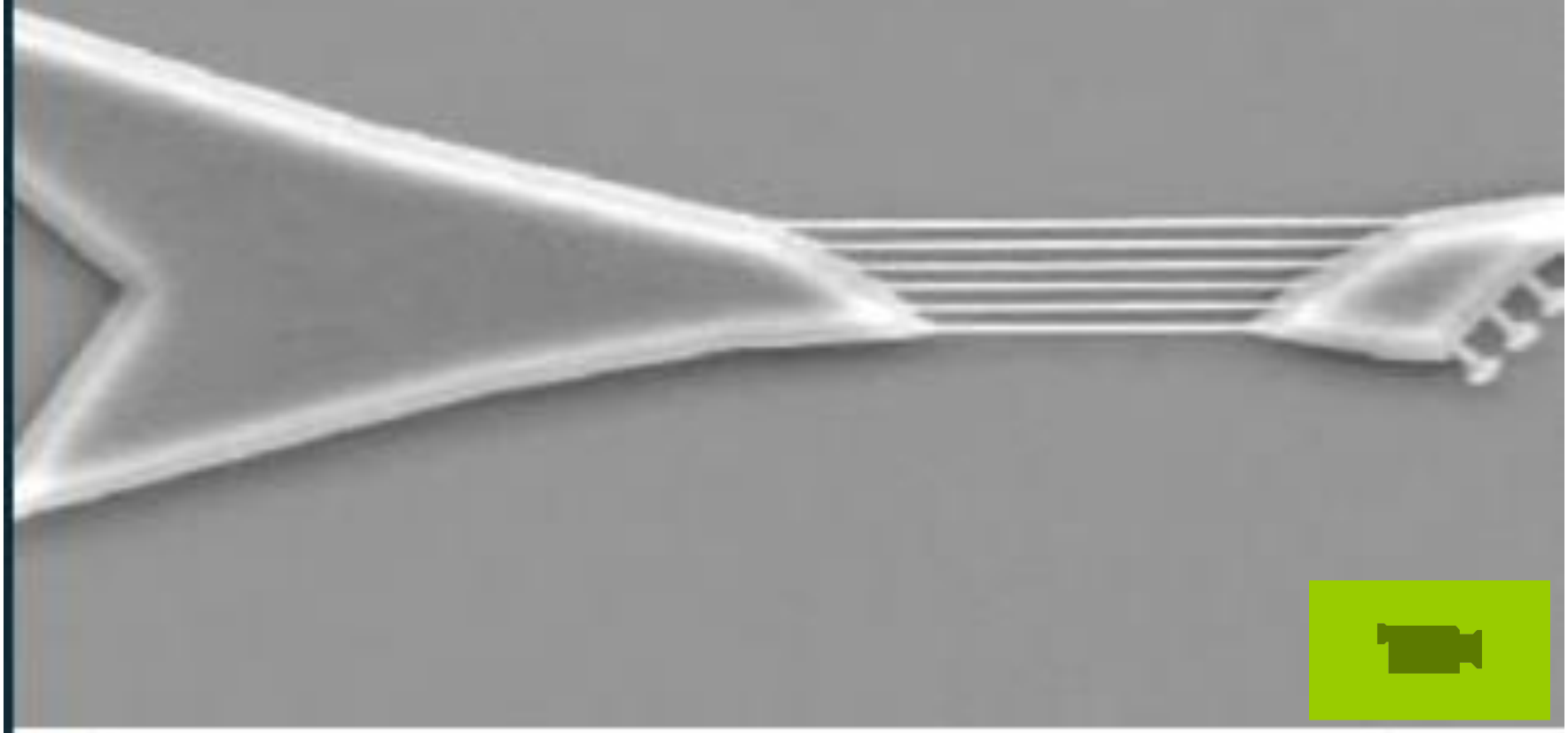
蚊子

61岁的退休科学摄影师克施迈斯内尔用一架扫描电子显微镜（SEM）把昆虫的形象放大一百万倍。

MANUFACTURING NANO-OBJECT

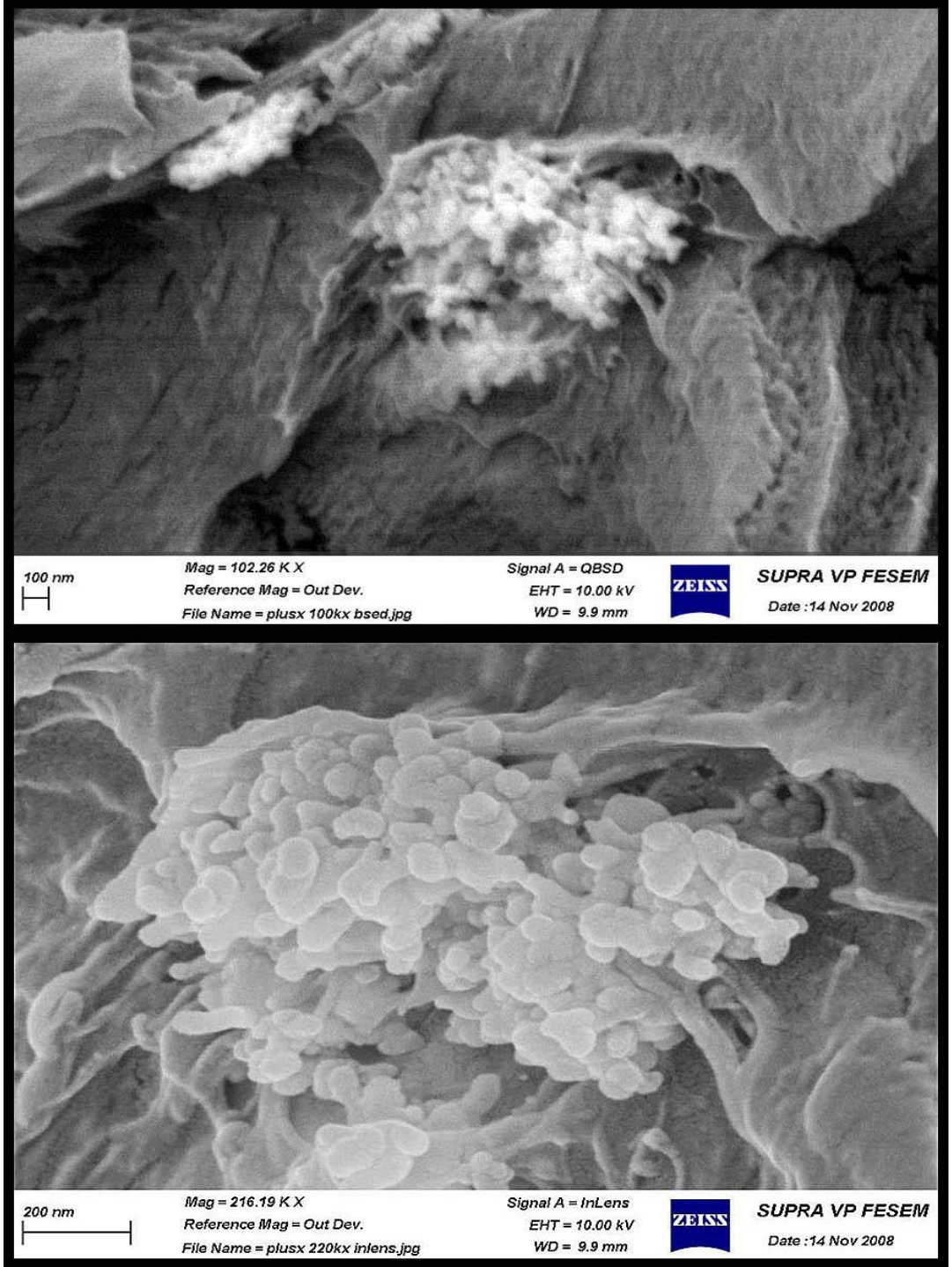
NANOGUITARS

This micro-instrument was made from silicon. **Each of its strings measures about 50 nm, while the thickness is 100 atoms.** Despite its tiny size, it was manufactured using the top-down technique. Physicists at Cornell University 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 MHz**.



SEM image of a grain of sand

It is infinite in the tiny world!




其大无外，
其小无内！
宏观？微观？
相对而言！
人类的认知能力永远都是有限的！

Contents of Nanotechnology

I. Nanofabrication and Characterization

II. Nanomaterials and Nanostructures

III. Nanoscale and Molecular Electronics

IV. Nanotechnology in Integrative System

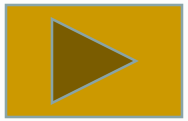
V. Nanoscale Optoelectronics

VI. Nanobiotechnology (time permitting)

VII. Nano-electronic-mechanical system (NEMS)

纳米科技涉及的纳米效应

小尺寸效应。当材料的体积减小到一定程度时，存在两种情形：一是材料本身的性质不发生变化，但那些与体积密切相关的性质发生变化，如电子自由程变小，磁体的磁区变小等；二是材料本身的性质发生了变化，当纳米材料的尺寸与传导电子的德布罗意波波长相当或更小时，周期性的边界条件将被破坏，材料的磁性、内压、光吸收、热阻、化学活性、催化活性及熔点等与普通材料相比都有很大的变化。

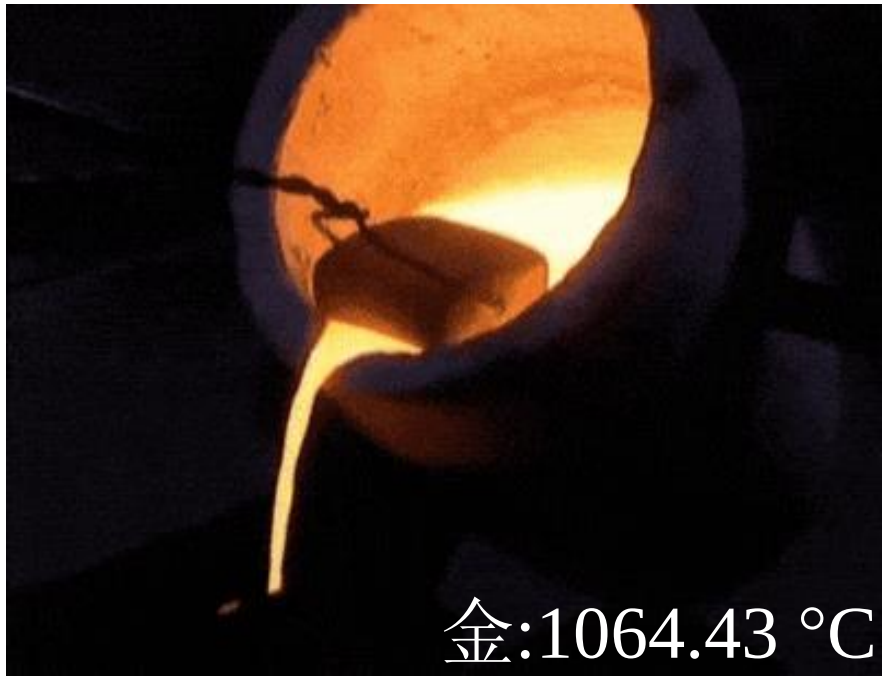


量子尺寸效应。随着纳米材料尺寸的下降，载流子在各个方向上均受到一定程度的限制，当尺寸接近或小于某一阈值（激子玻尔半径）时，费米能级附近的电子能级由准连续能级变为分立能级或者能级变宽。金属或半导体纳米材料的电子态由体相材料的连续能带过渡到具有分立结构的能级，表现在光学吸收谱上，是从没有结构的宽吸收过渡到有结构的特征吸收。量子尺寸效应带来的能级改变、能隙变宽，使纳米材料的发射能量增加，光学吸收向短波长方向移动。同时，纳米材料由于能级改变从而产生大的光学三阶非线性响应，使得还原及氧化能力增强，从而具有更优异的光电催化活性。

纳米世界中的小尺寸效应

纳米戒指

熔点问题

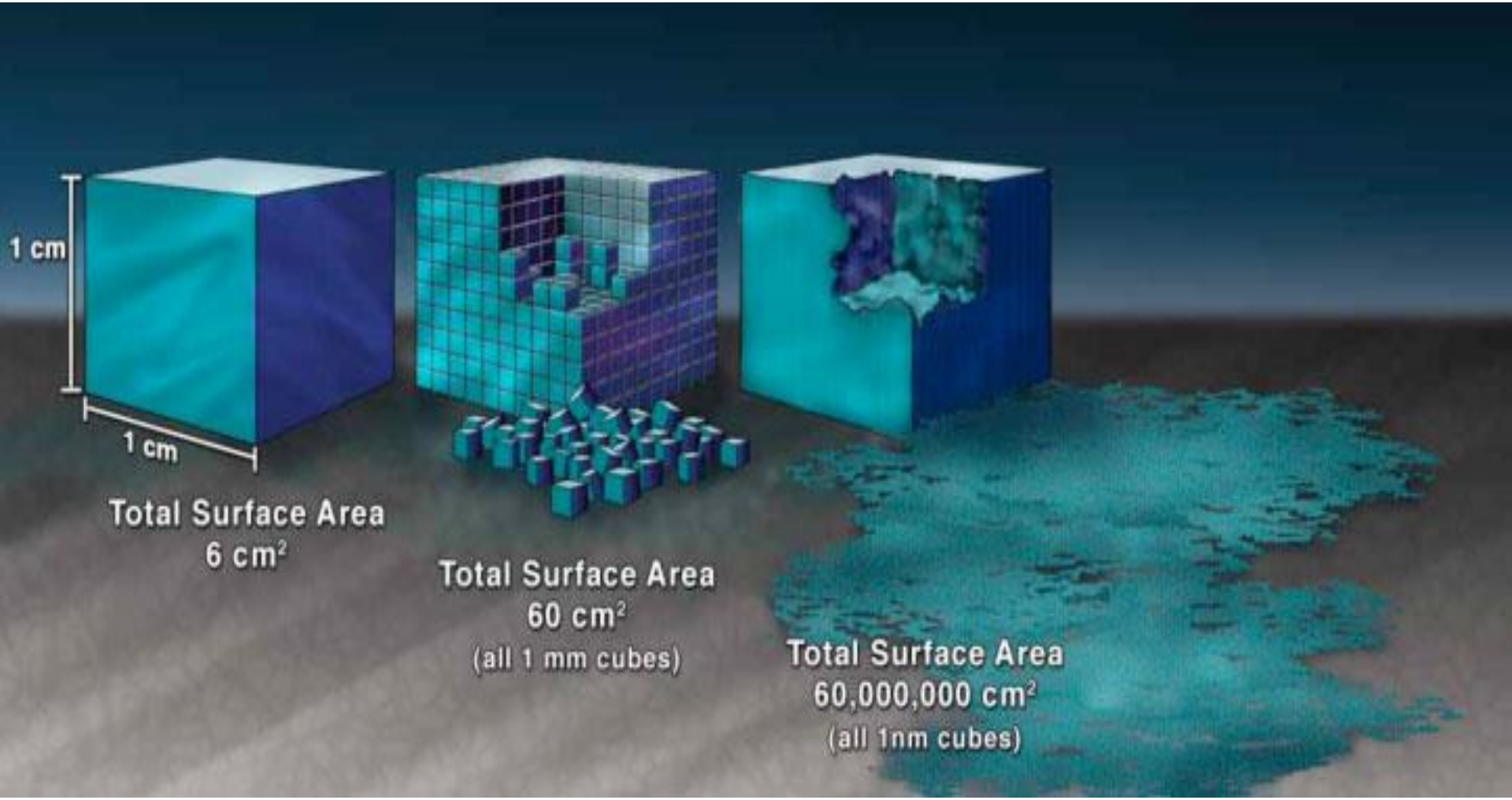


纳米金的熔点却仅为**330℃**

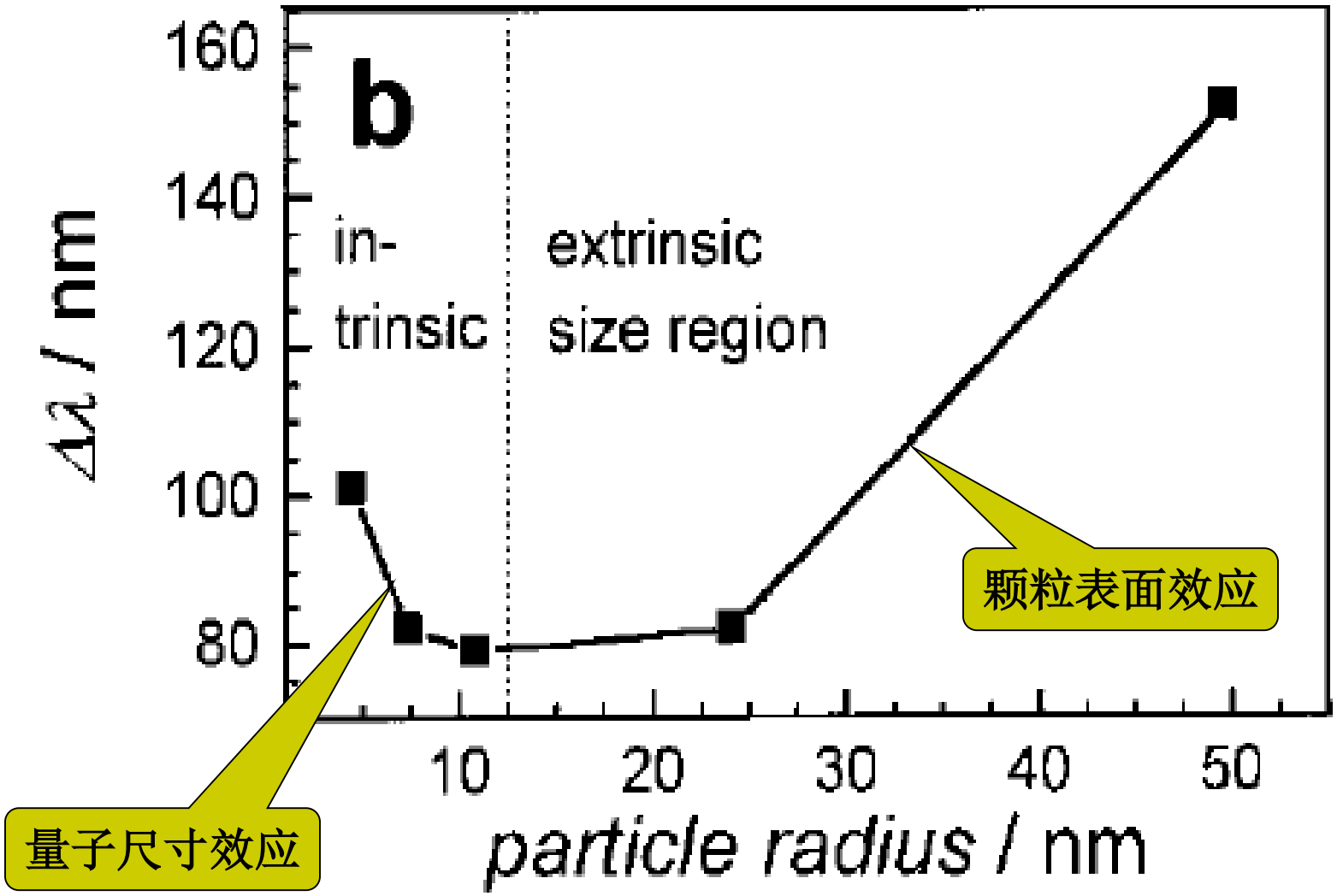
表面效应。随着纳米材料尺寸的减小，比表面积值（表面积/体积）和表面原子数量迅速增加，表面积、表面能和表面结合能随之迅速增大。由于表面原子周围相邻的原子较少，存在大量的悬键，具有不饱和性，容易通过与其他原子相结合而形成稳定结构，因此具有很高的化学活性且极不稳定。

宏观量子隧道效应。量子隧道效应是基本的量子现象之一，即当微观粒子的总能量小于势垒高度时，该粒子仍能穿越这一势垒。近年来，人们发现一些宏观量，例如微粒的磁化强度、量子相干器件中的磁通量以及电荷等也具有隧道效应，它们可以穿越宏观系统中的势垒并发生变化，称为宏观量子隧道效应。宏观量子隧道效应是普遍存在于纳米材料之中的特性之一。

表面效应（Effect of Surface Area）



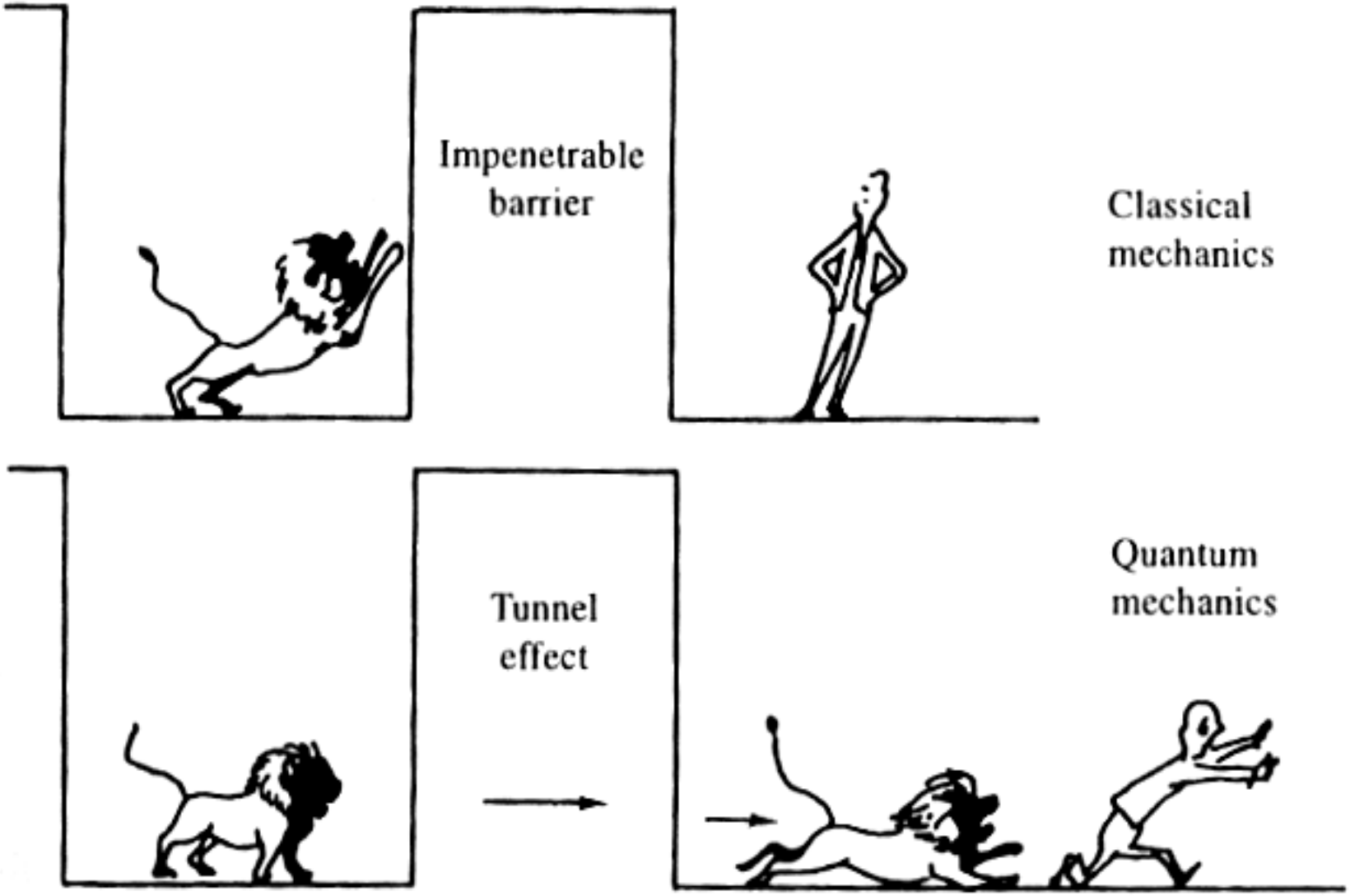
表面效应与量子尺寸效应的关联



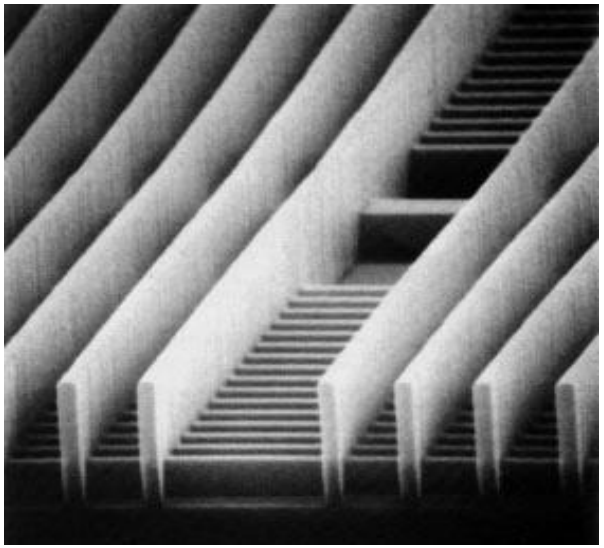
介电限域效应。纳米材料分散在异质介质中后，由于界面引起的体系介电增强的现象，主要来源于纳米材料表面和内部局域场强的增强。当介质的折射率与纳米材料的折射率相比差值很大时，就产生了折射率边界，导致纳米材料表面和内部的场强比入射场强明显增加，这种局域场强的增强称为介电限域。一般来说，过渡族金属氧化物和半导体材料都可能产生介电限域效应，纳米材料的介电限域对光吸收、光化学、光学非线性等都会有重要的影响。

库仑阻塞与量子隧穿。当体系（微粒）的尺度进入到纳米级（一般金属颗粒为几个纳米，半导体颗粒为几十个纳米）后，体系（微粒）是电荷“量子化”的，某个电子隧穿进入了体系（微粒）后，它将阻止随后的第二个电子再进入同一体系（微粒），因为这将导致体系（微粒）系统总能量的增加，所以是不允许发生的过程，这就是库仑阻塞现象，即充电和放电过程是不连续的。如果两个体系（微粒）通过一个“结”连接起来，一个体系（微粒）上的单个电子穿过势垒到另一个体系（微粒）上的行为称作量子隧穿。利用库仑堵塞和量子隧穿效应可以设计如单电子晶体管和量子开关等纳米结构器件。

