INSTITUTO SUPERIOR TÉCNICO

DEQB

MATERIAIS NANOESTRUTURADOS E NANOTECNOLOGIAS

NANOTECHNOLOGY: AN OVERVIEW

NANOMATERIALS IN ART

NANOMATERIALS IN NATURE

KEYWORDS

NANOSCALE

NANOSCIENCE

NANOTECHNOLOGY

WHAT IS NANOTECHNOLOGY?

NANOTECHNOLOGY IS ALL ABOUT THE STUDY AND DEVELOPMENT OF NEW FUNCTIONAL MATERIALS AND DEVICES IN A NANOMETRIC SCALE

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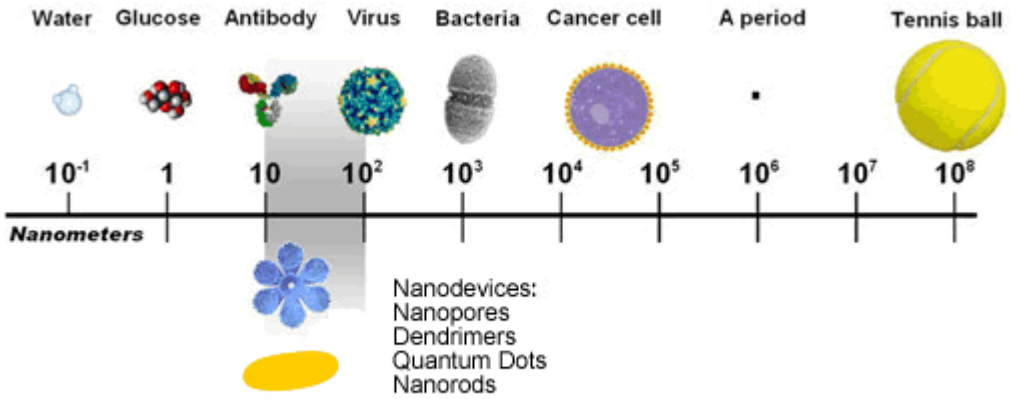
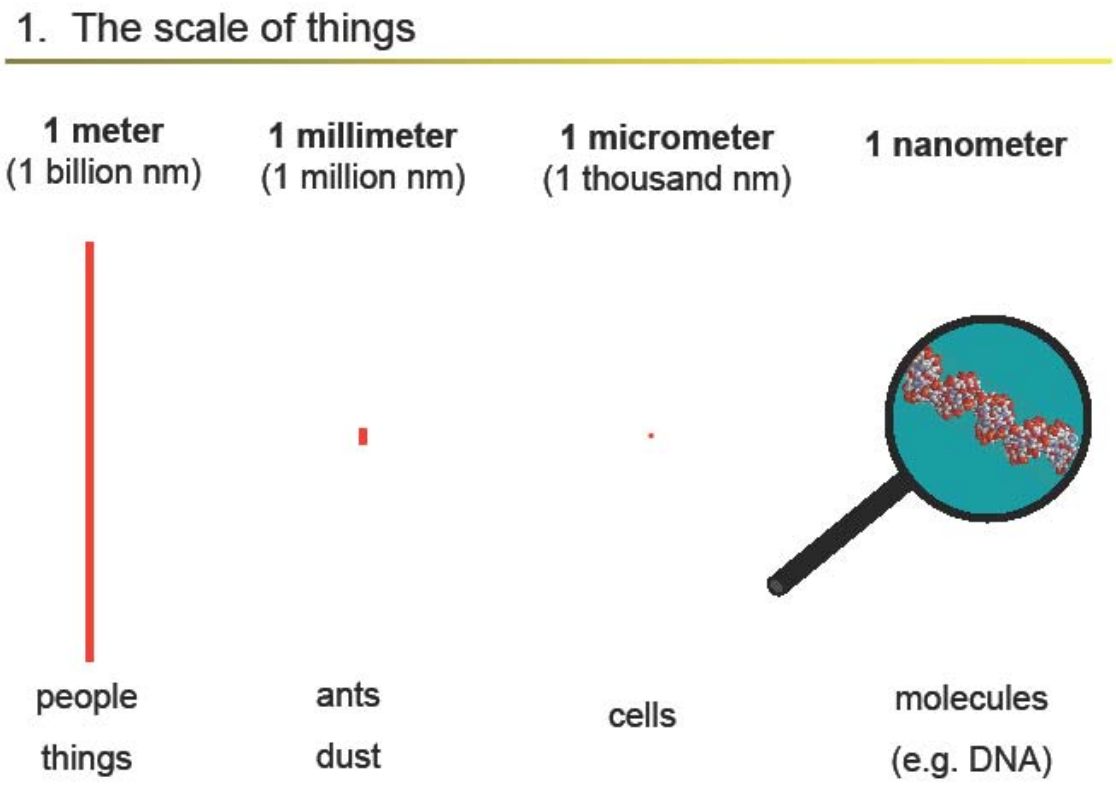
A NANOOBJECT HAS AT LEAST ONE CRITICAL DIMENSION BELOW 100 NM