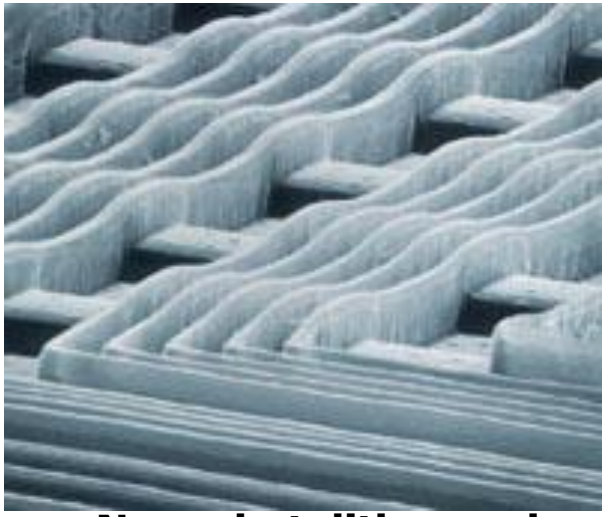
量子隧穿效应


Impenetrable
barrier
Classical
mechanics
Tunnel
effect
Quantum
mechanics

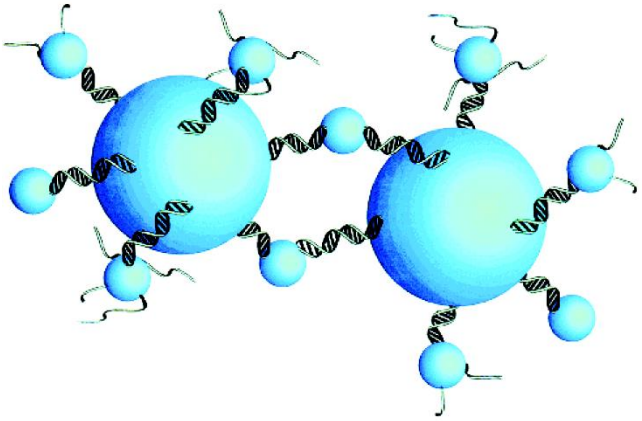
I. Nanofabrication/Characterization



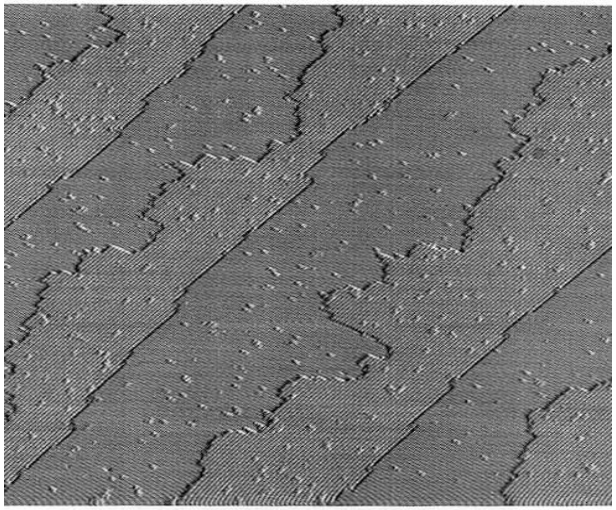
Will provide an overview of technologies that enable nanoscale research



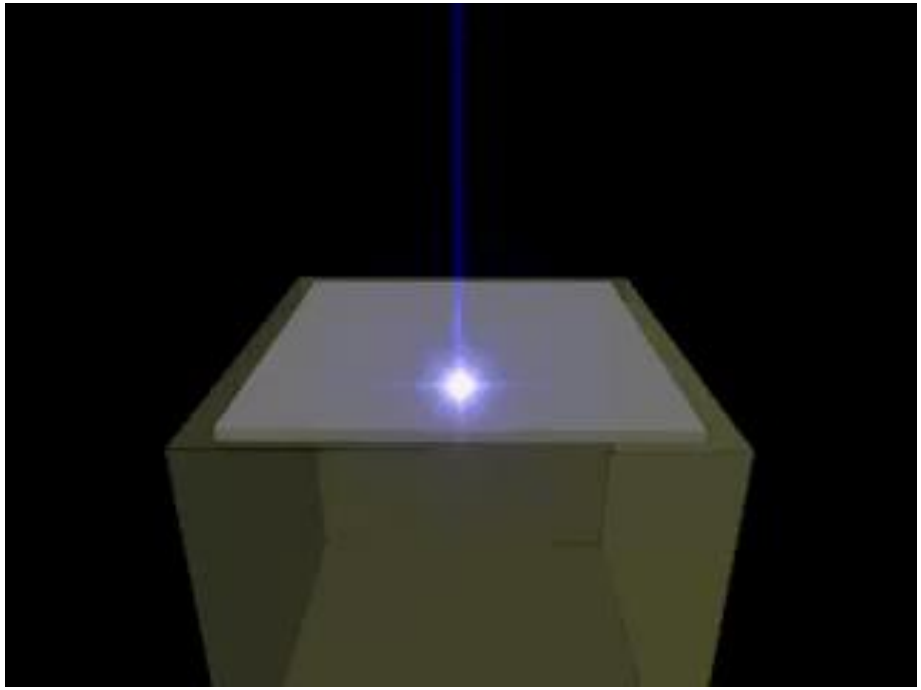
Nanophotolithography



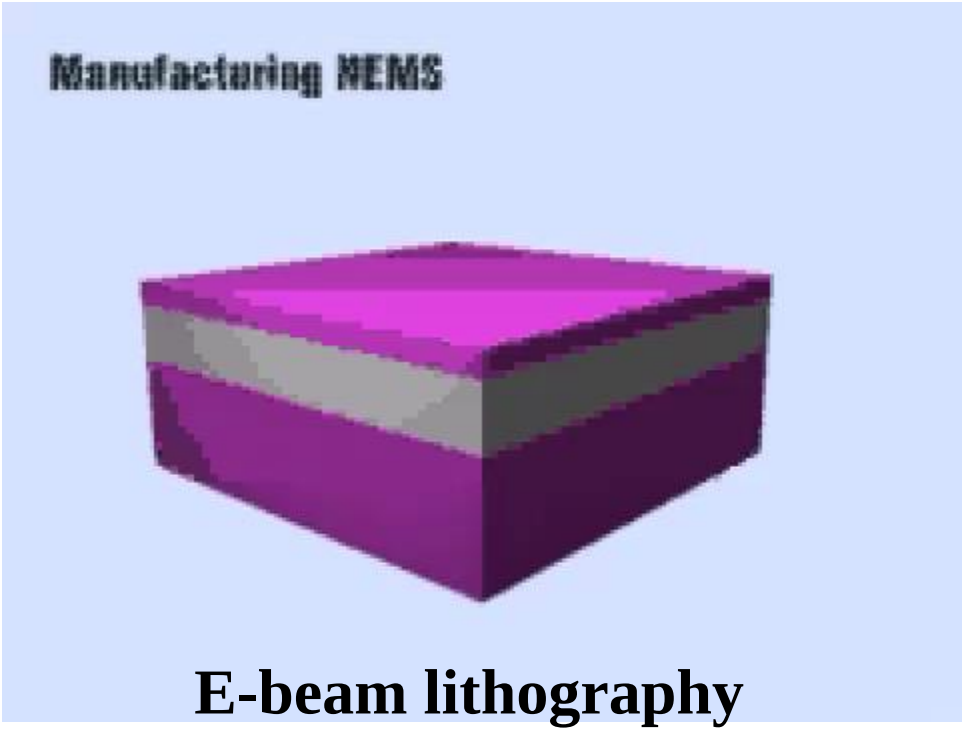
Self-Assembly



Probe Microscopy



Laser sterolithography



E-beam lithography

Atomic force microscope

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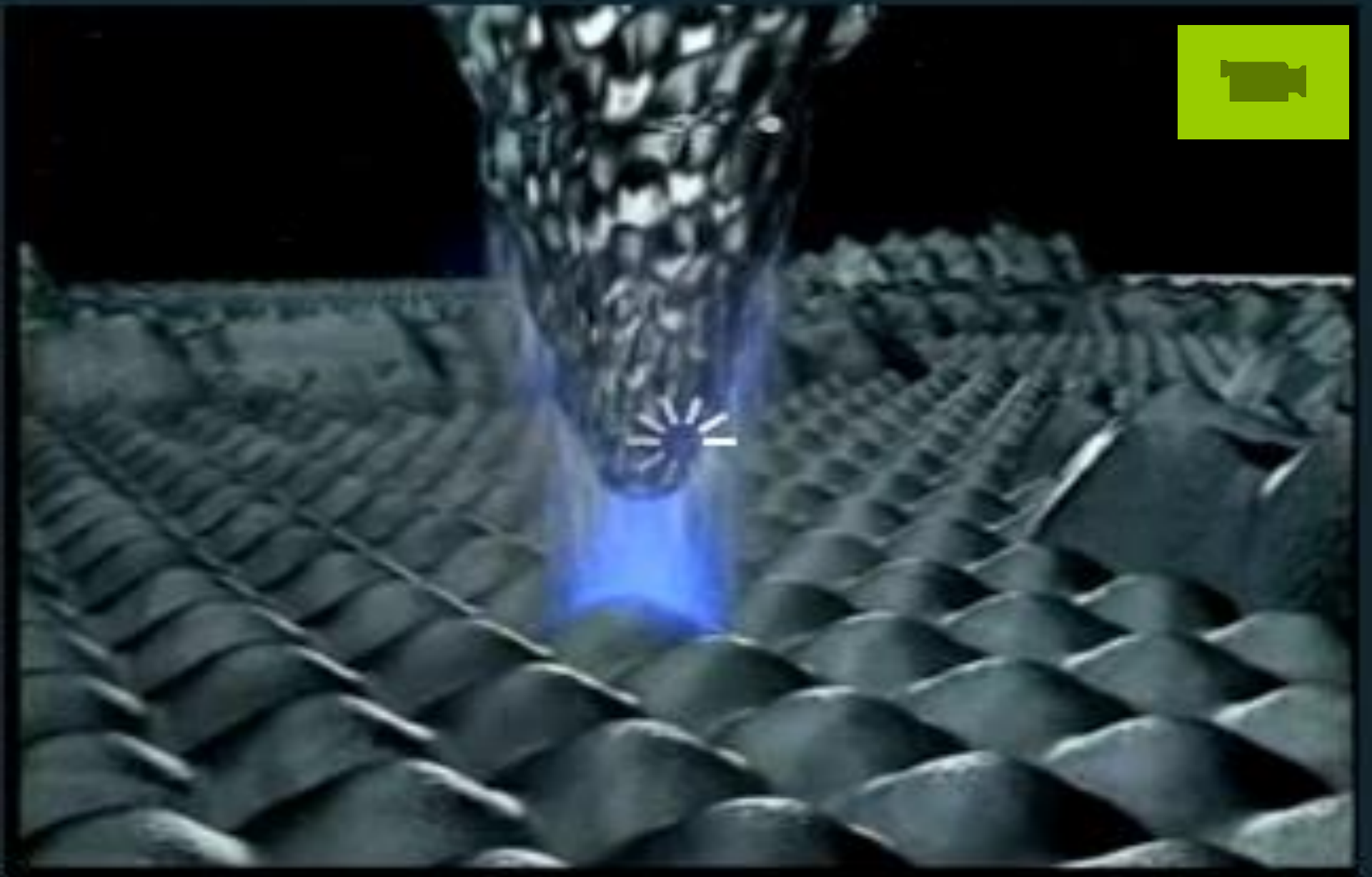
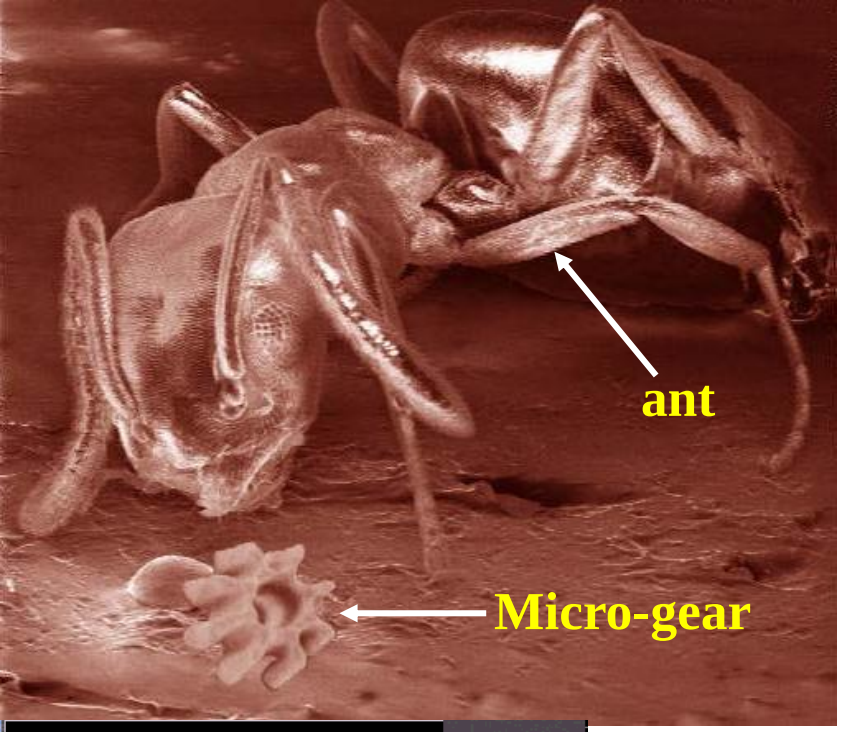
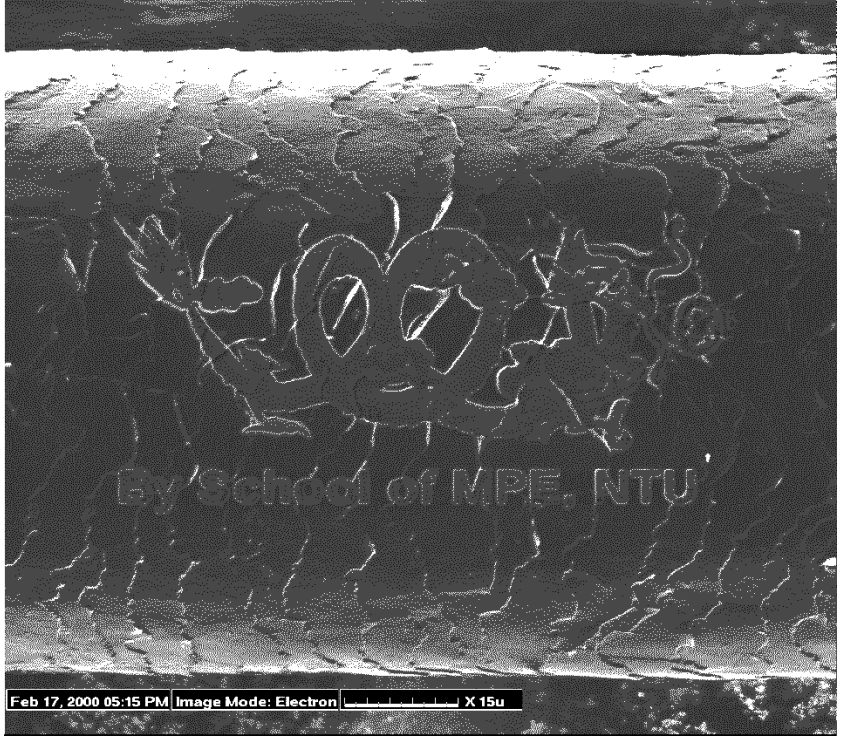
SEEING AND MANIPULATING THE INVISIBLE



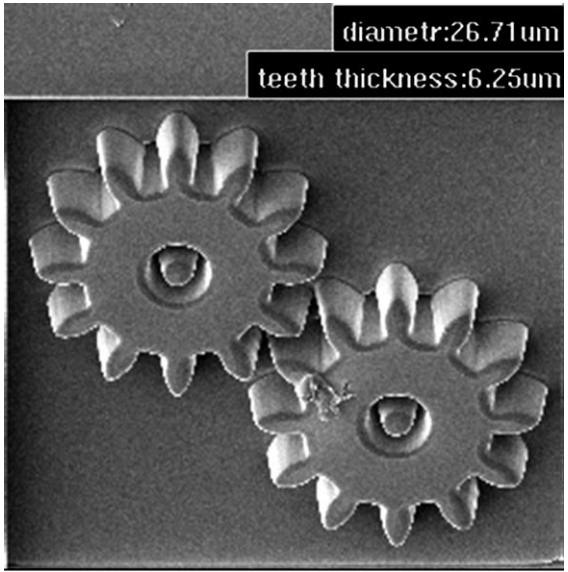




Dragon pattern milled on human hair with diameter of **60 micron** by FIB technology

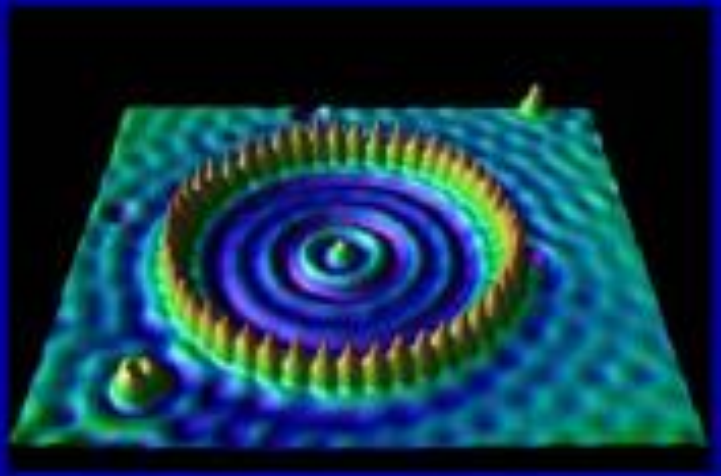
FOCUSED ION BEAM TECHNOLOGY

Gear with **26.71μm** pitch diameter

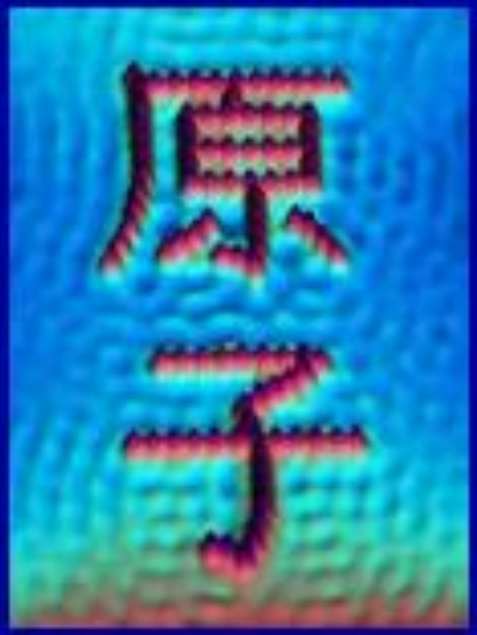


物理学院
School of Physics

氙原子在镍(110)表面
排成的最小IBM商标



铜(111)表面上的铁原子围栏

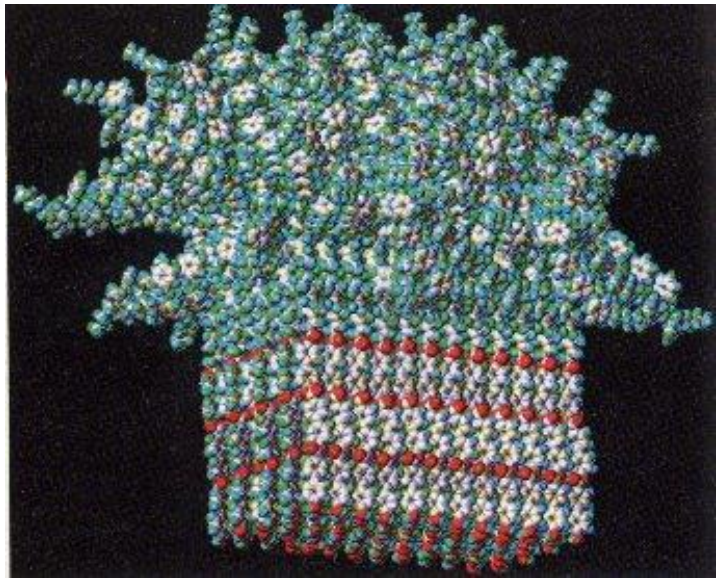


铁原子在铜(111)表
面排成的汉字

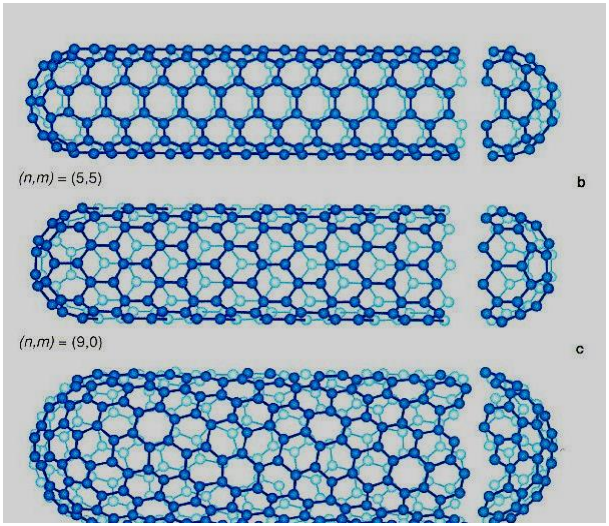
铂表面上一氧化碳分
子排成的“纳米人”

搬走原子写“中国”

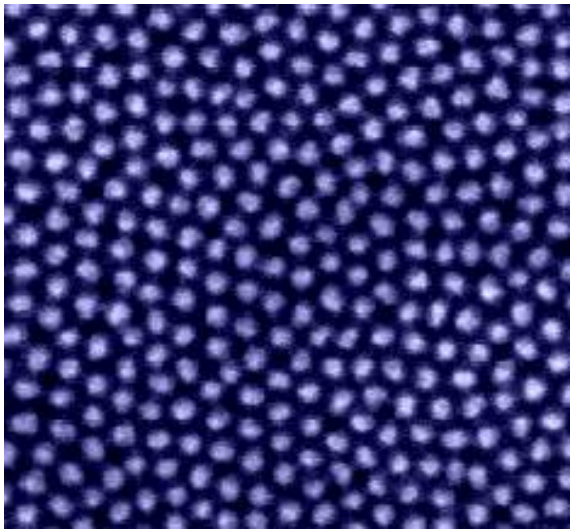
II. Nanomaterials and Nanostructures



Will provide an overview of nanomaterials and nanoscale synthesis techniques



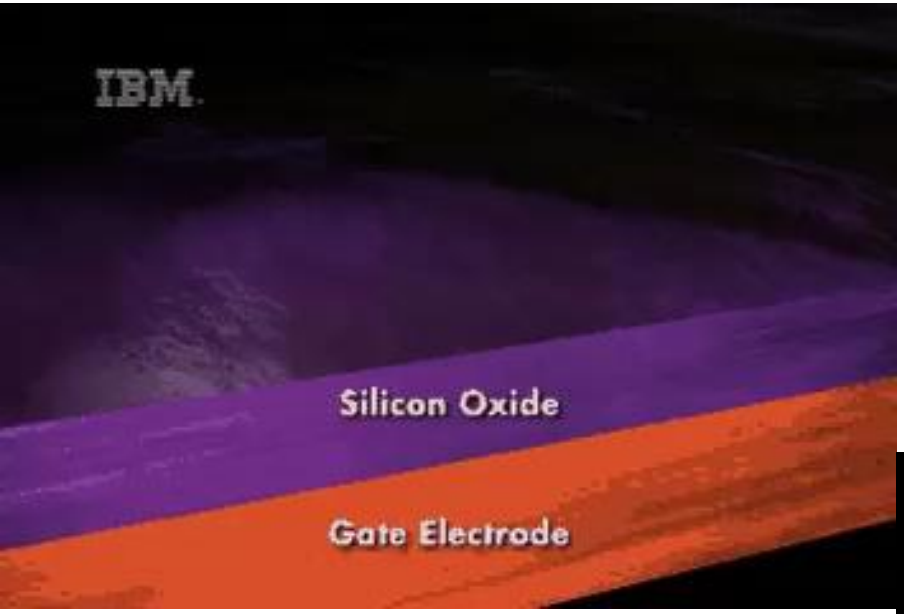
Fullerenes and Nanotubes



Quantum Dots

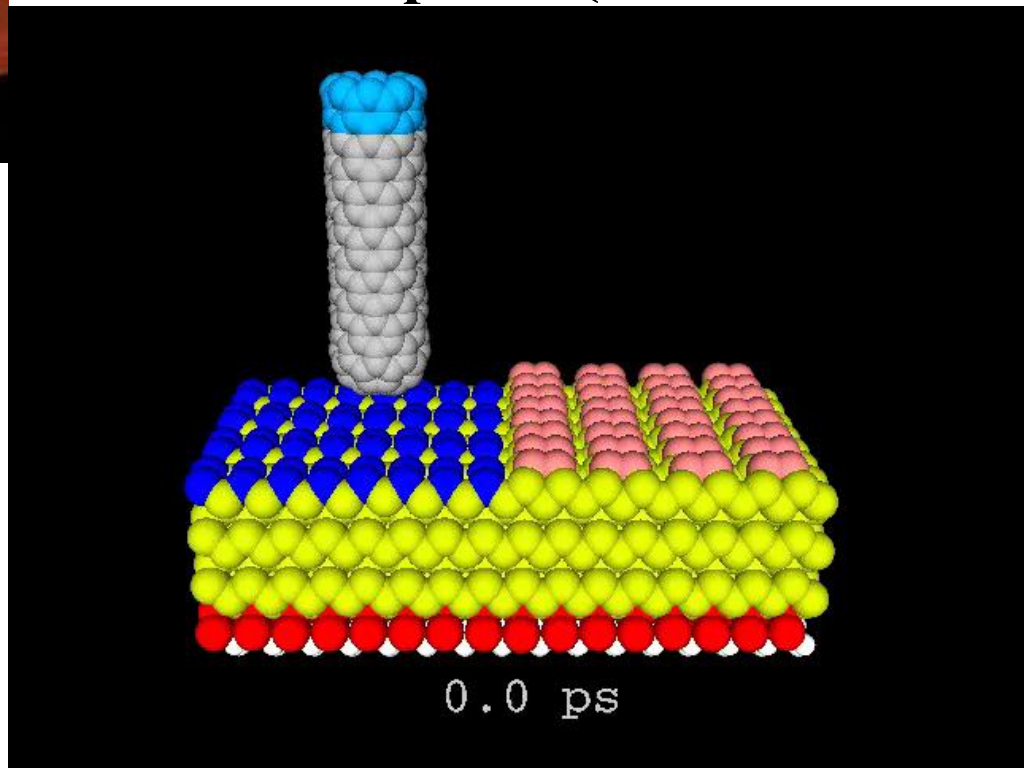

NANOTECHNOLOGY
WINDSHIELD SEALANT

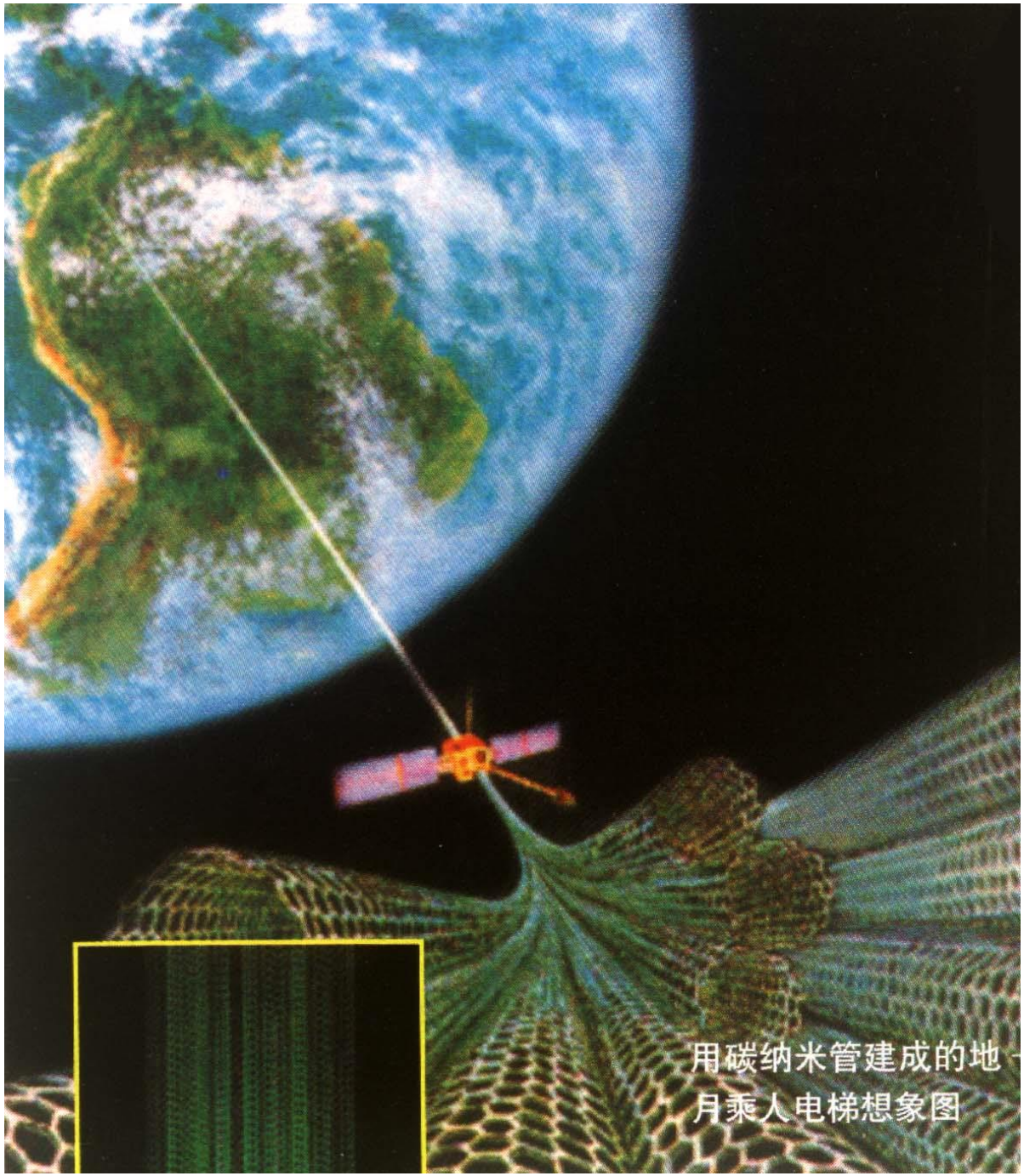
Nanotube movies



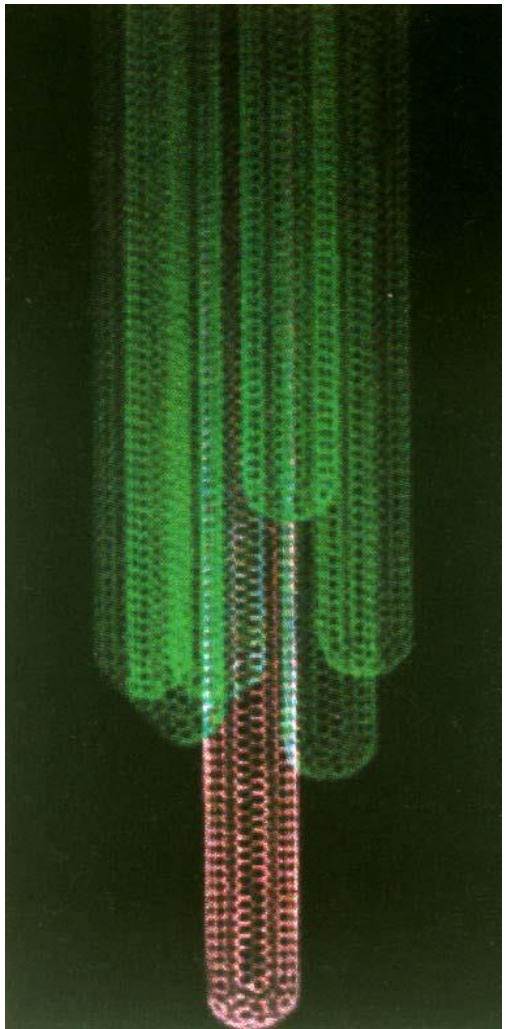
IBM Carbon nanotube-based nanoelectronic circuits

Carbon nanotube-based nanoprobe (“nanotubetip”)



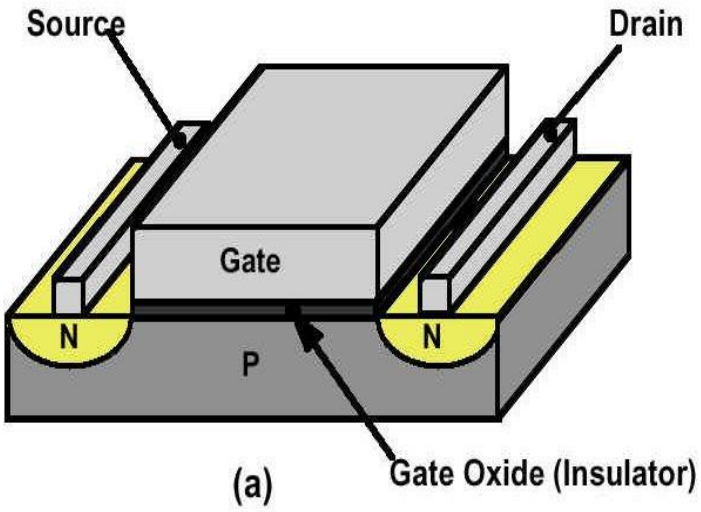


用纳米碳管建成的地月载人电梯构想图



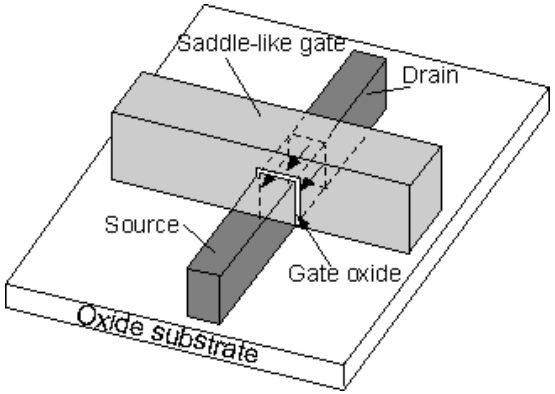
Nanofactory

III. Nanoscale Molecular Electronics

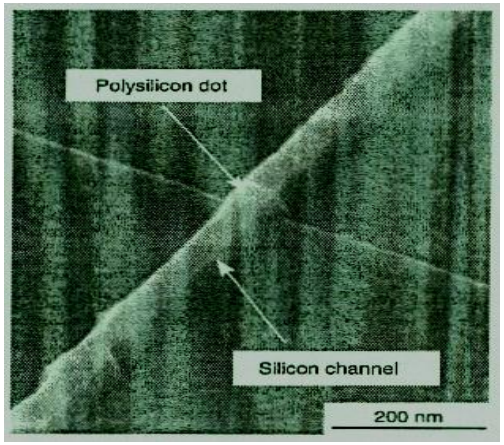


Challenges in electronic devices

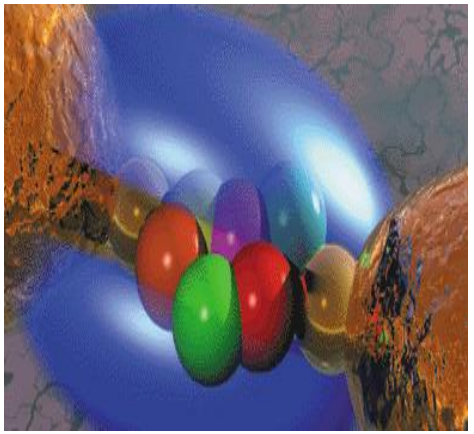
Sustained need of smaller and faster electronics may require revolutionary approaches to device manufacturing



Nanoscale CMOS

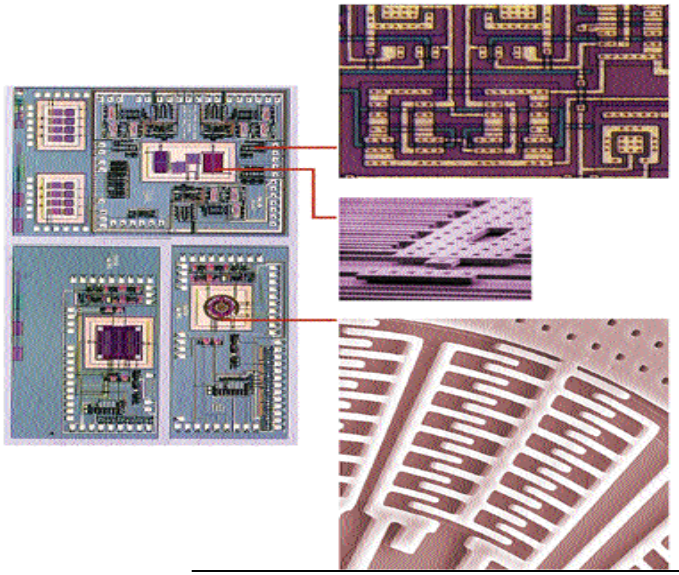


Single-Electron Device



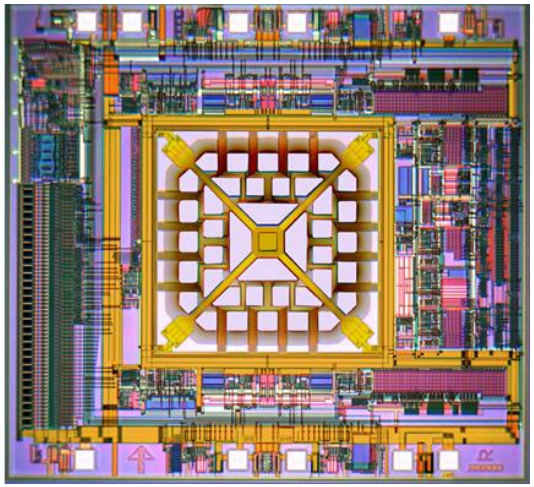
Molecular Electronics

IV. Nanotechnology in Integrative Systems

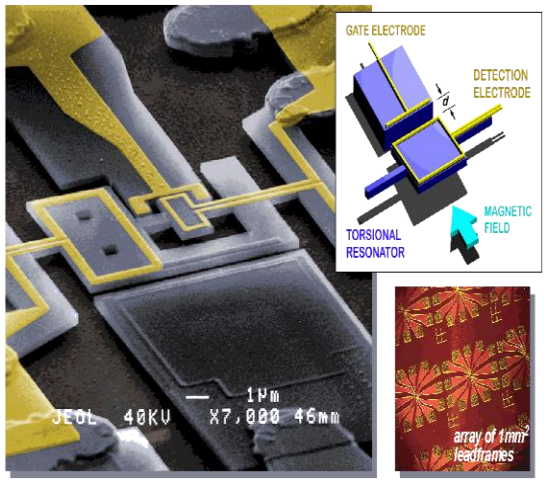


Challenges in microsystems

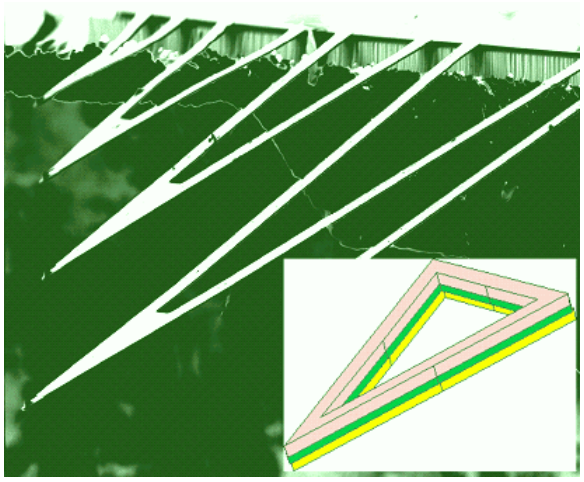
- complex architectures
- reduction of system size
- lower power consumption
- requires new "success" stories



Introduction to MEMS



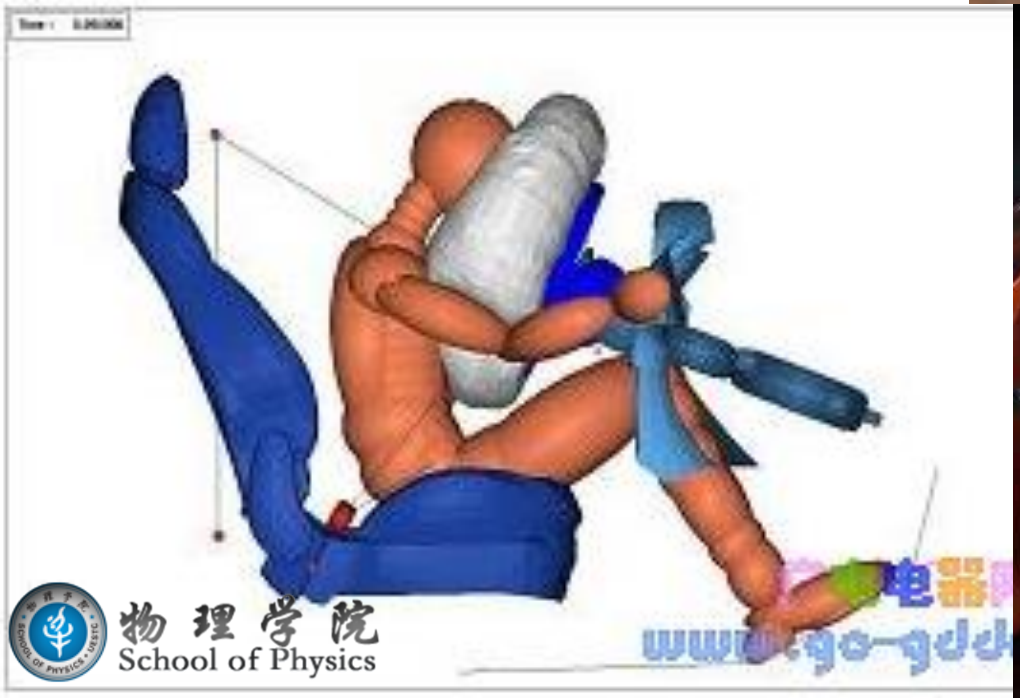
Nanoelectromechanical Systems（NEMS）



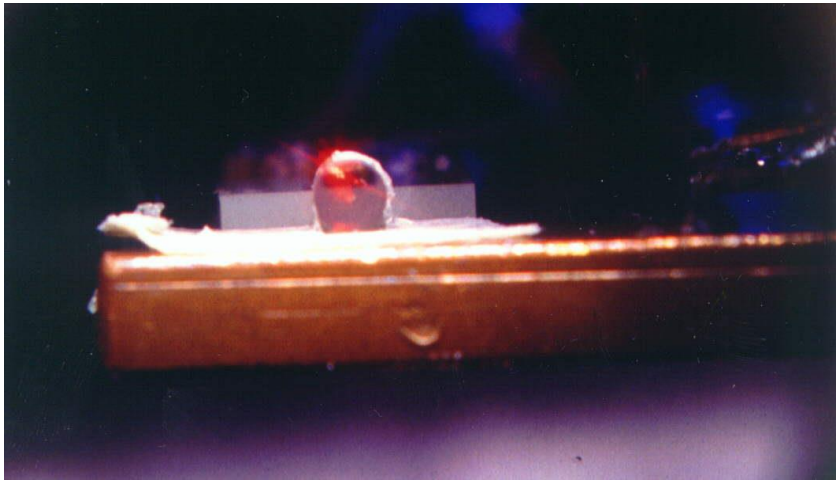
Micromechanical Sensors

微加速度计的经典应用之一：

汽车安全气囊

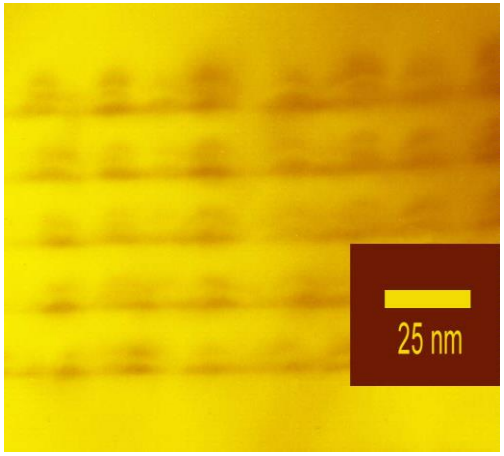


V. Nanoscale Optoelectronics

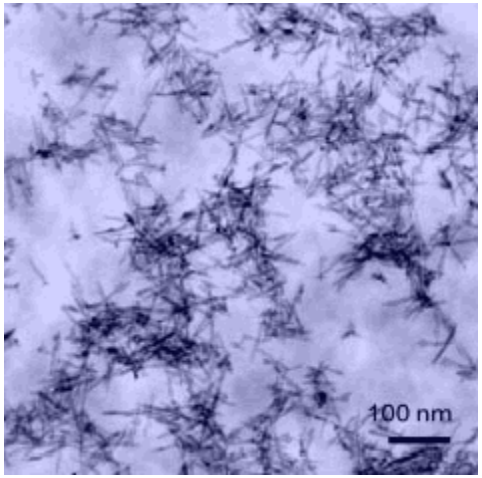


Challenges in optoelectronics

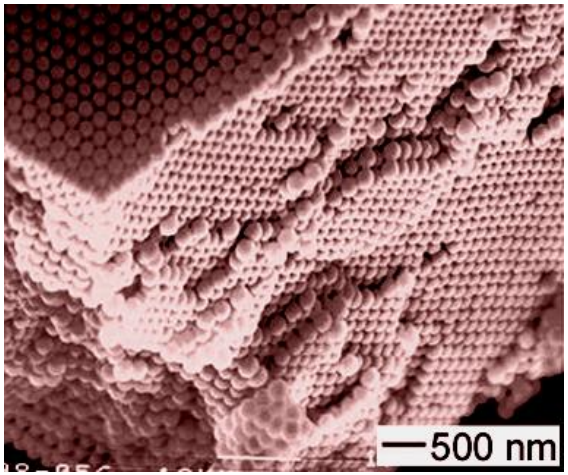
- device efficiency
- device tunability
- device integration
- novel materials for new applications



Quantum devices

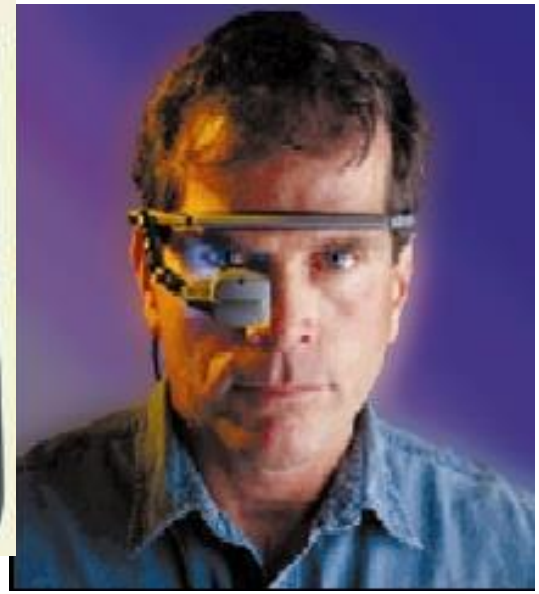


Organic Assemblies



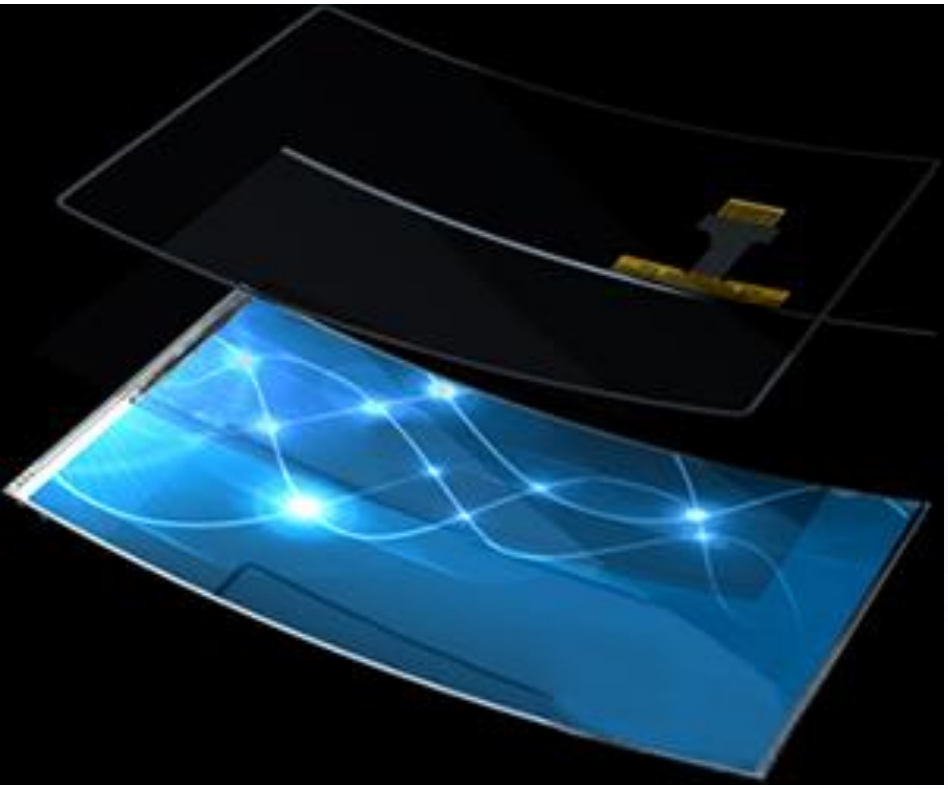
Photonic Crystals

Organic Optoelectronics



- 聚合物的合成在现代生活中很普及，如塑料容器、化纤布料等。
- 1970末共轭聚合物的发现使其在电子活性层、光学、光电子材料等应用上超过金属。
- **OLEDs**用共轭有机分子构成，用于显示器单元的制作，如汽车音响、手机、数码相机等。

基于石墨烯材料的柔性显示屏



华为折叠手机新款

售价：17500元

概念机视频：完爆目前任何一款手机！

iPhone7

有光就能上网：比Wi-Fi牛的Li-Fi

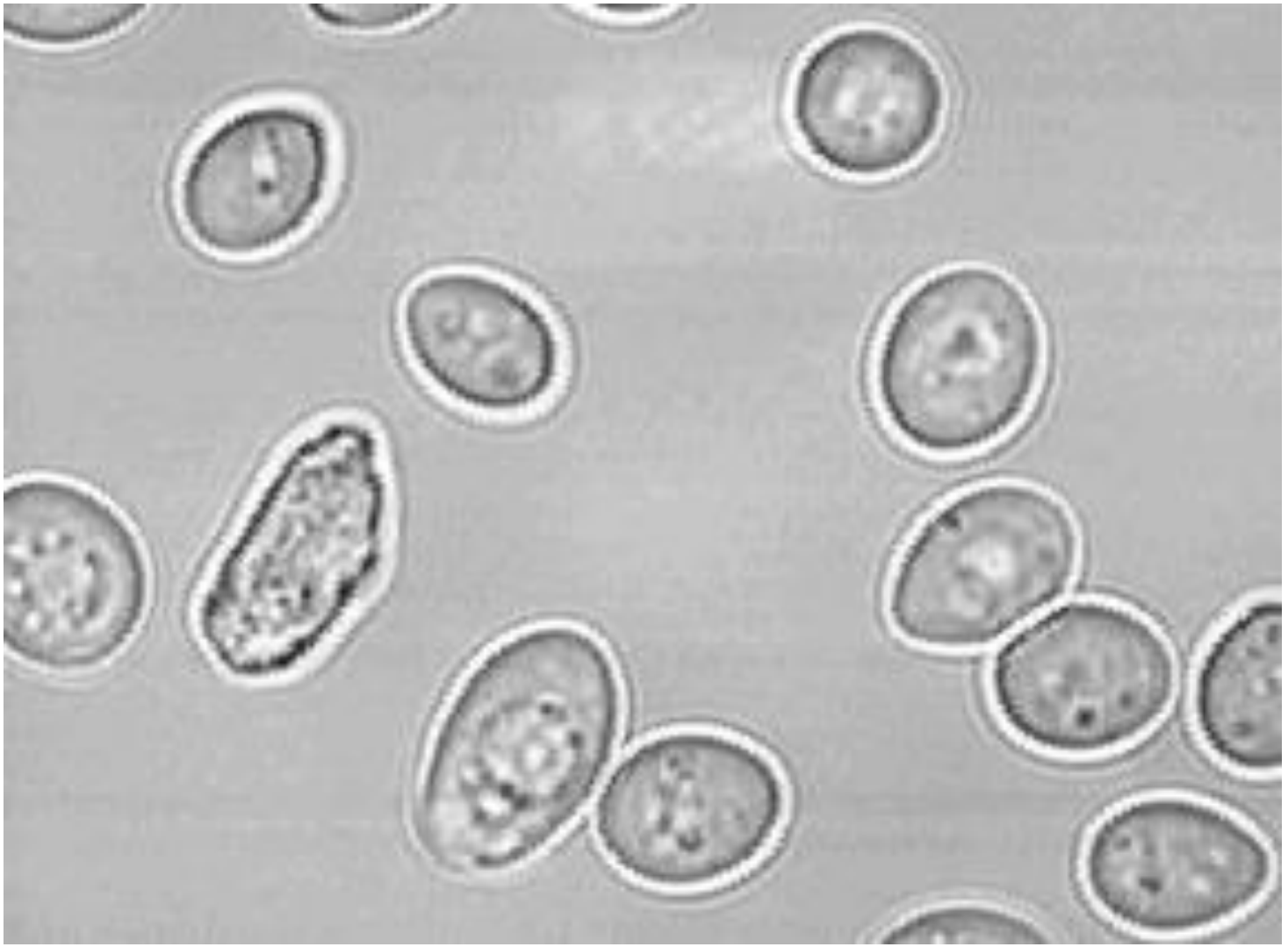
Li-Fi (Light Fidelity)是一种新型无线网络连接技术，它是主要通过可见光频谱来实现无线数据的传播。这项激动人心的技术最早出现在 Harold Hass 教授 2011 年的一次演讲中。在2015年的西班牙巴塞罗那 MWC 世界移动通信大会，PureLi-Fi 公司向我们展示了 Li-Fi 的实际产品。


pureLiFi

工作原理：

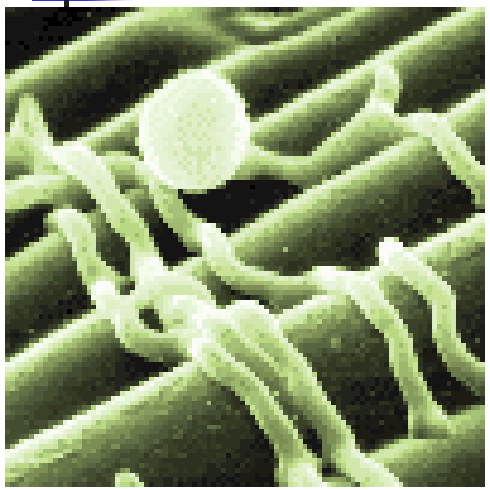
通过 LED 灯来传播无线信号，它有点类似于 Wi-Fi，但是我们使用的是 LED 灯等照明介质来完成无线数据通信。设置有用于传输无线数据的兼容 Li-Fi 的 LED 灯和发射器。

Movies



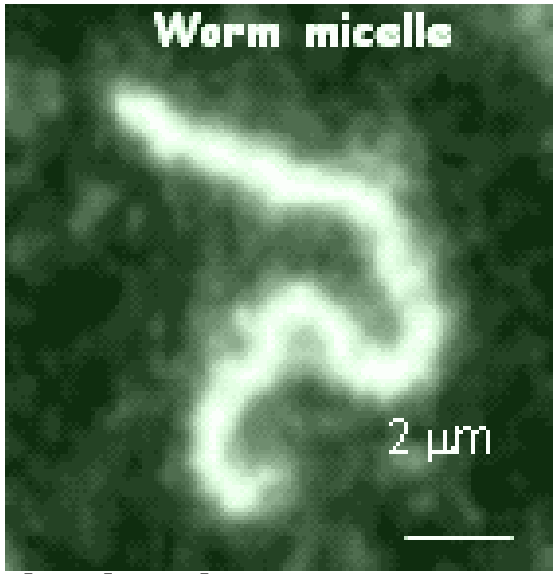
Optical tweezers

VI. Nanobiotechnology

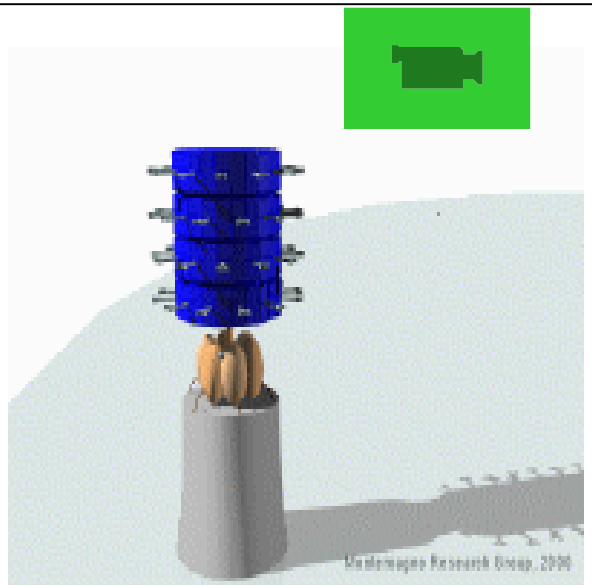


Challenges in biotechnology

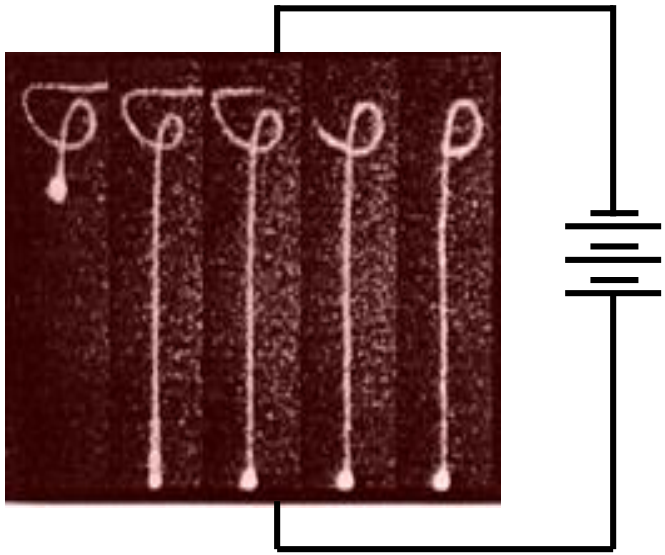
- understanding of natural nanosystems
- replication of nanosystems for novel device design



Biomimetic Nanostructures



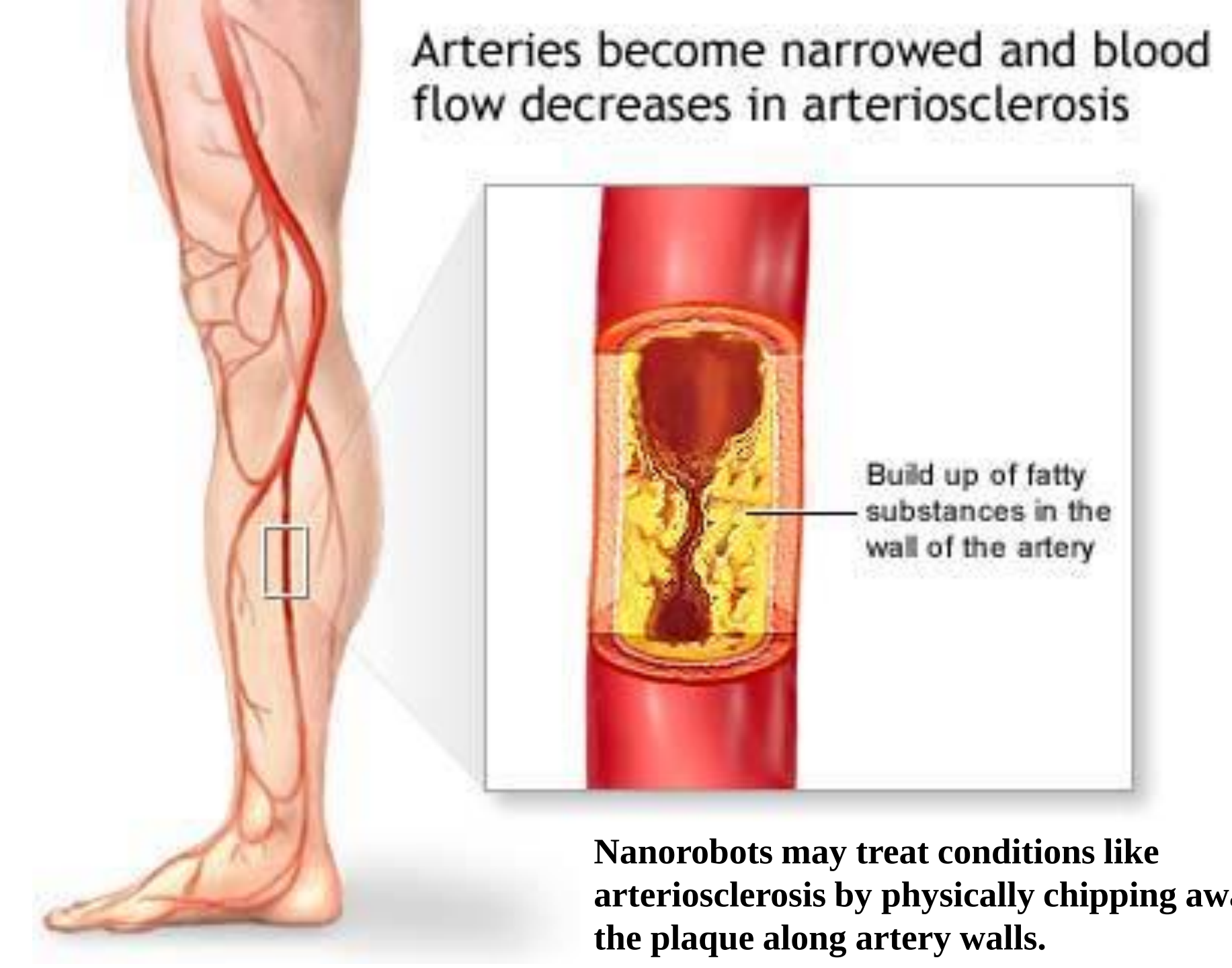
Molecular Motors



Nanofluidics

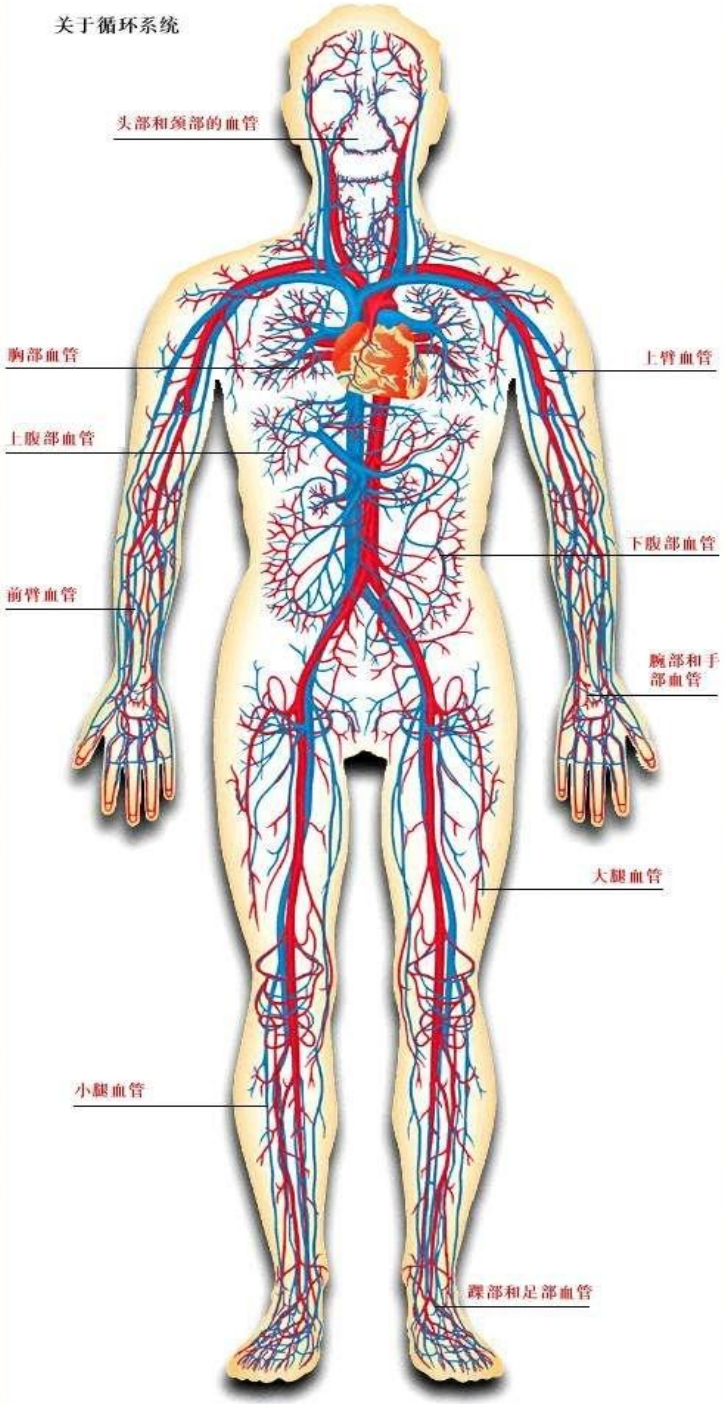
Nanorobots for life science

Future dreams



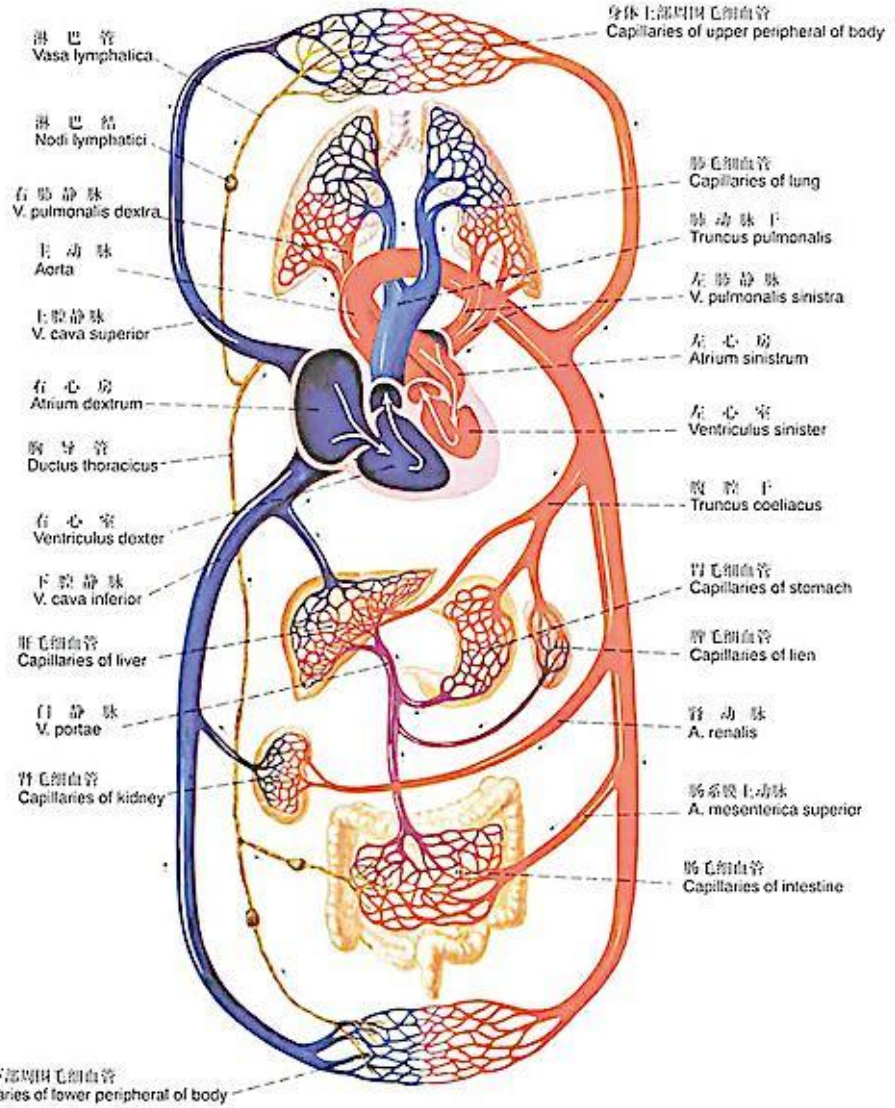
Nanorobots may treat conditions like arteriosclerosis by physically chipping away the plaque along artery walls.

关于循环系统

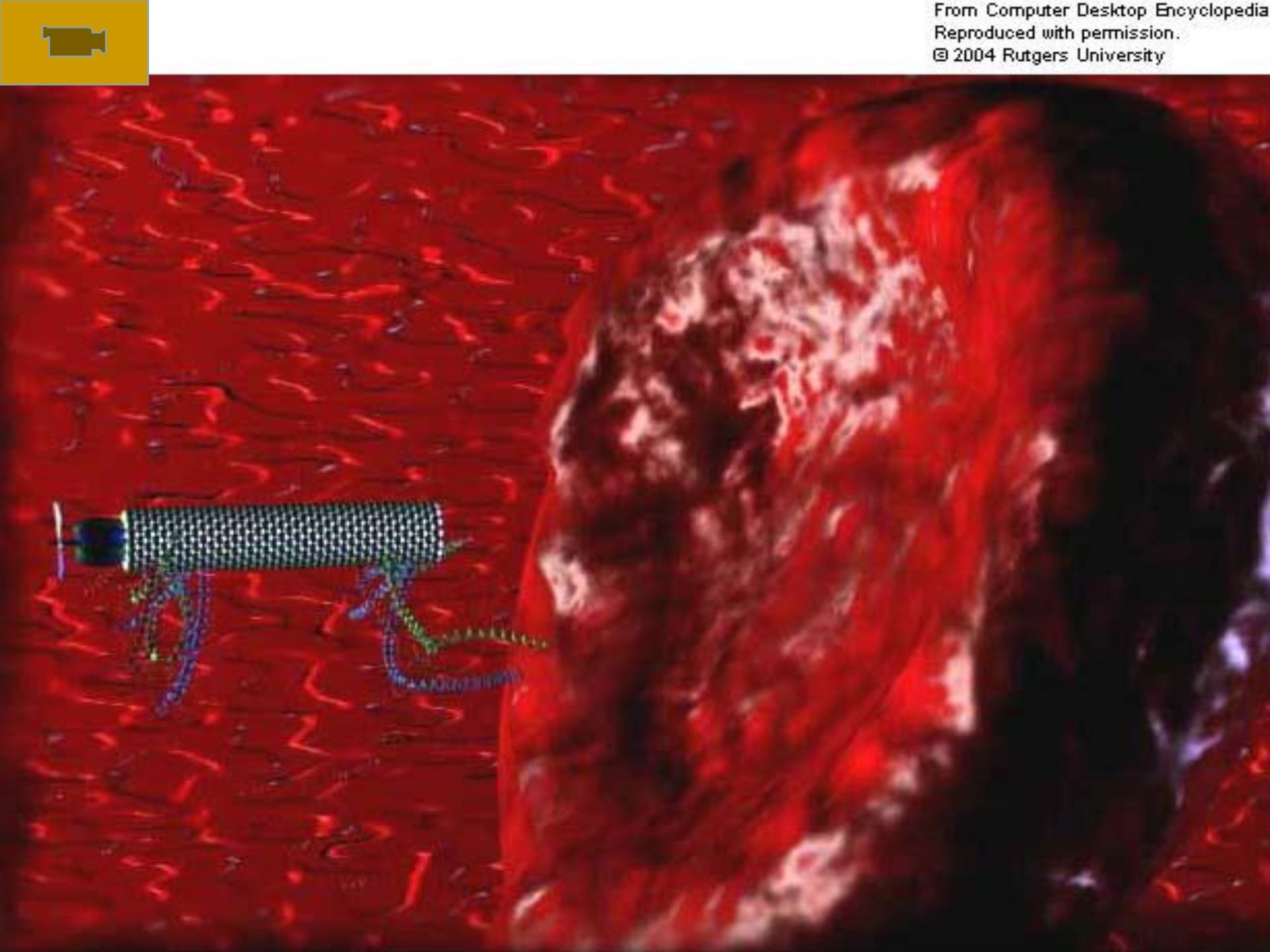


Blood circulation

血液循环示意图

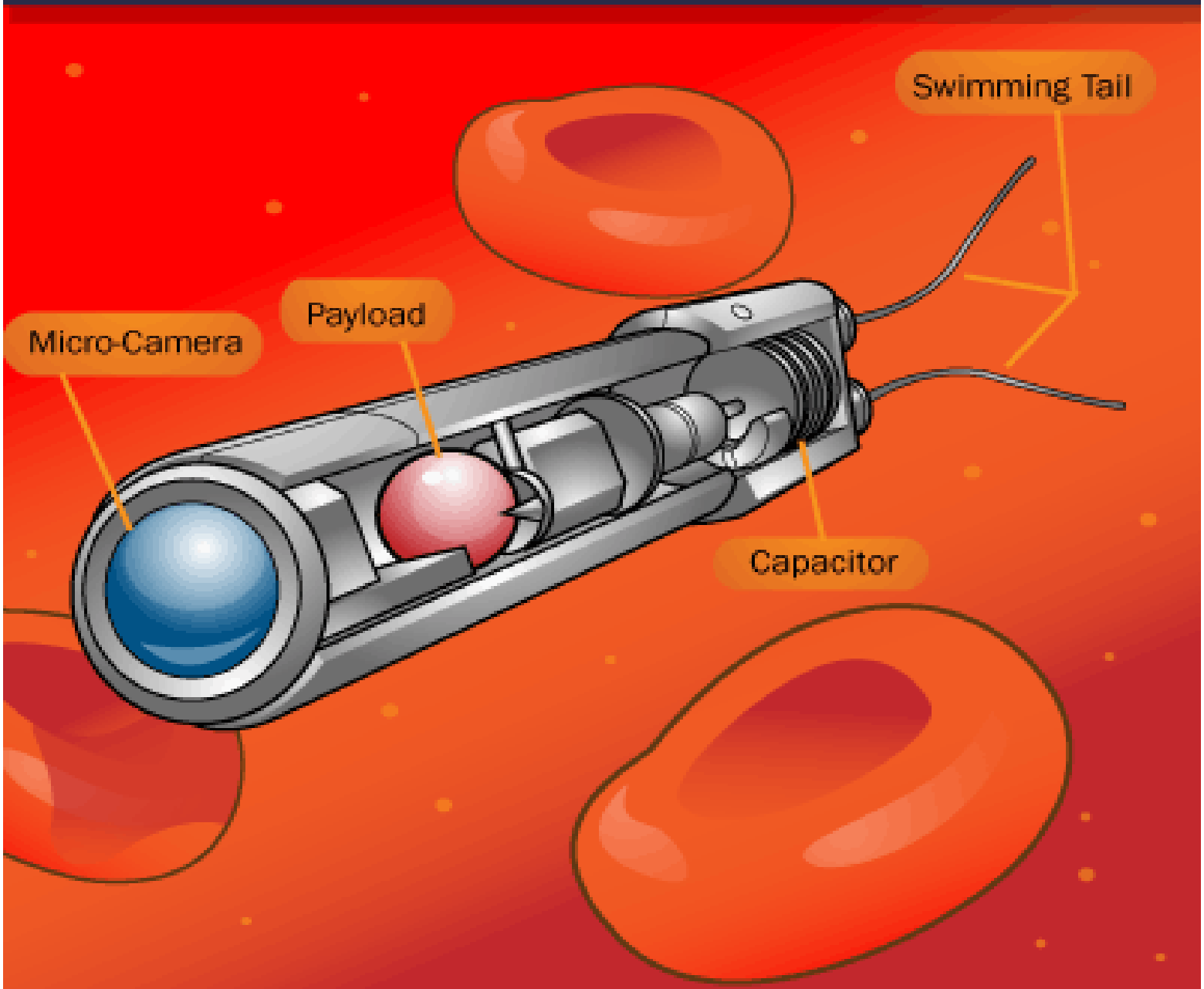


Tiny nanorobots the size of cells are programmed to travel through the bloodstream, finding and repairing defects in the body's organs and tissues.

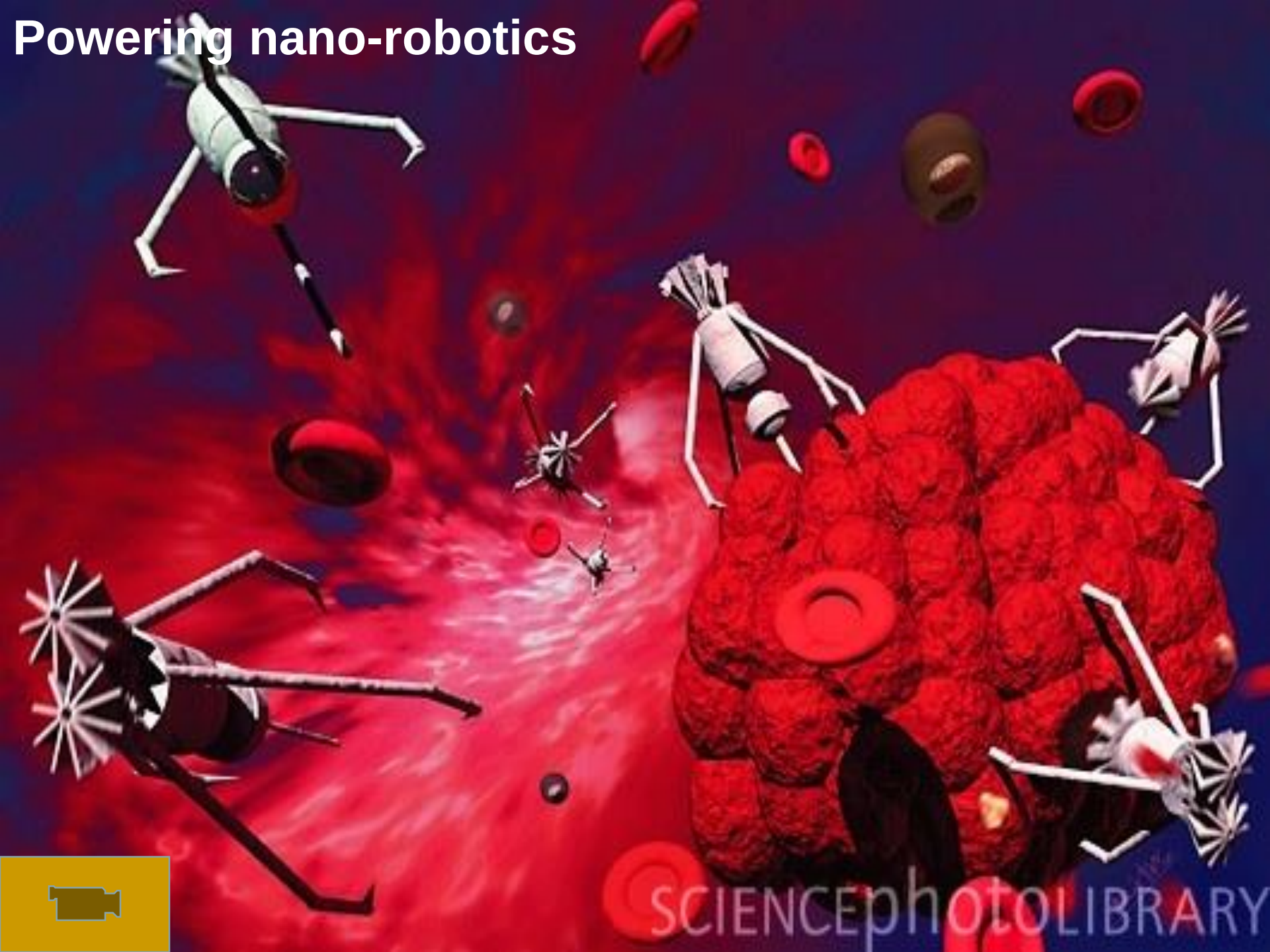



NEWSin3D.com

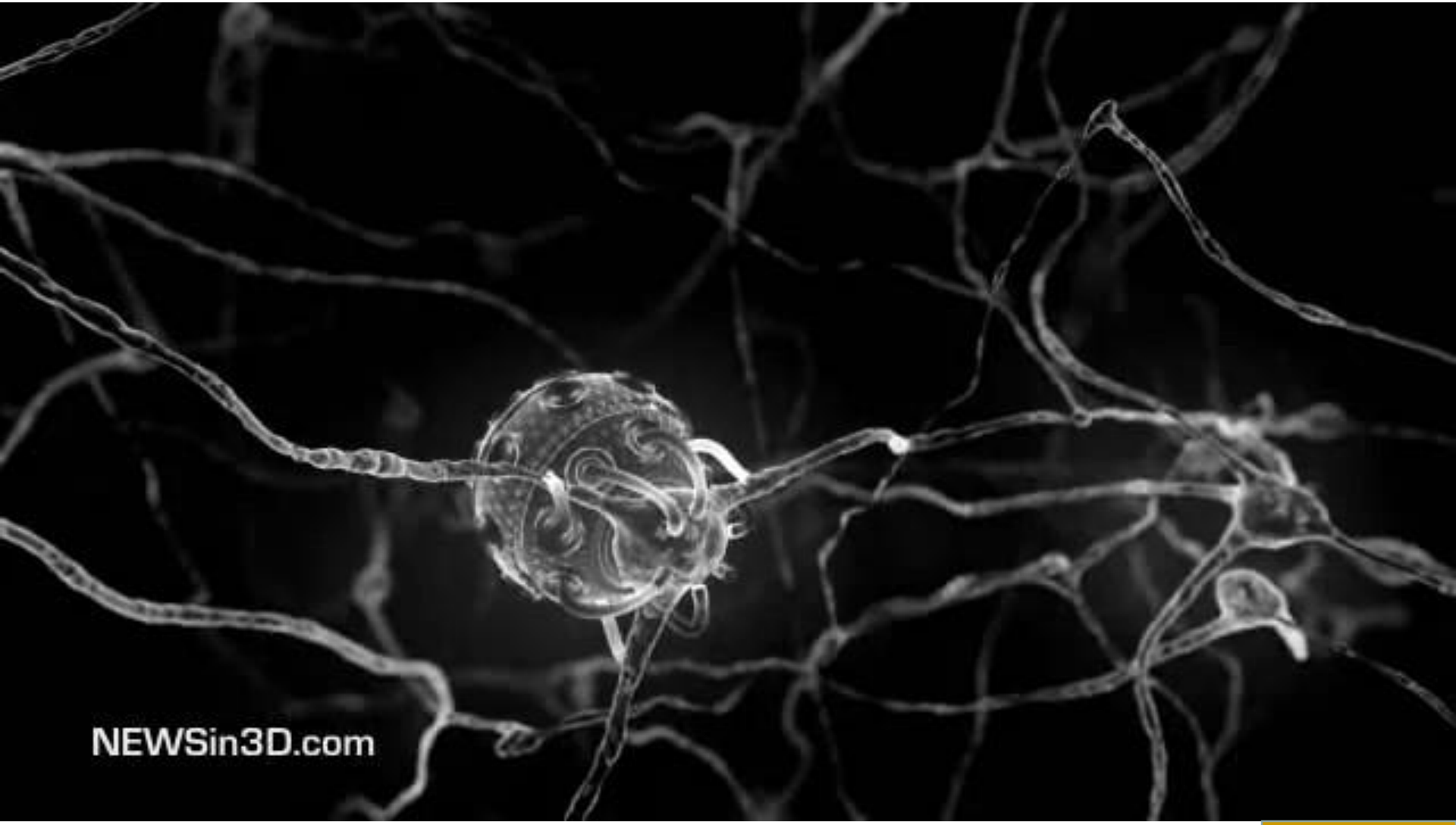
How Blood Swimming Robots Work

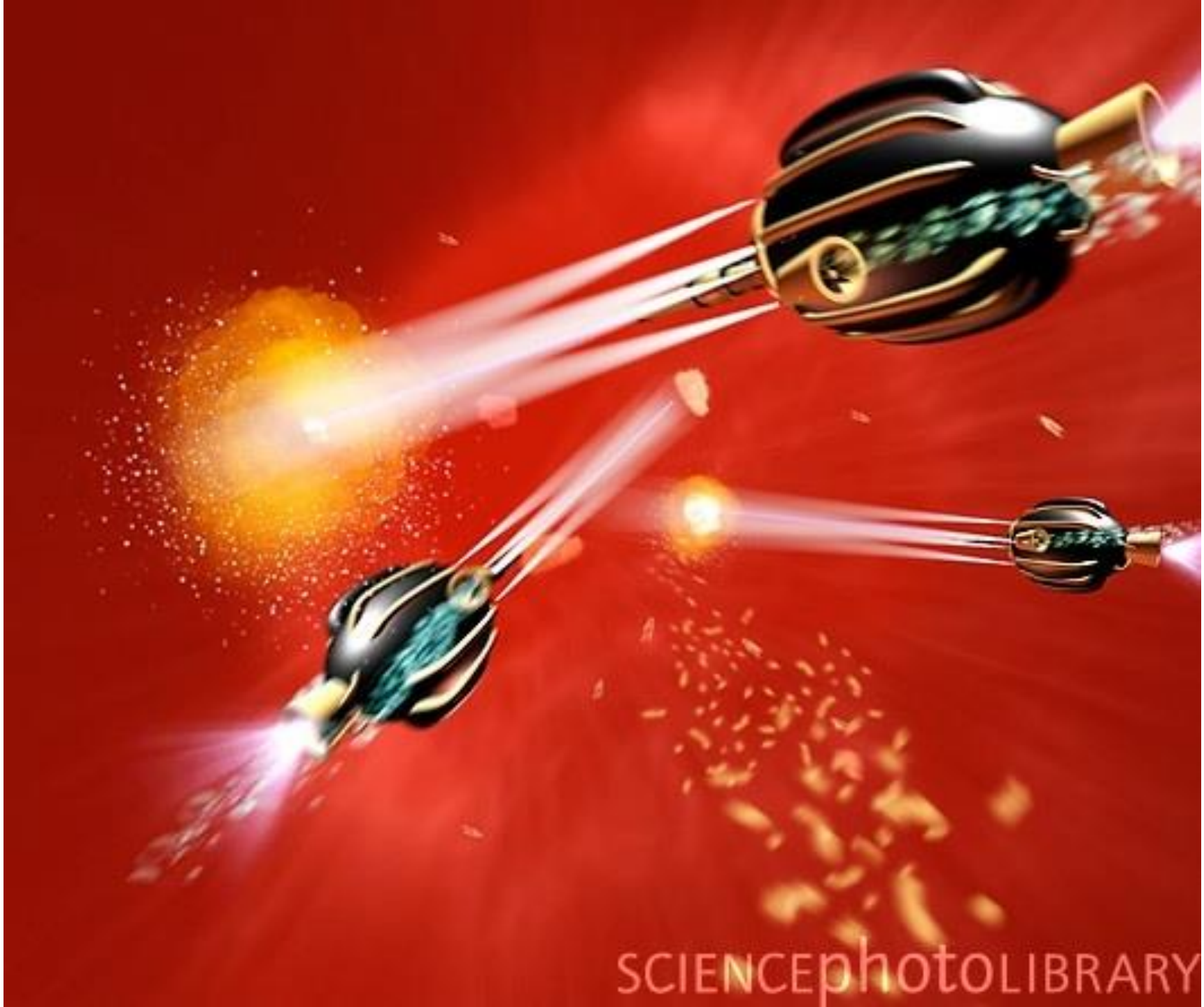


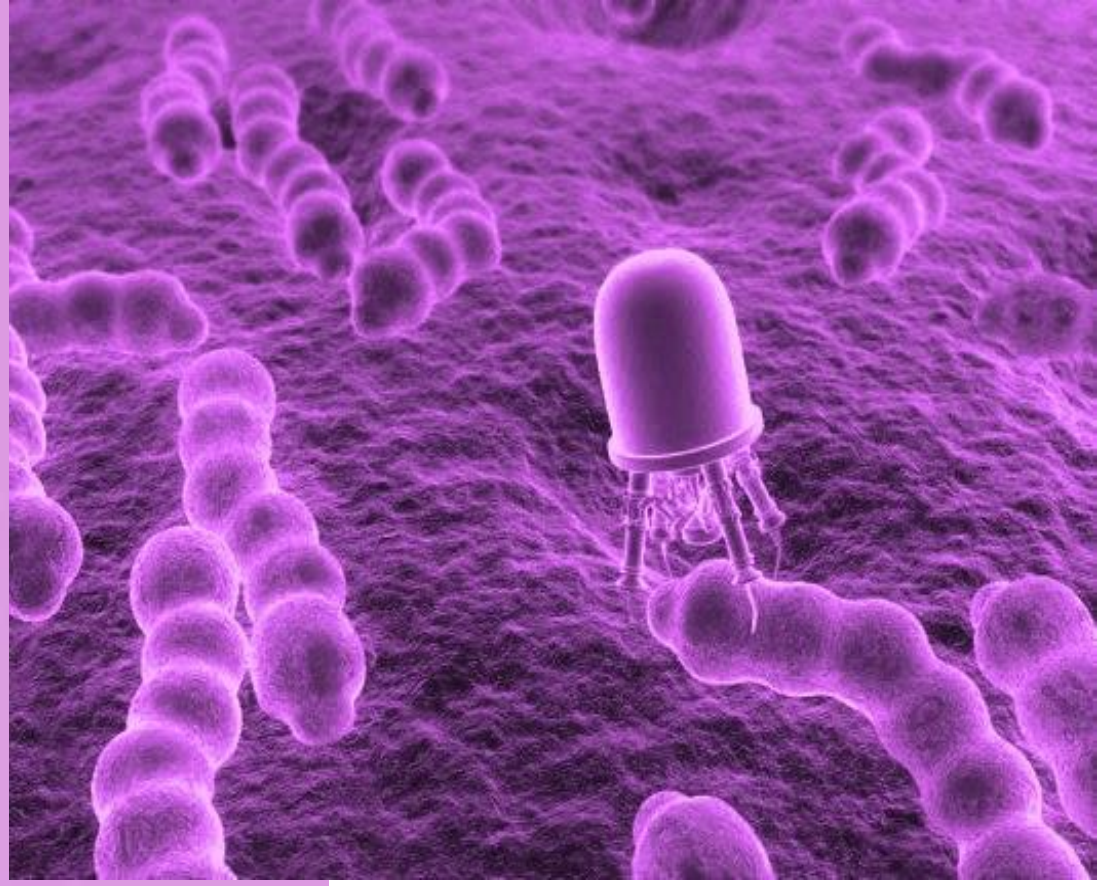
Powering nano-robotics



Nanorobot replacing nerons

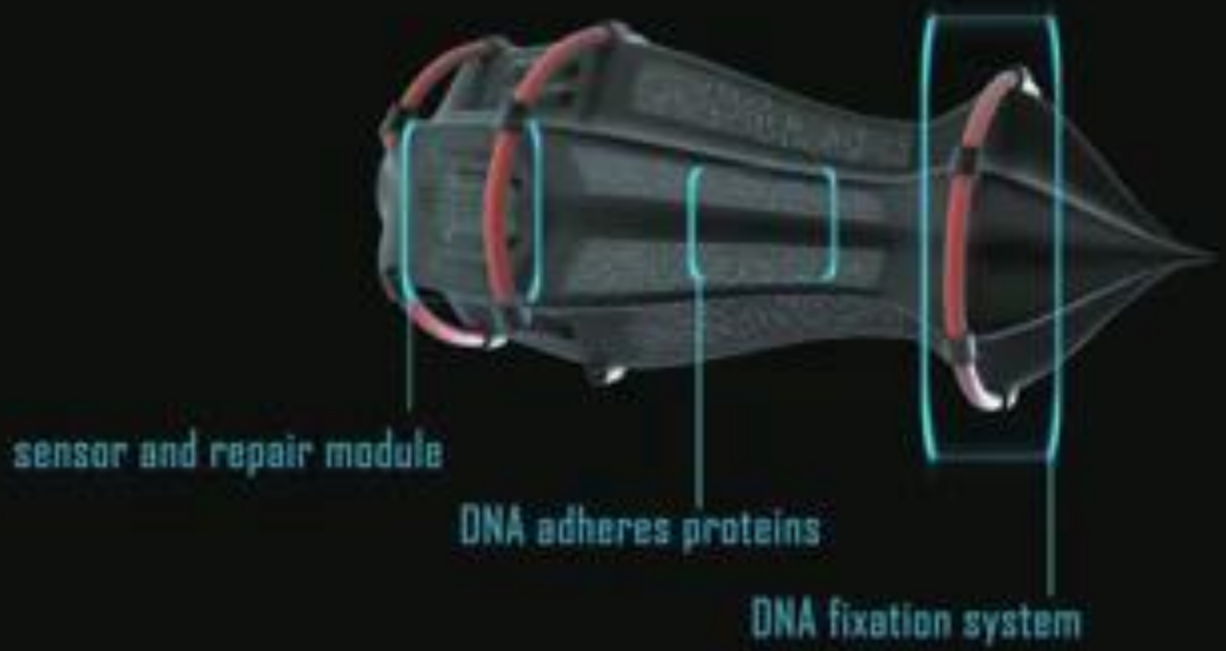


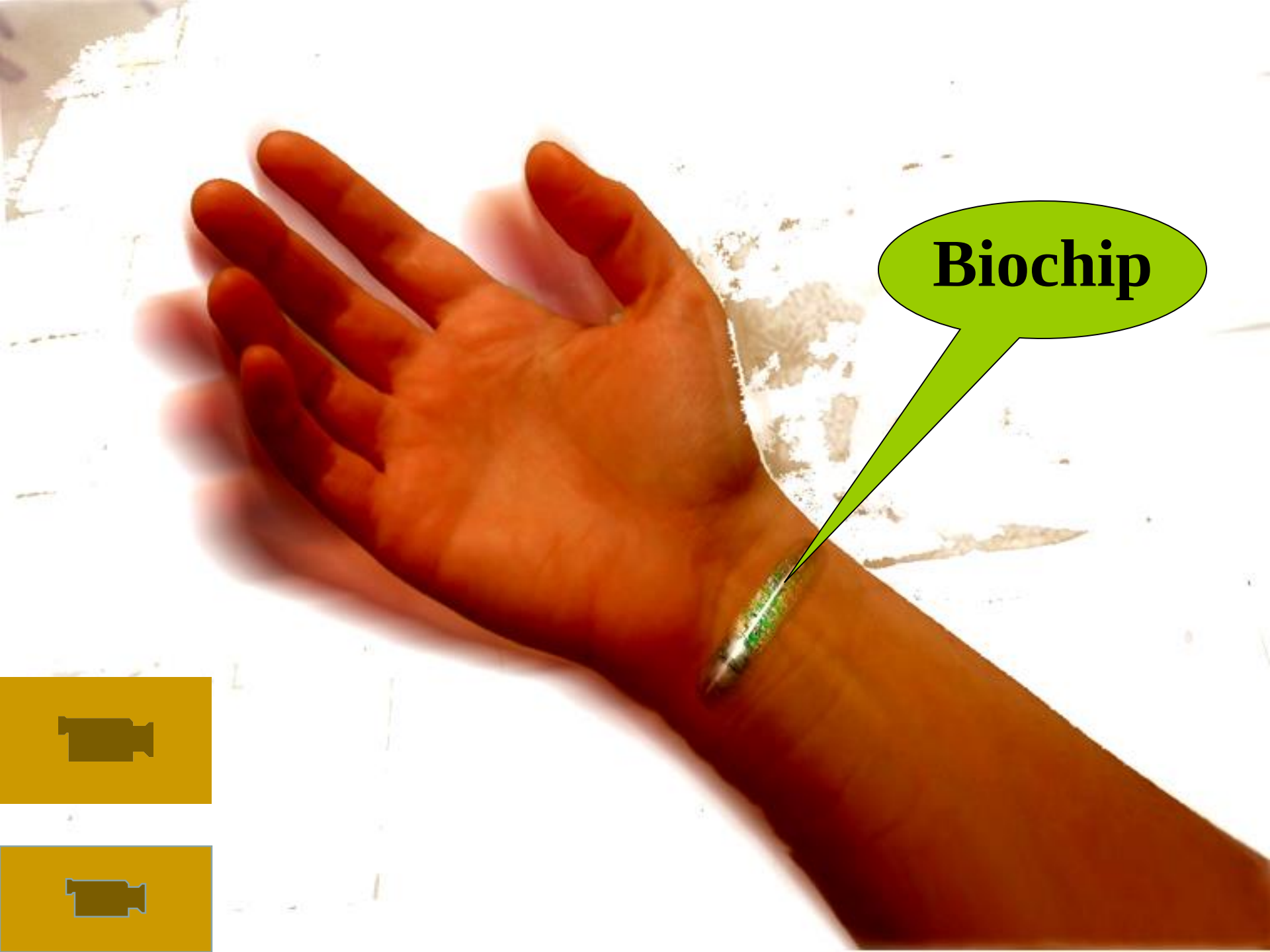

SCIENCEphotoLIBRARY



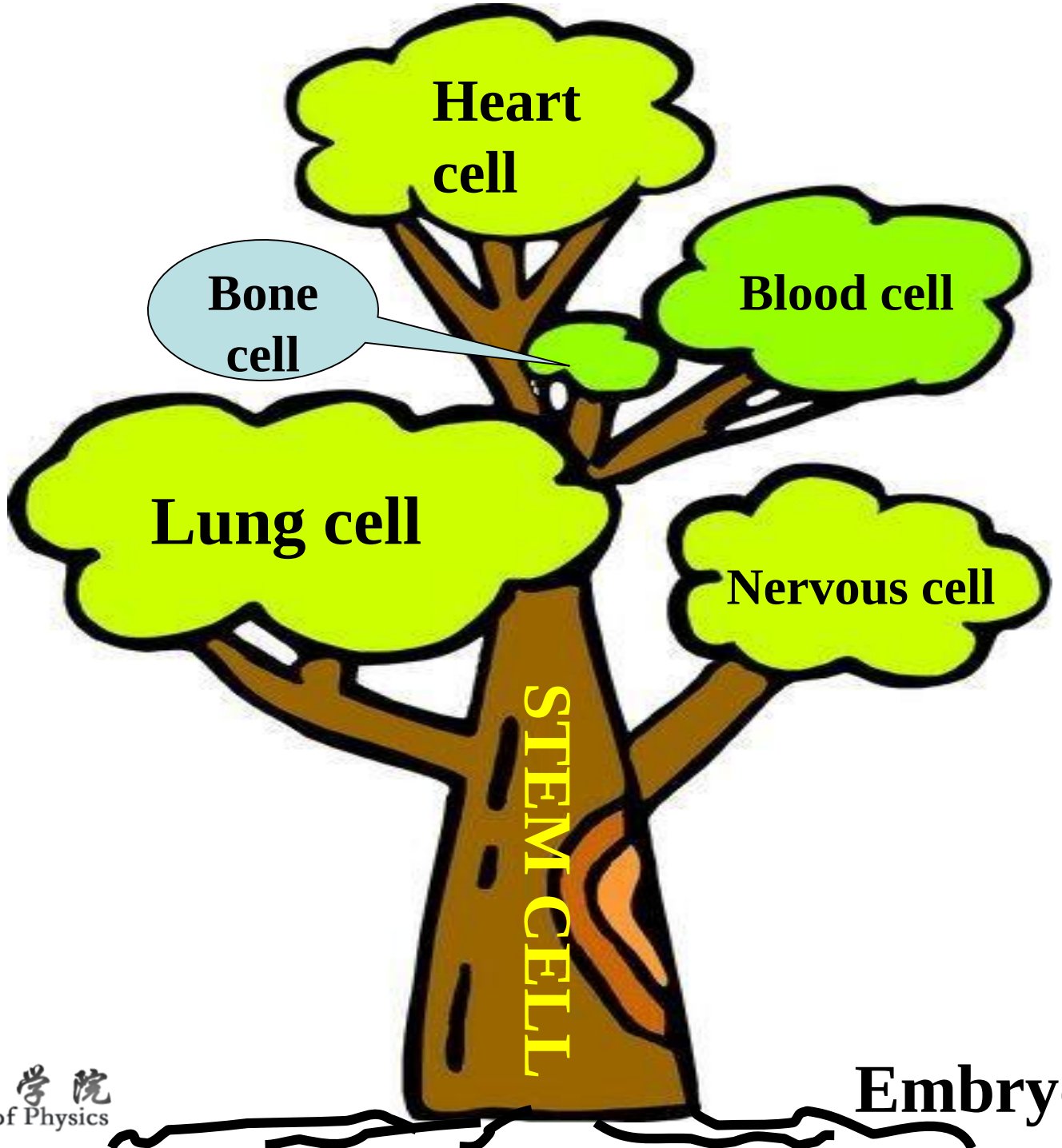
Nanorobots can be injected into human body by this way!!

DNA-repair nanorobot concept

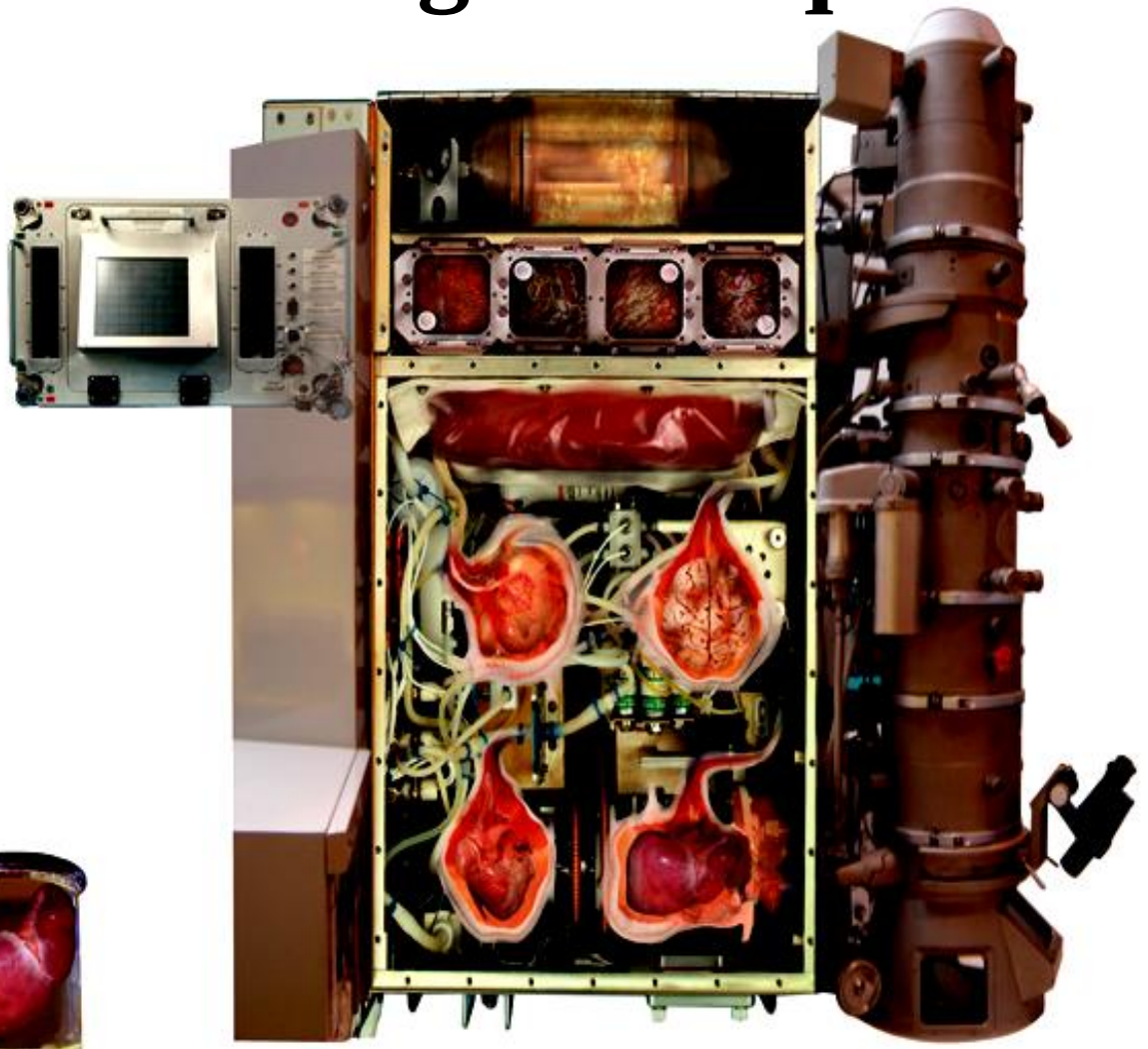



Biochip

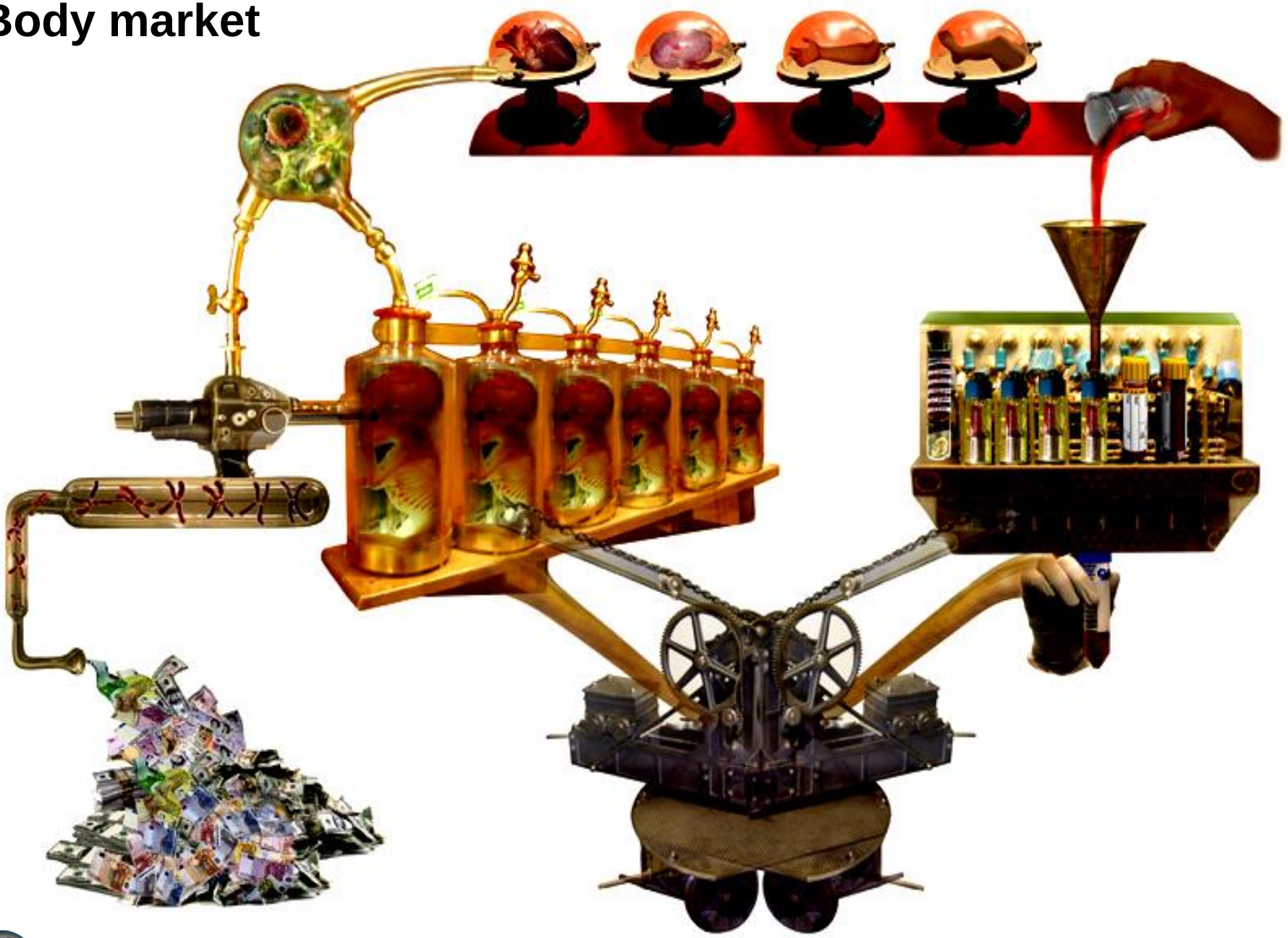
STEM CELL



Stem cell utilization: regenereation + cloning technique



Body market



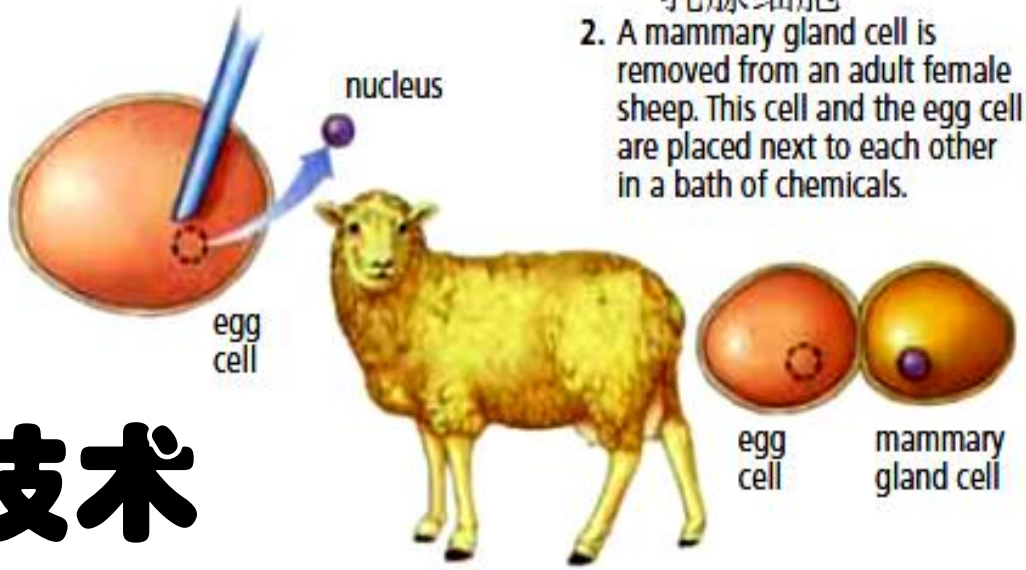
克隆技术

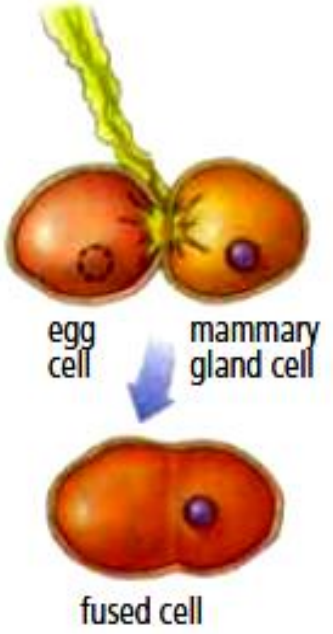
乳腺细胞

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

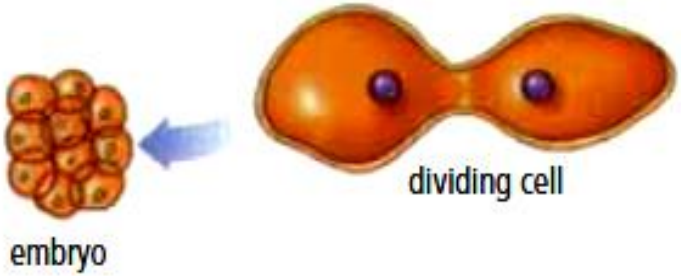
2. A mammary gland cell is removed from an adult female sheep. This cell and the egg cell are placed next to each other in a bath of chemicals.

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





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.



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

Figure 5.32 The reproductive cloning process

Future technology

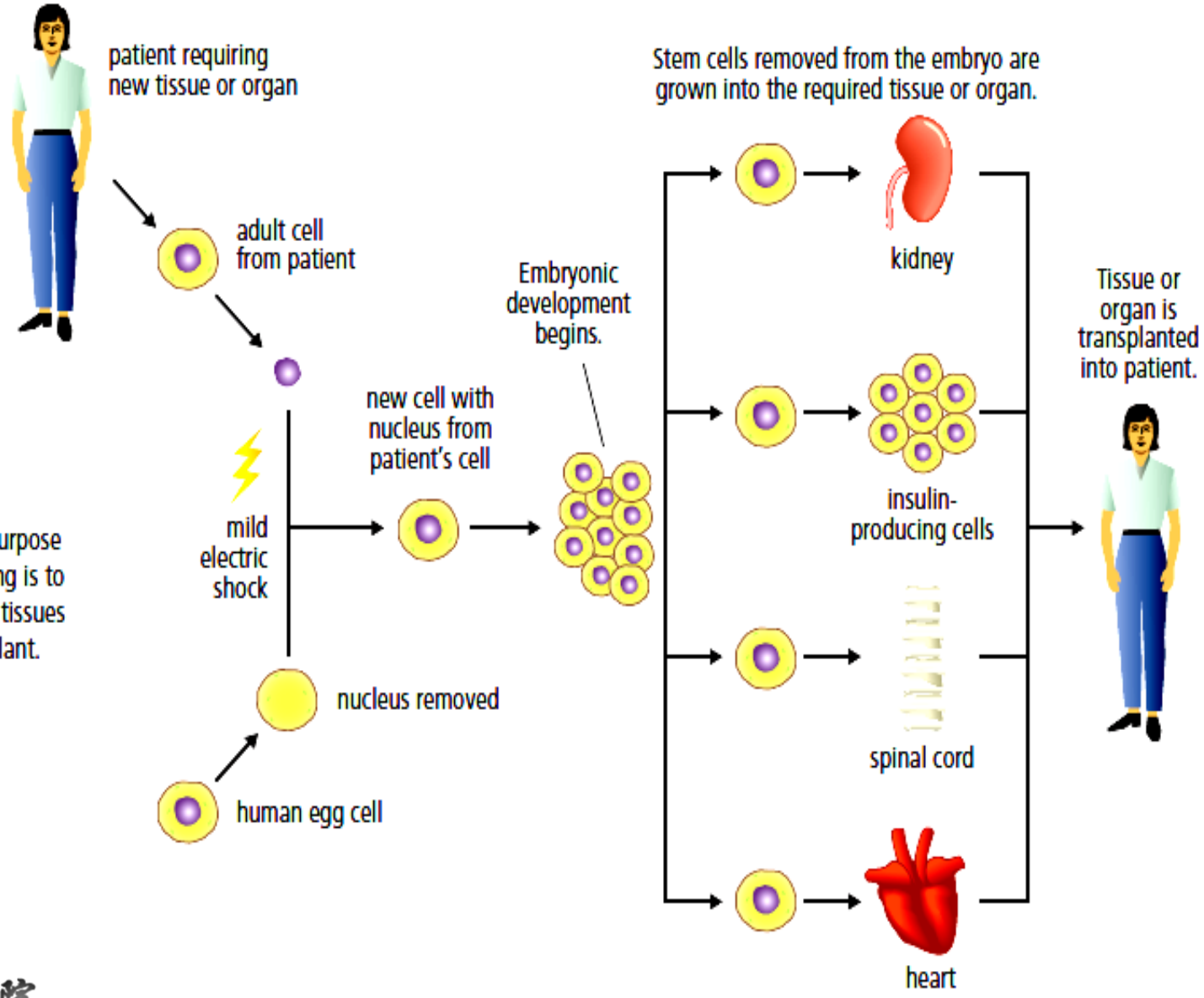


Figure 5.33 The purpose of therapeutic cloning is to produce specialized tissues or organs for transplant.

素材来源

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School of Physics

Human-assisted Cloning

You have learned that a number of asexual cloning methods occur in nature: binary fission, budding, fragmentation, vegetative reproduction, and spore production. In plants that reproduce asexually, each cell has the potential to grow into an identical plant. Because of this ability, researchers can clone plants from cuttings, as discussed earlier in this section. Less complex animals such as sponges, hydras, and worms can clone themselves by asexual methods. Unlike less complex animals and plants, more complex, multicellular animals lose this cloning ability as their cells become specialized. In order for cloning to take place, human assistance is required.

Human-assisted plant and animal cloning can be used to save the genetic information from endangered animal species or to mass produce an organism with a desired trait. For instance, in British Columbia, researchers are working to clone pine trees that are naturally resistant to the mountain pine beetle (Figure 5.31).

Explore More

Cloning can also be used to produce pigs whose organs are used for human transplants. Find out more about different types of cloning. Begin your research at www.bcscience8.ca.

Figure 5.31 Many forests of lodgepole pines have been killed by mountain pine beetles. Some trees have been able to produce enough sticky resin to keep the pest from having sleep inside the tree. Planting clones of these particular trees might stop the destruction of pine forests.

Reproductive cloning

Reproductive cloning is also called adult DNA cloning. The purpose of this type of cloning is to produce a genetic duplicate of an existing or previously existing organism with desirable qualities. For example, if you have a cow that produces a lot of milk, you might want to clone this particular animal. Since all the cow's cells have become specialized, you cannot turn just any body cell—say, a skin cell—into another individual. However, you could take the nucleus from the skin cell and put it into an egg cell that has had the nucleus removed.

The method used to clone Dolly, the world's most famous cloned sheep, transferred the nucleus from a mammary gland cell into an egg cell without a nucleus (Figure 5.32). The fused cell was then transplanted into a surrogate (substitute) mother, and Dolly was eventually born. A problem with this process is that only 10 percent of clones usually survive. Also, the surviving clones can be abnormally large and have higher rates of infection and cancer. Dolly lived for only six years, dying of a lung disease common in sheep. Before her death, she appeared to be aging faster than sheep usually do.

internet connect

Try simulating the cloning process yourself by going to www.bcscience8.ca.

Therapeutic cloning 治疗性克隆

Therapeutic cloning is used to correct health problems. ("Therapeutic" means to have healing ability.) Both human embryonic stem cells and adult stem cells can be used for this purpose. Stem cells are cells that have the potential to become many different types of cells. Embryonic stem cells are more desirable for therapeutic cloning because they can become any one of our 200 types of body cells.

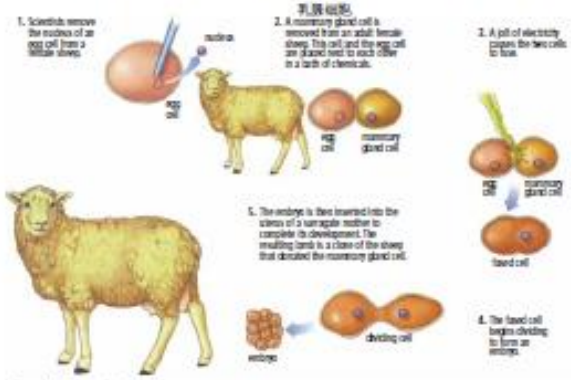


Figure 5.32 The reproductive cloning process

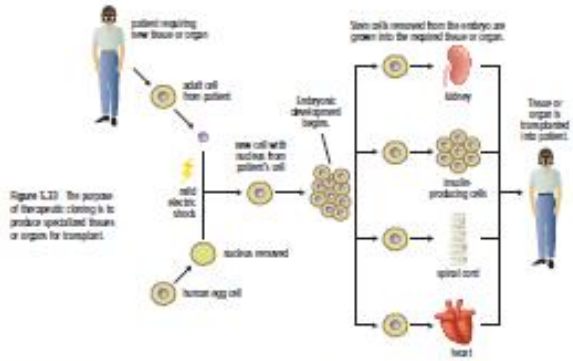


Figure 5.33 The purpose of therapeutic cloning is to produce specialized tissues or organs for transplant.

Did You Know?

Canadian biophysicist James Till and hematologist Ernest McCulloch were the first scientists to identify stem cells. Their research in the

Stem cells can be used to replace damaged cells in patients with diabetes, spinal injuries, or Parkinson's disease. Since adult stem cells are not as adaptable, embryonic stem cells are often used in therapeutic cloning (Figure 5.33). However, adult stem cells from bone marrow have been used in transplants for 30 years, and recently other kinds of adult stem cells have been used to regenerate nerves and heart tissue and to treat diabetes.

5-2B Determining the Best Conditions for Yeast Reproduction

Conduct an INVESTIGATION

Inquiry Focus

SkillCheck

- Observing
- Measuring
- Controlling variables
- Working co-operatively

Yeast are small single-celled fungi. They obtain energy from sucrose in a process called fermentation. During this process, carbon dioxide and alcohol are produced. Yeast are used to make bread, beer, wine, and cheese. In this investigation, you will first observe yeast budding under the microscope, and then you will conduct two experiments to determine what the optimum conditions are for yeast reproduction. You will consider the effect of nutrients and pH level (acidity and alkalinity) on yeast reproduction. As more yeast are produced, more fermentation will occur. The amount of fermentation that occurs can be compared by collecting the carbon dioxide gas produced. You may conduct all three parts of this investigation, or your teacher may ask you to conduct only one part and report your findings to the rest of the class.

Safety

- Be careful when handling acids (vinegar) and bases (ammonia).
- Wash your hands thoroughly after doing this investigation.

Question

What are the optimum conditions for yeast reproduction?

Materials

Part 1

- petri dish
- 0.5 g yeast
- 1 g sucrose (table sugar)
- 5 mL warm tap water (24–27°C)

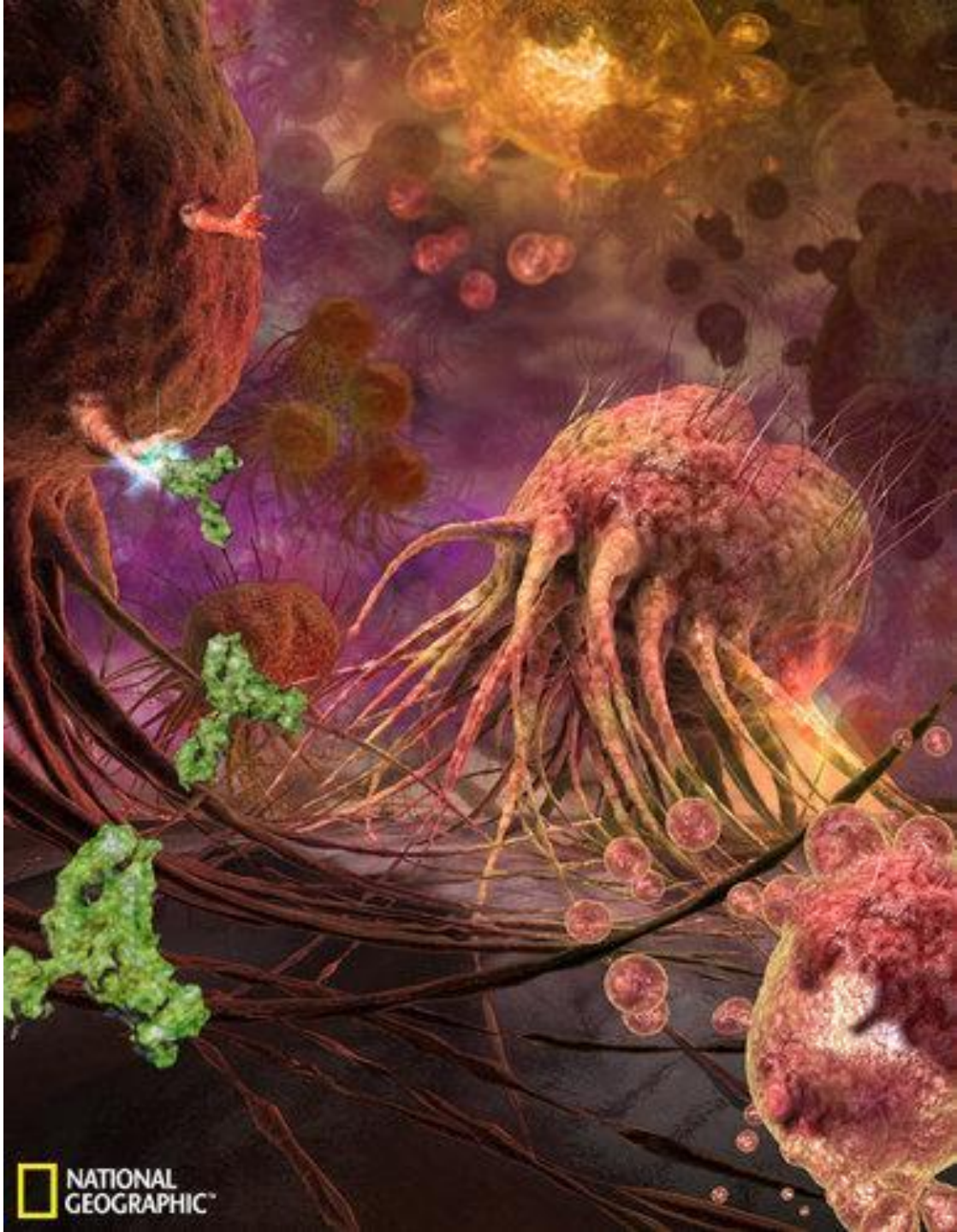
Procedure

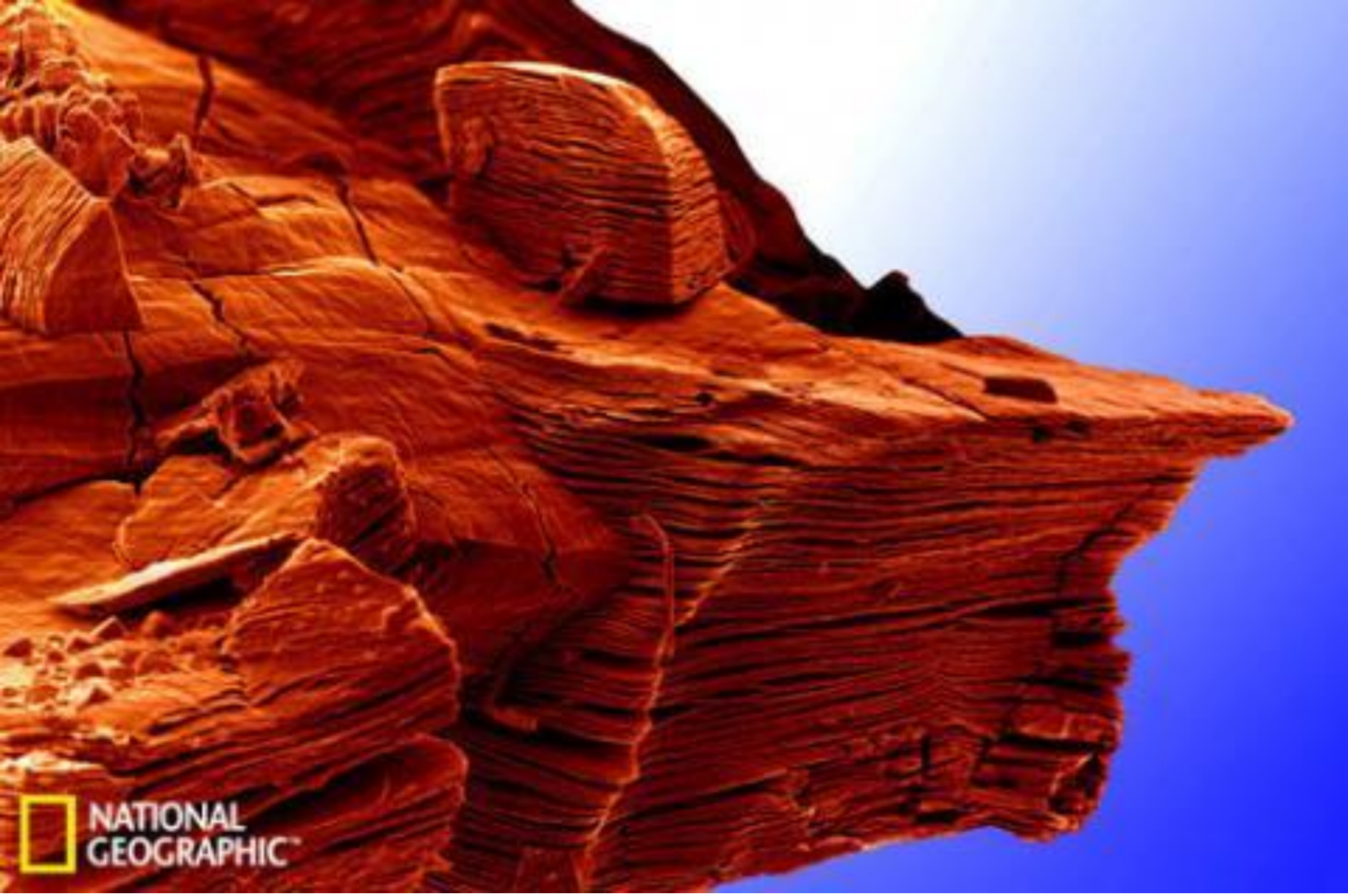
Part 1 Observing Budding in Yeast

1. Place 0.5 g of yeast and 1 g of sugar in a petri dish.
2. Confirm that the water temperature is correct using the thermometer, then add 5 mL warm water and let the dish sit covered on your lab bench for 10 min.
3. Smear a yeast sample on a slide with a toothpick or place a small drop on the slide using a medicine dropper. Cover with the cover slip.
4. Observe the yeast under the microscope using high power. You may need to reduce the light using the diaphragm below the stage.
5. You should see circle-shaped yeast cells. Look for cells that appear to have a

纳米世界艺术画廊

在这幅灵感来源于H. P. 洛夫克拉夫特的插图中，乳腺癌细胞看起很像触须一样的外星生物。一种用来对抗乳腺癌的抗体——TRA-8漂浮在前景画面中。





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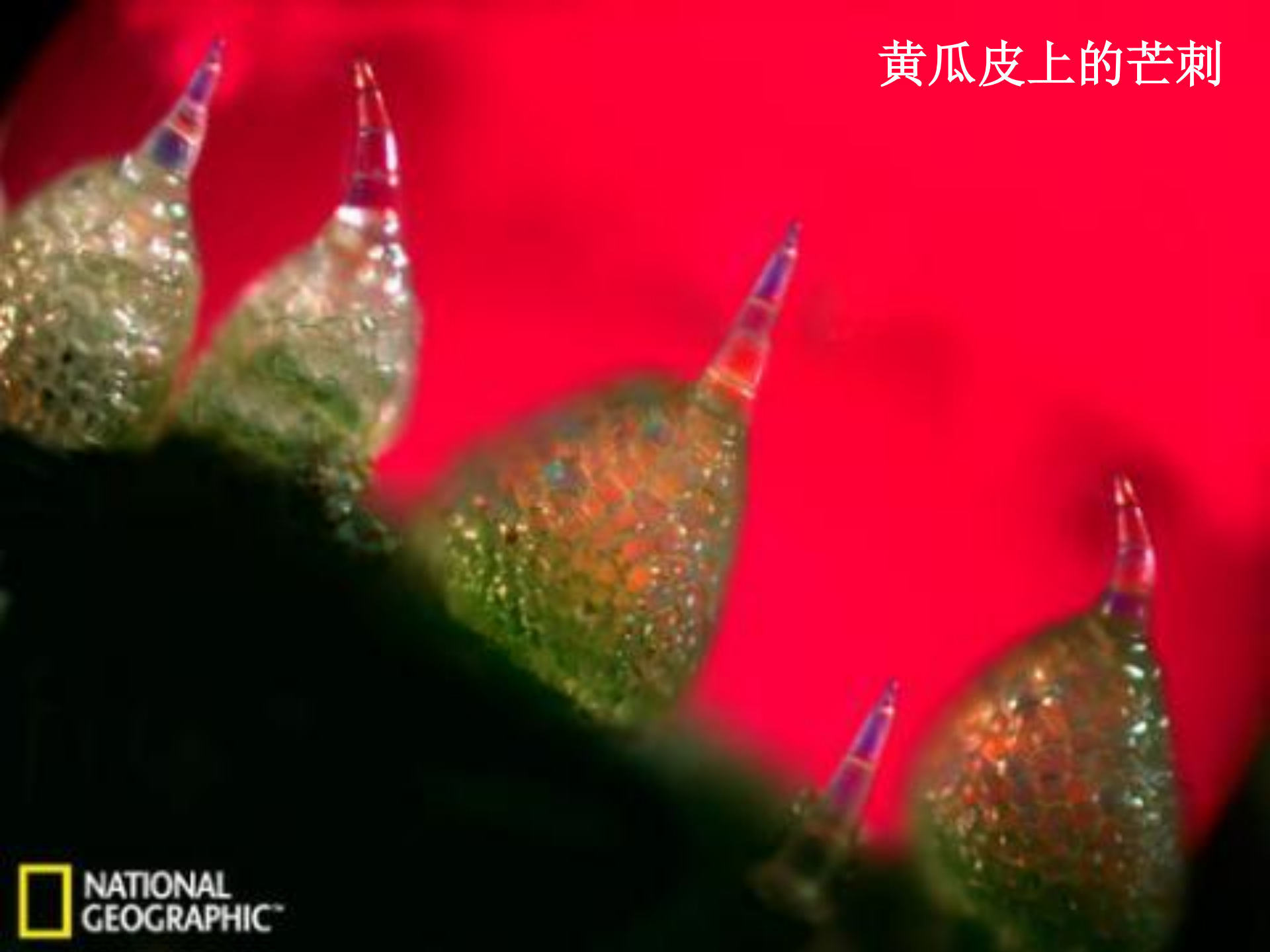
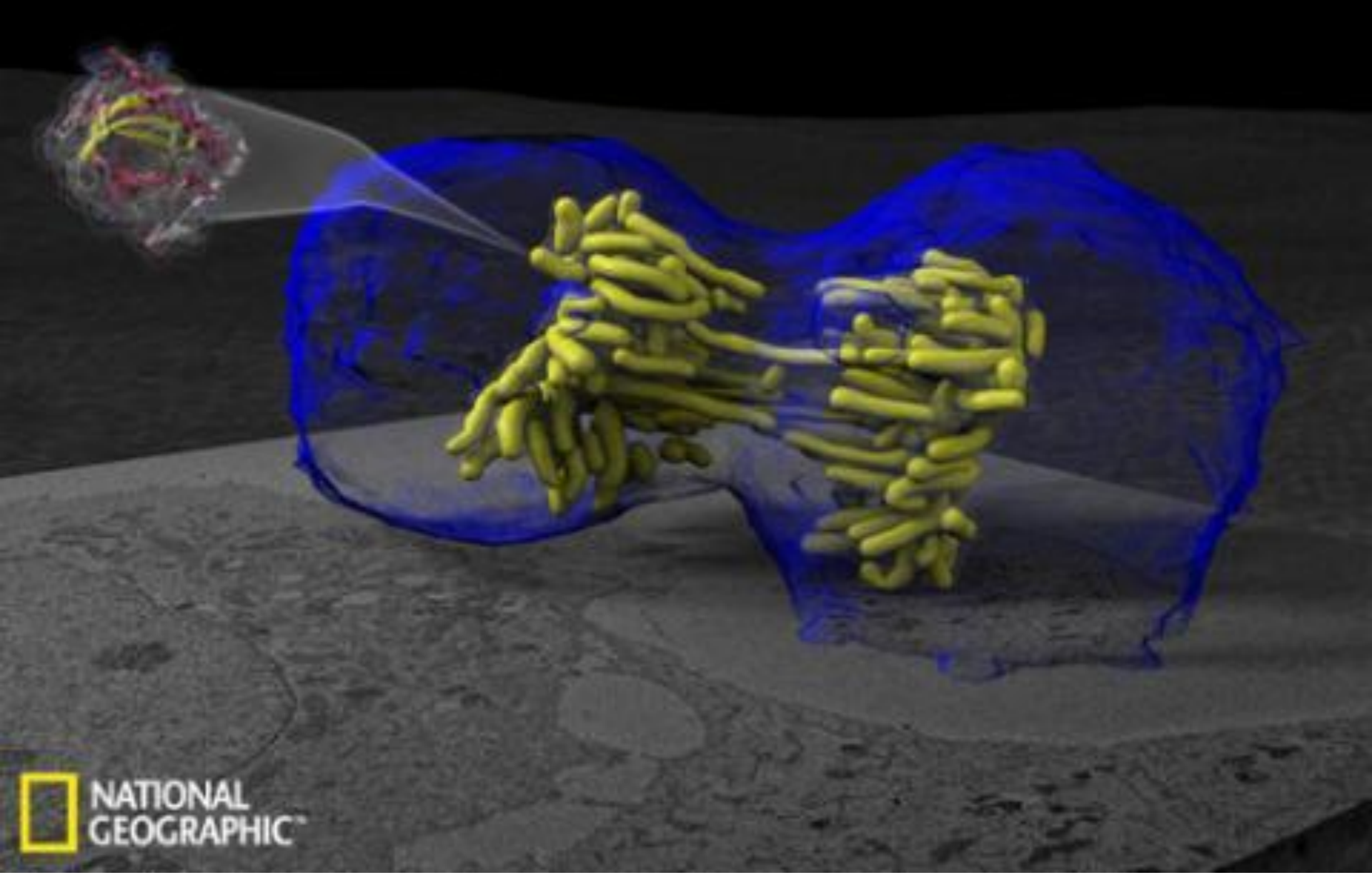
金属叶片上纳米级悬崖


黄瓜皮上的芒刺
NATIONAL
GEOGRAPHIC

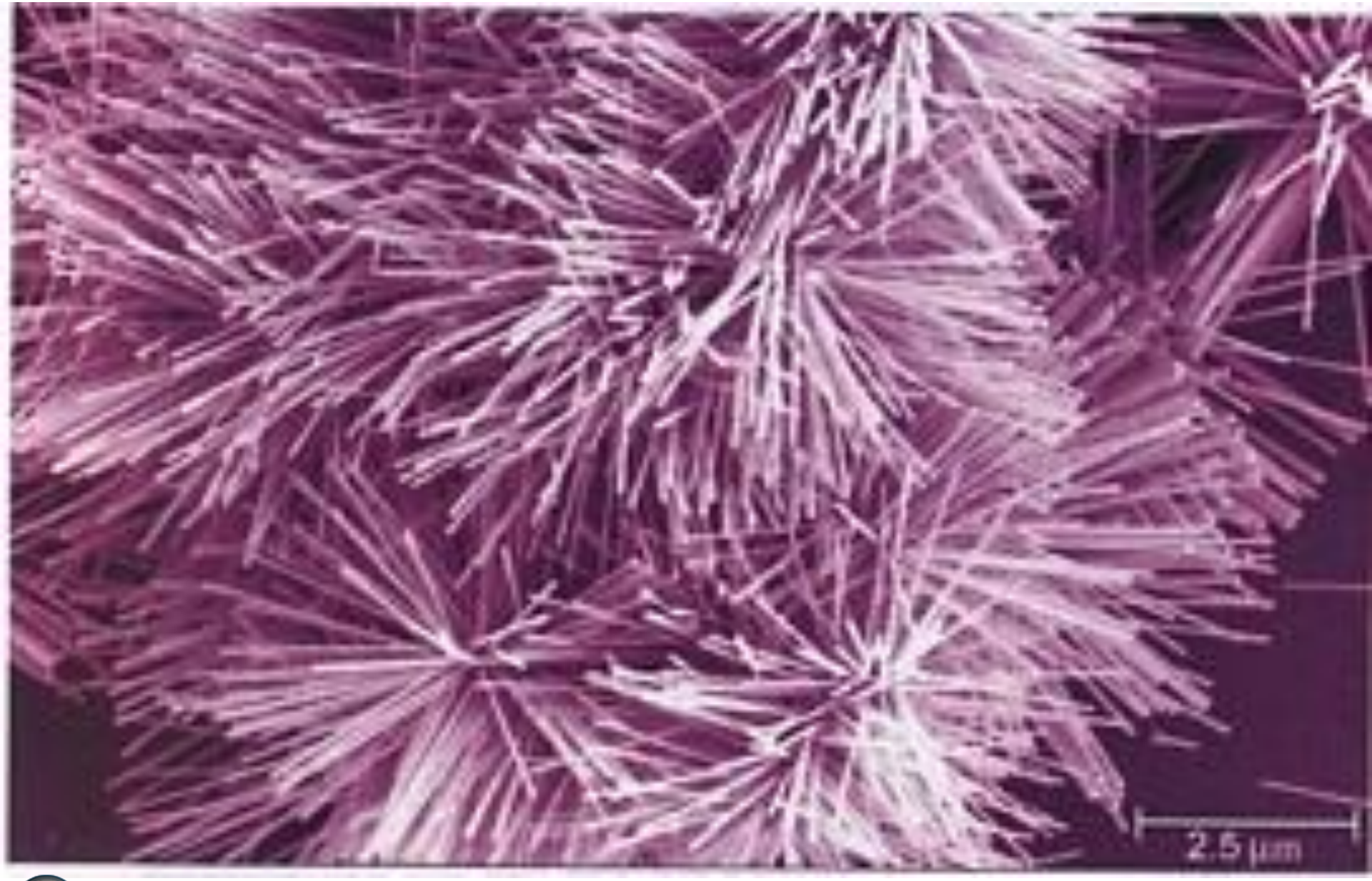
碳纳米管

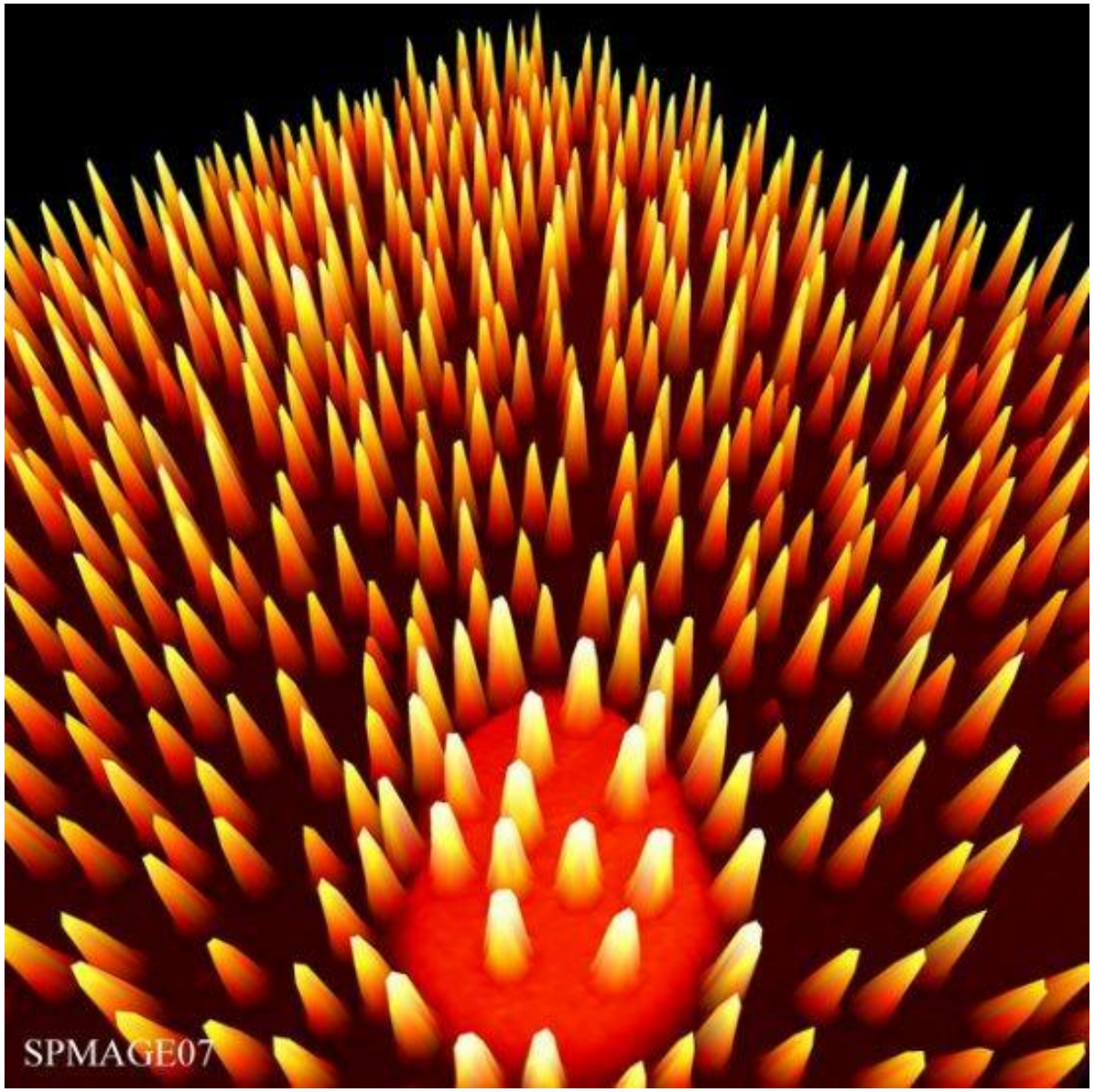


细胞分裂

埃波拉病毒

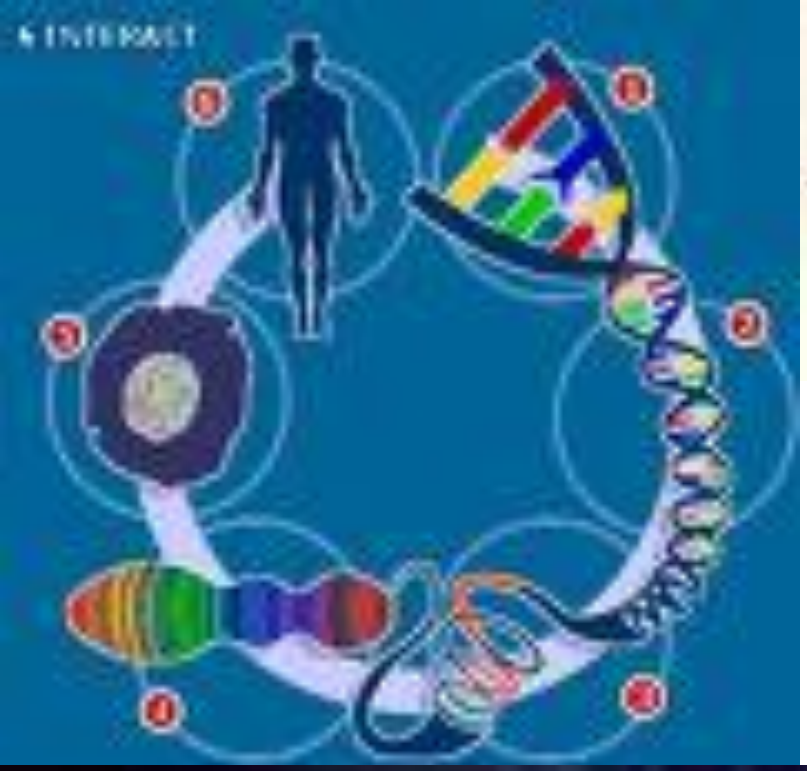
庆典礼花:用物理气相沉积(PVD)法制备的ZnO纳米棒的SEM图象



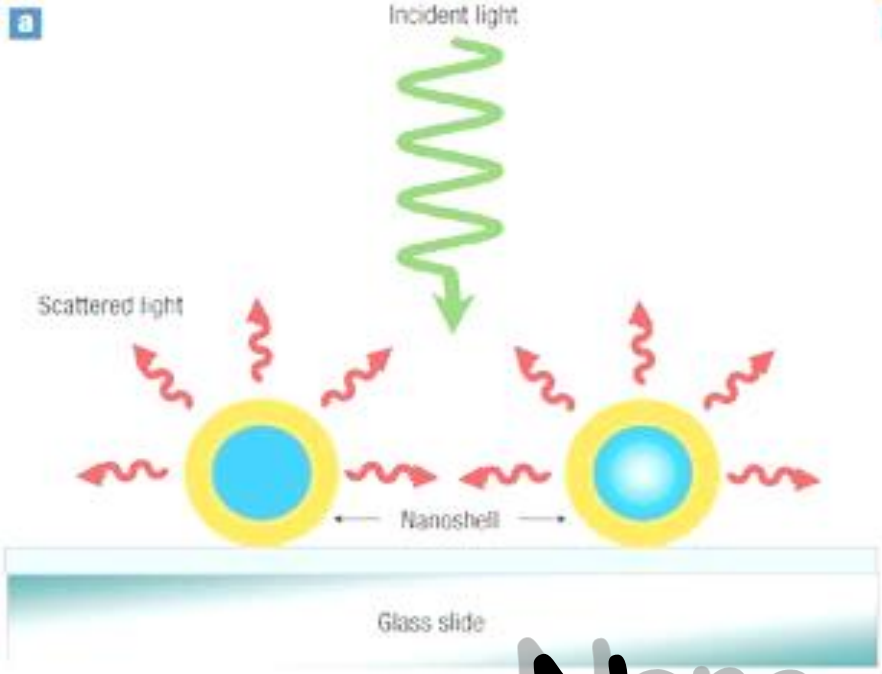


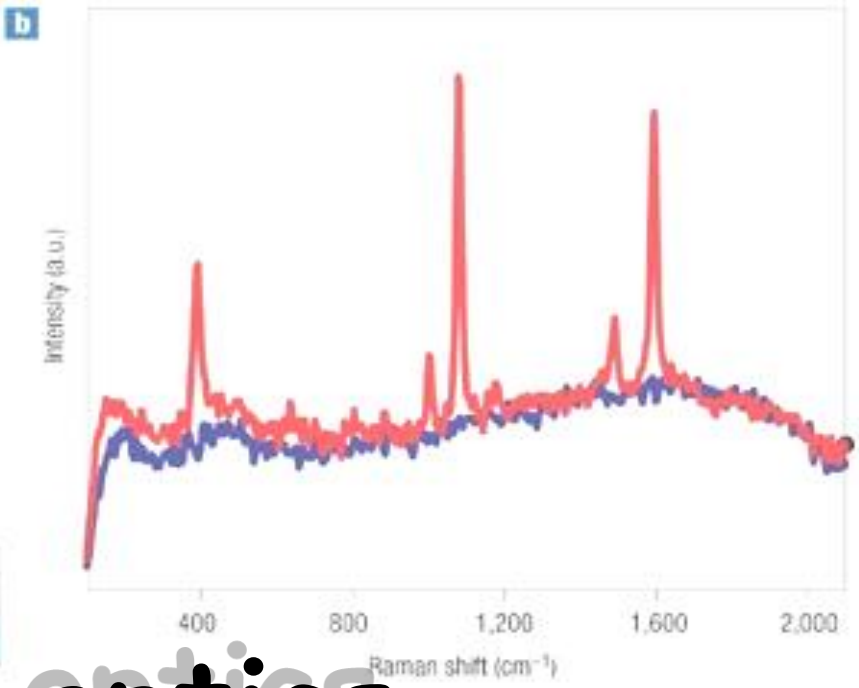
2007年最佳纳米级显微图像揭晓：量子森林

托斯藤-兹欧姆巴在德国实验室中捕获，它展示了锗硅量子点：高15nm，直径70nm。



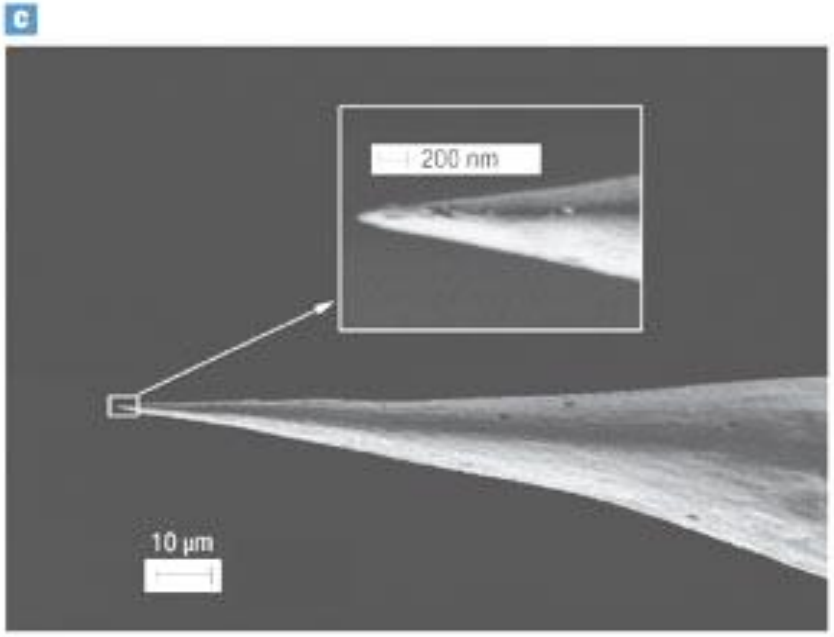
宇宙其大无
外其小无内

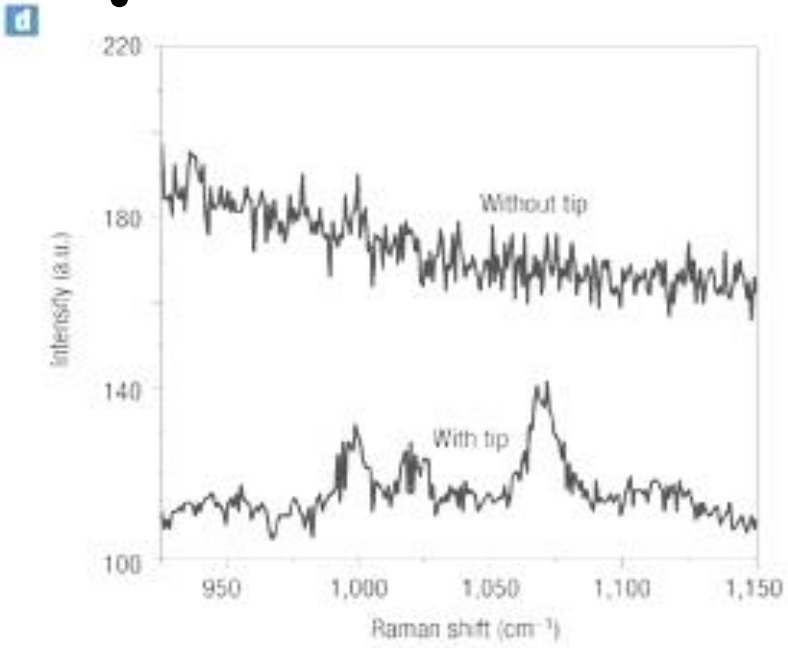




Nano-optics

Nano-optics



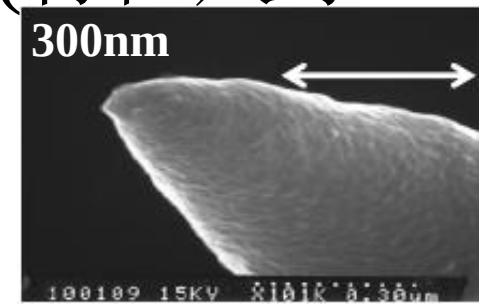


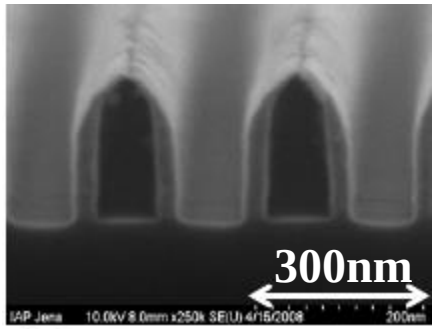
What is Nano-Optics?

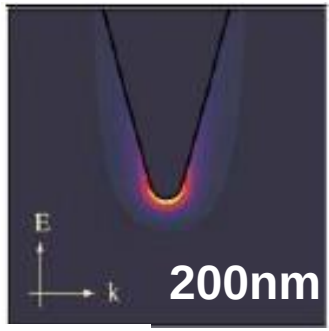
An example definition

光与纳米结构及物质之间的相互作用 (特征尺寸 <200 nm)

研究具有以下三个特征：



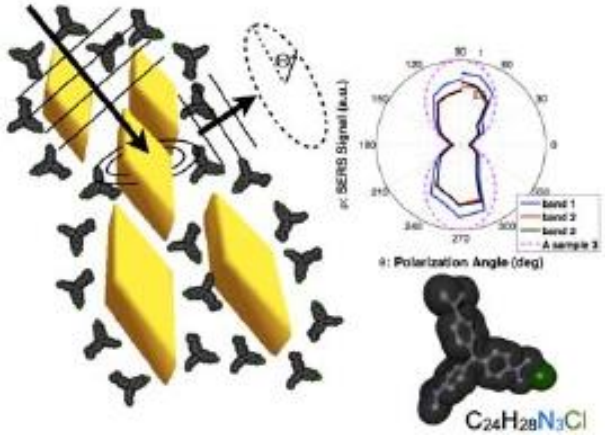




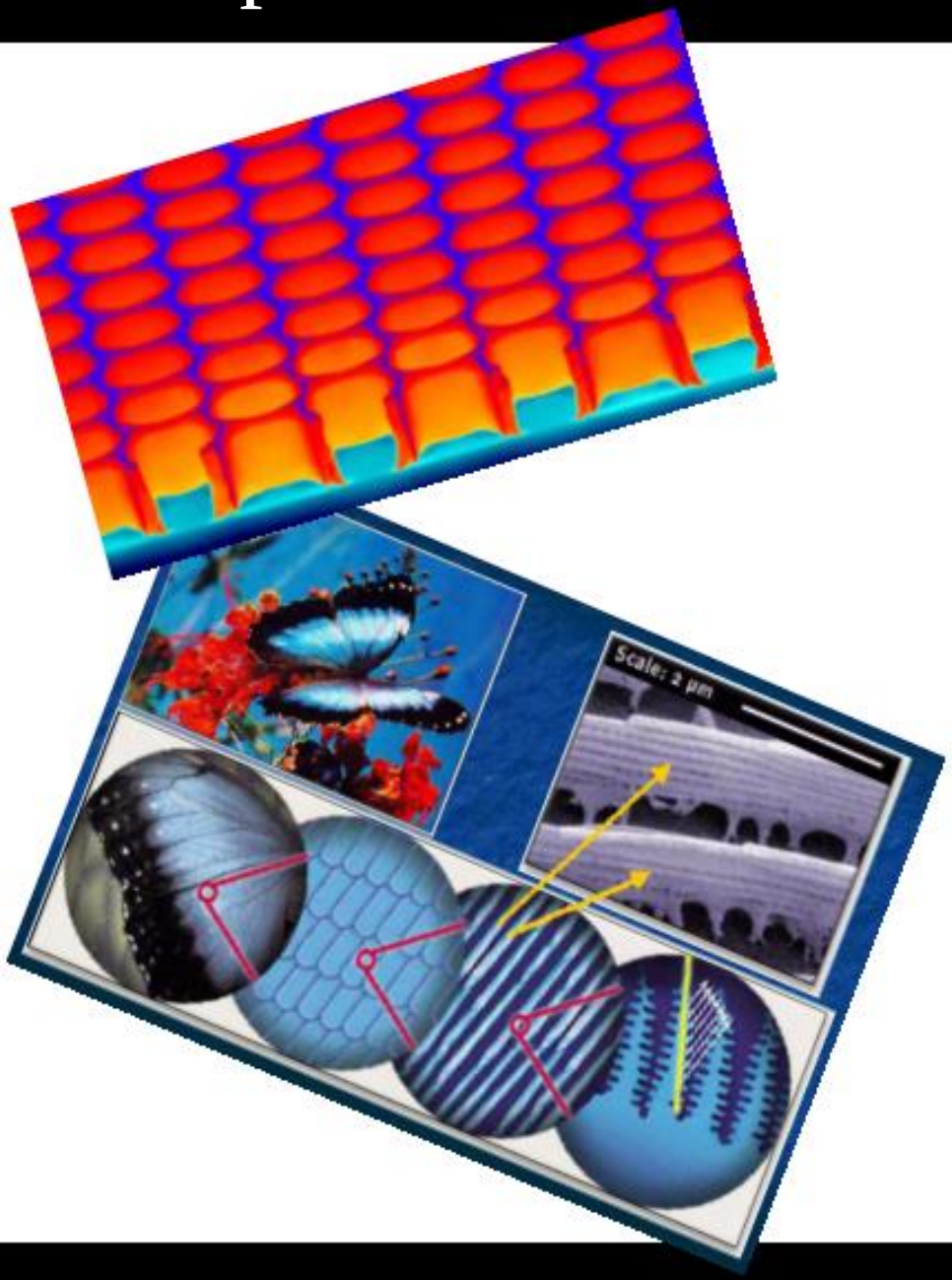
1. 将光定域在纳米尺度；

2. 将物质定域在纳米尺度；

3. 在纳米尺度内控制光子的过程。



Example: 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

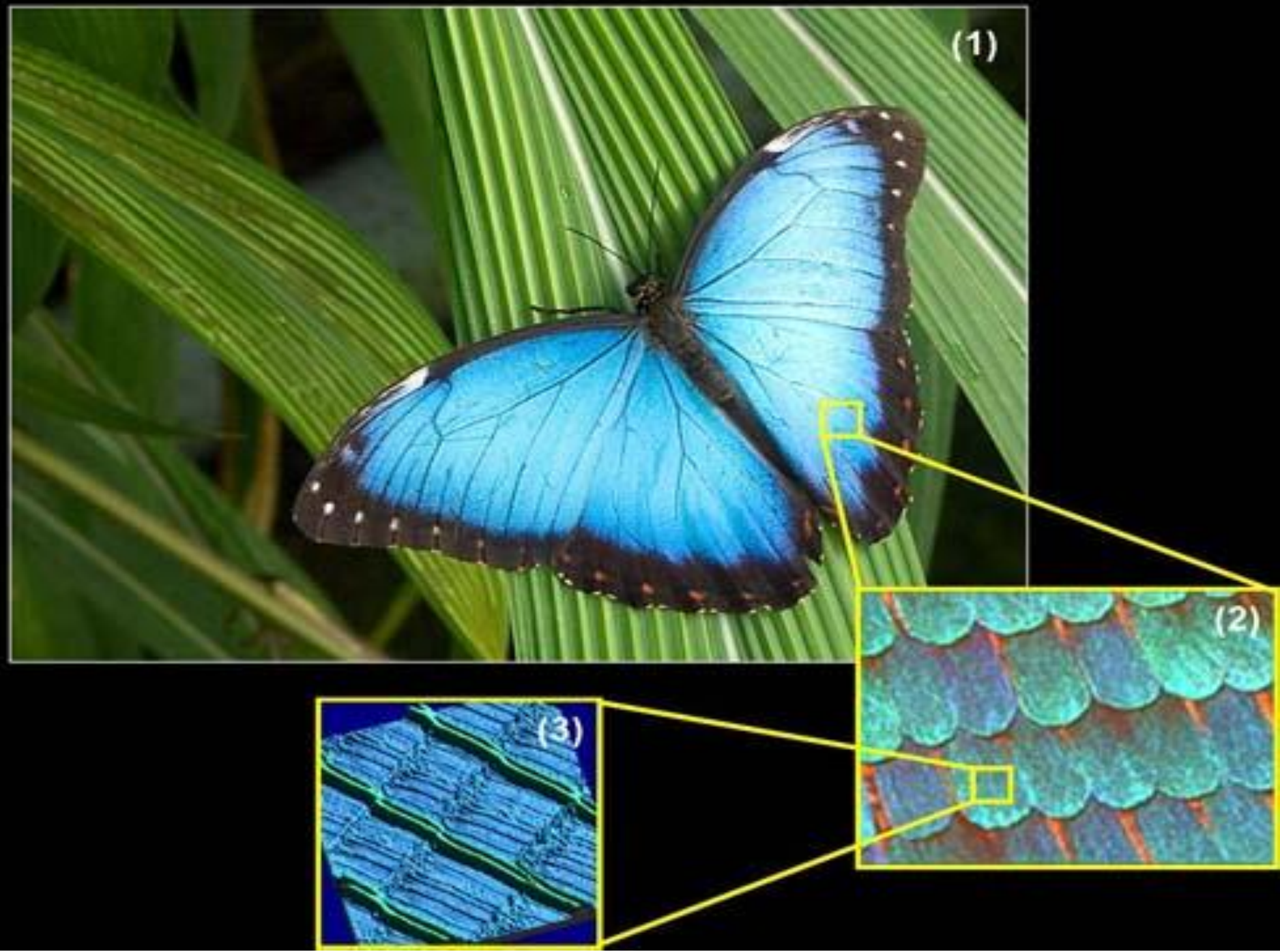
... typically are ***not*** well described using effective parameters ε, μ, n, Z

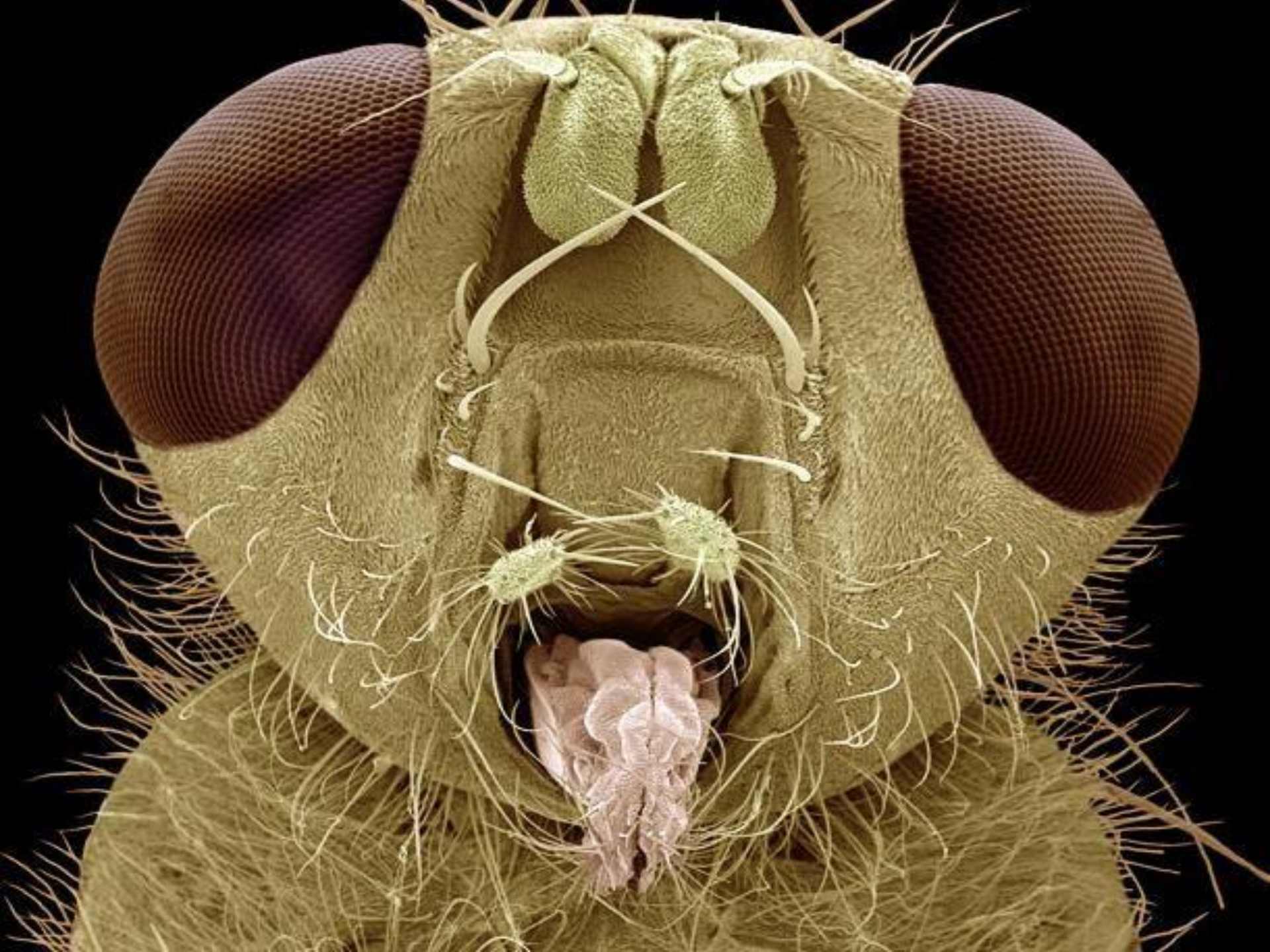
... often behave like but they are ***not*** true metamaterials

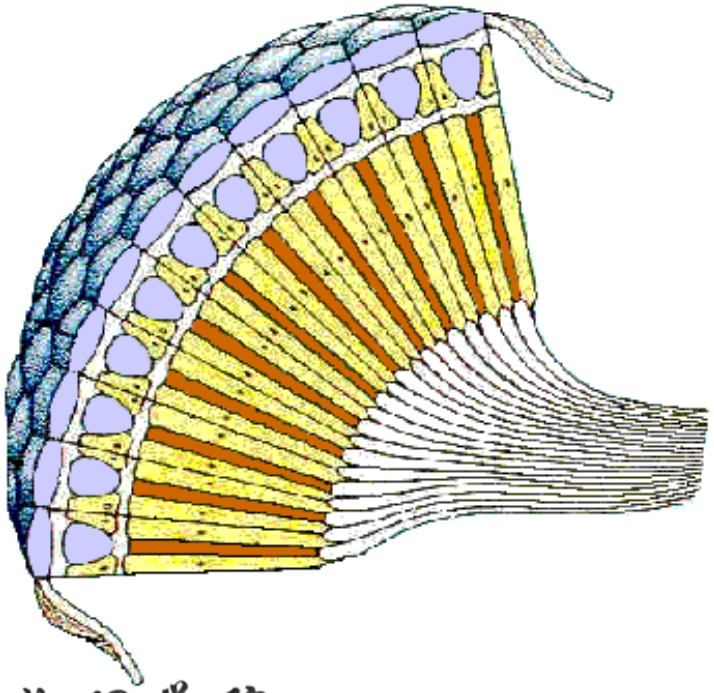
光子晶体（photonic crystal）

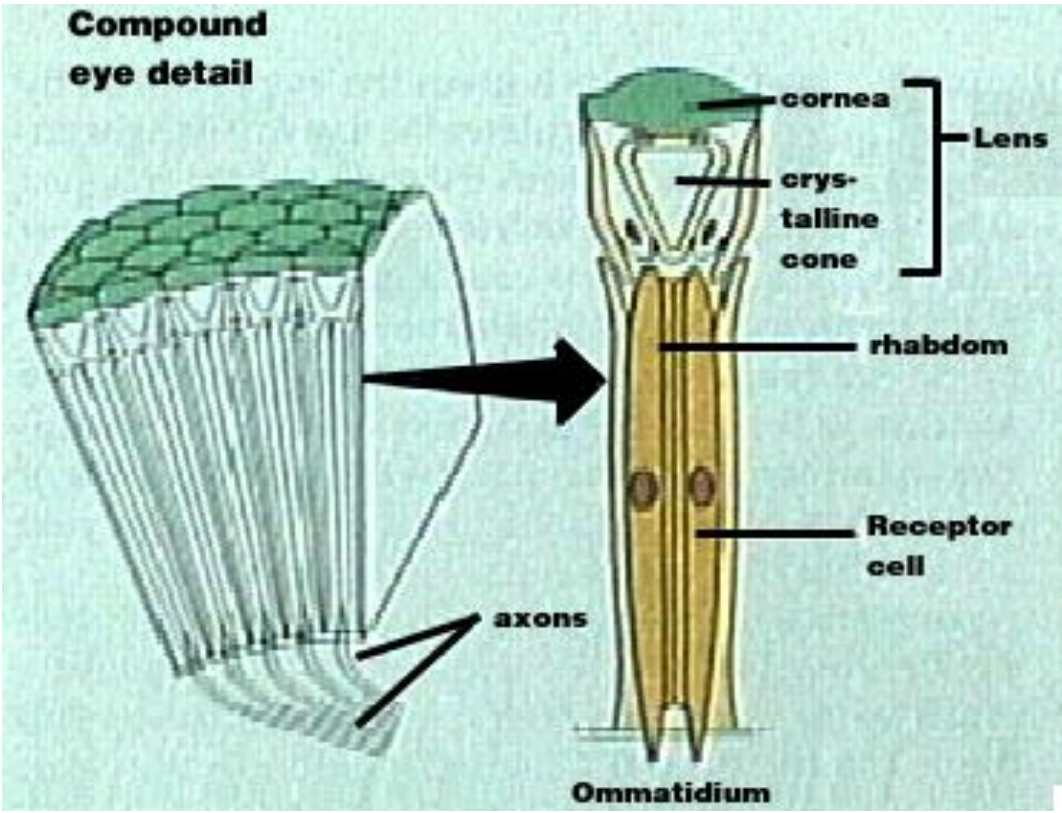
是一种介电常数随空间周期性变化的新型光学微结构材料。

从晶体结构来说，晶体内部的原子是周期性有序排列的，正是这种周期势场的存在，使得运动的电子受到周期势场的布拉格散射，从而形成能带结构，带与带之间可能存在带隙。

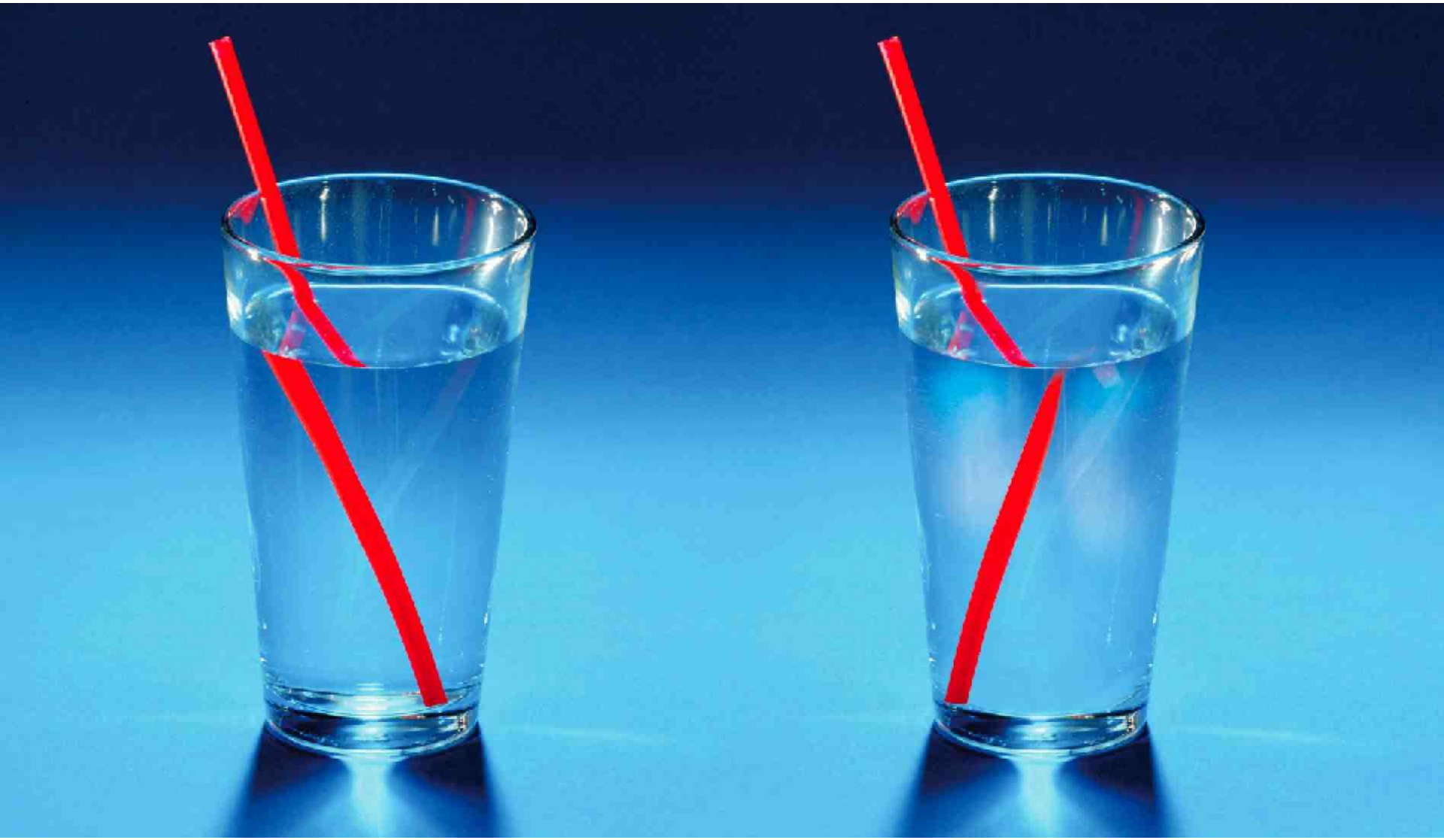

(1)
(2)
(3)



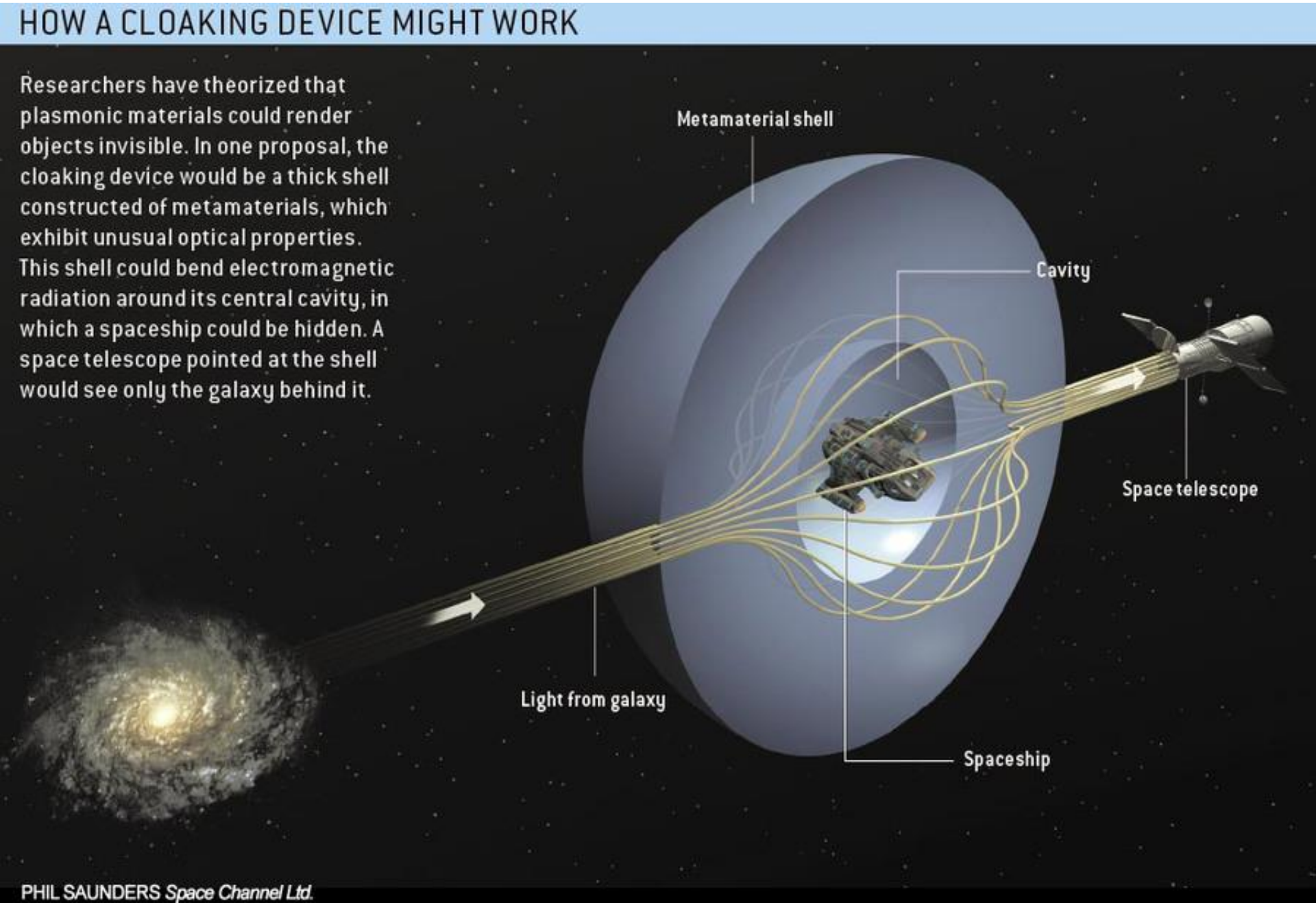




Any special with negative refraction?



Metamaterials for invisible effect



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

Roman Nanotechnology

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).

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

含有少量的金（ 40 ppm ）與銀（ 300 ppm ），粒徑約為70nm，金、銀比例約為3：7。

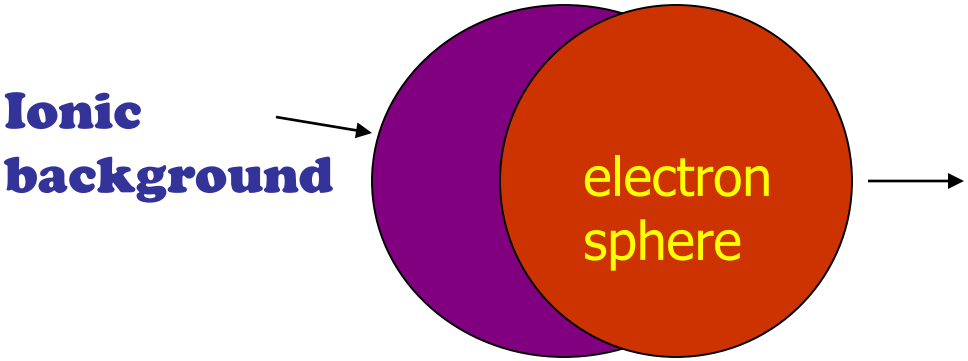
莱格拉斯：古希腊人名，他制定了古斯巴达律法。

The cup was "perhaps made in Alexandria" or Rome in about 290-325 AD.

“Labors of the Months” (Norwich, England, ca. 1480).
(The ruby color is probably due to embedded gold nanoparticles.)

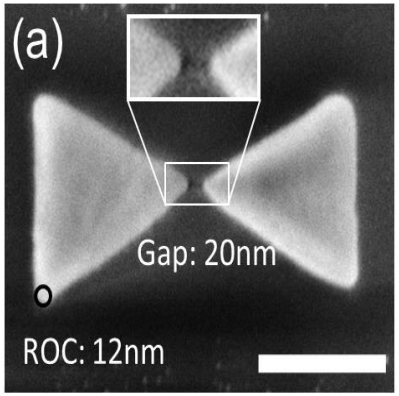
颜色来自于何处?
答案:“表面等离激元”

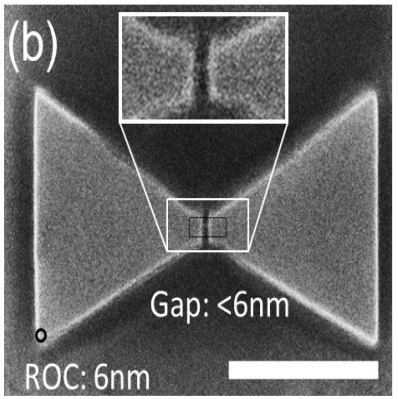
- 表面等离激元是金纳米颗粒表面电子云的自然震荡;
- 振荡频率取决于介电常数和纳米颗粒的形状及尺寸

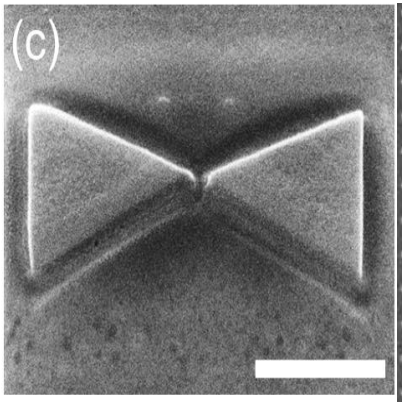


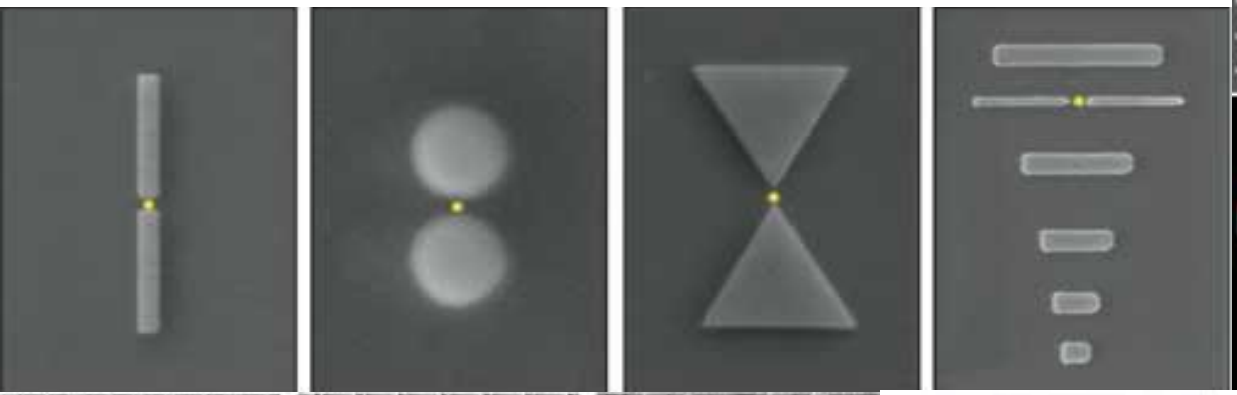
电子云以SP的震荡频率共振; 离子提供所需的震荡的恢复力。

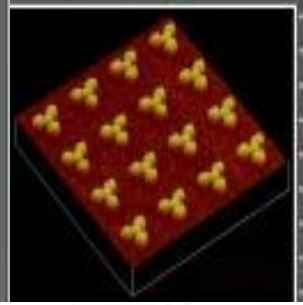
Concept of structure design in nano-optics

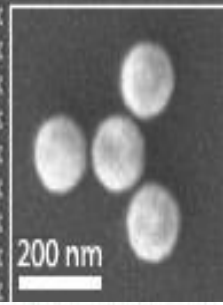


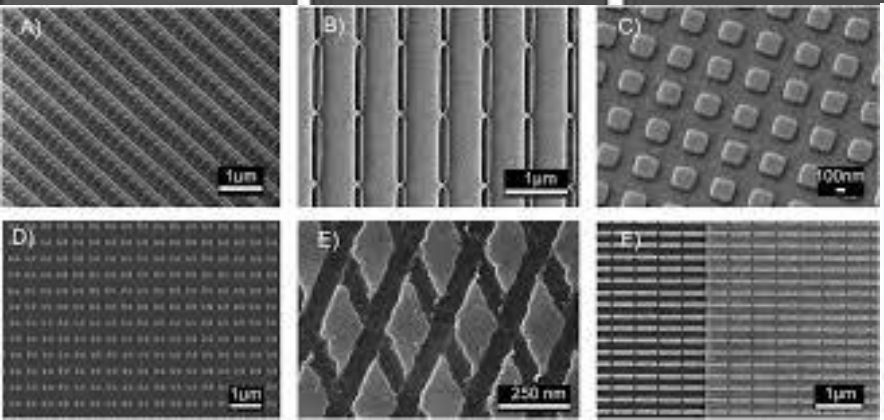


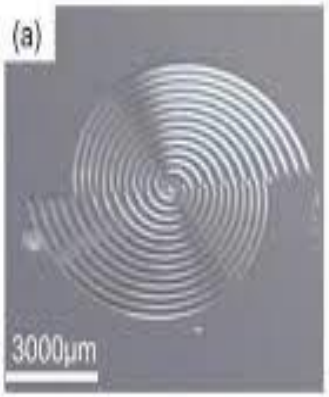


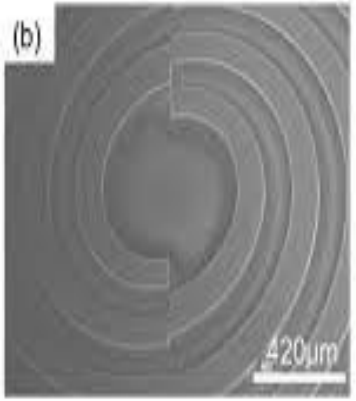






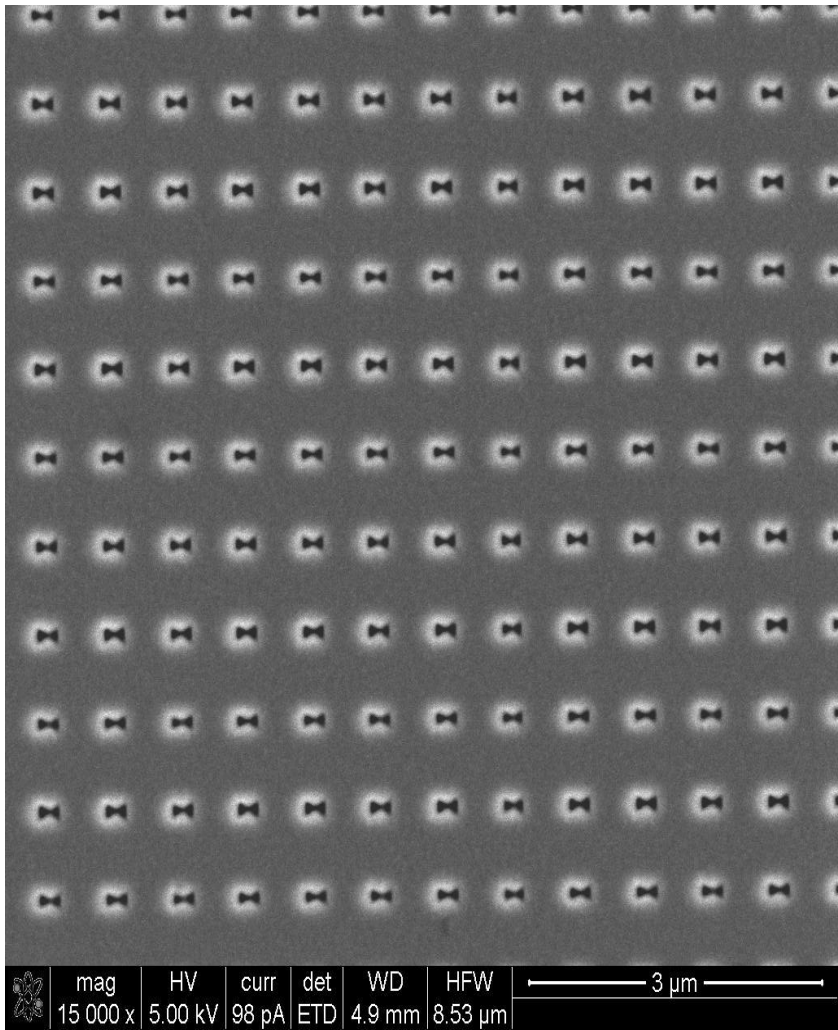







HSBC

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

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