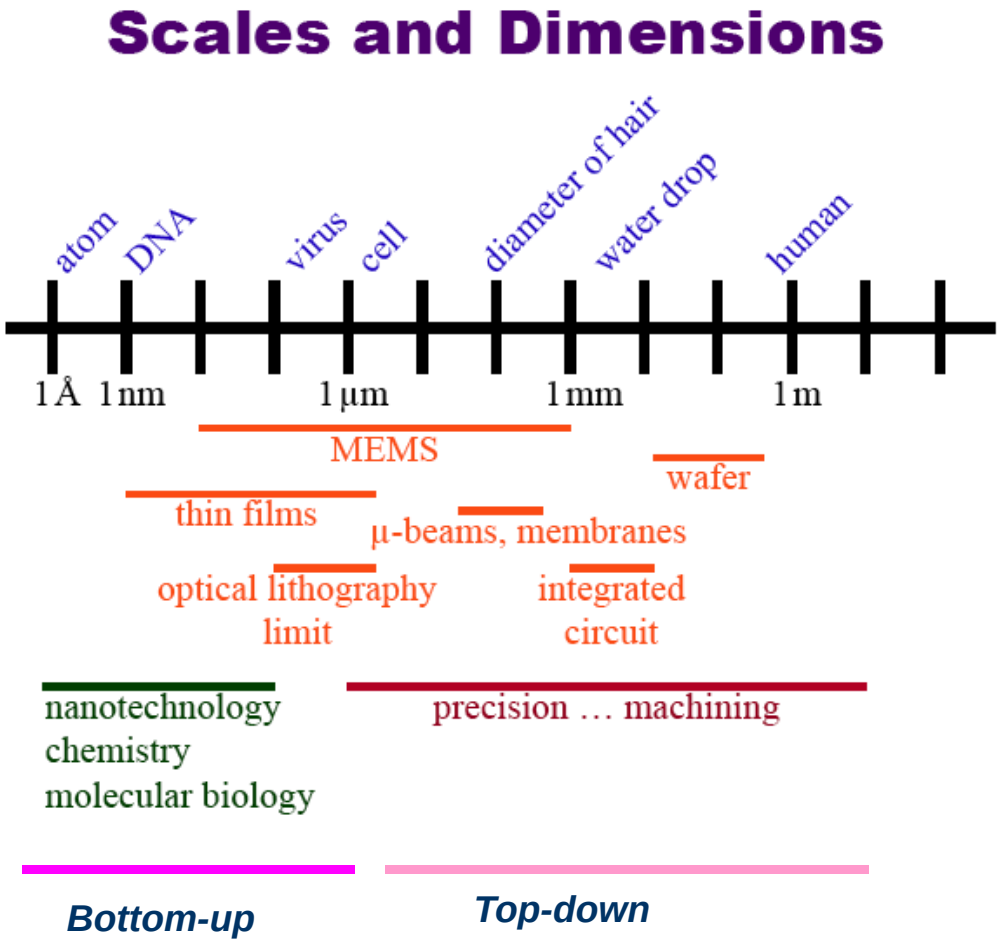
NANOSCALE


Water
Glucose
Antibody
Virus
Bacteria
Cancer cell
A period
Tennis ball
10^{-1}
1
10
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
10^{8}
Nanometers
Nanodevices:
Nanopores
Dendrimers
Quantum Dots
Nanorods

NANOSCALE


1. The scale of things
1 meter
(1 billion nm)
1 millimeter
(1 million nm)
1 micrometer
(1 thousand nm)
1 nanometer
people
things
ants
dust
cells
molecules
(e.g. DNA)

NANOSCALE


Scales and Dimensions
atom
DNA
virus
cell
diameter of hair
water drop
human
1 Å
1 nm
1 µm
1 mm
1 m
MEMS
wafer
thin films
µ-beams, membranes
optical lithography limit
integrated circuit
nanotechnology
chemistry
molecular biology
precision … machining
Bottom-up
Top-down

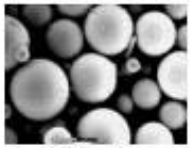
The Scale of Things – Nanometers and More

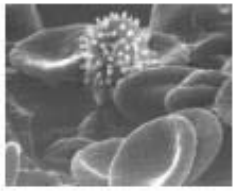
Things Natural

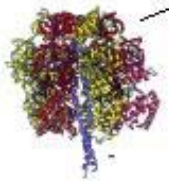

Dust mite
200 µm

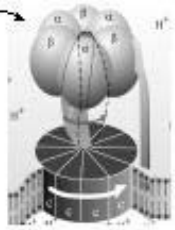

Ant
~ 5 mm

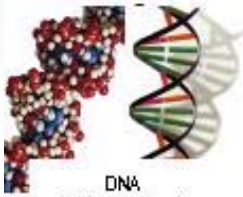

Human hair
~ 60-120 µm wide

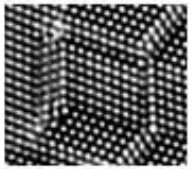

Fly ash
~ 10-20 µm

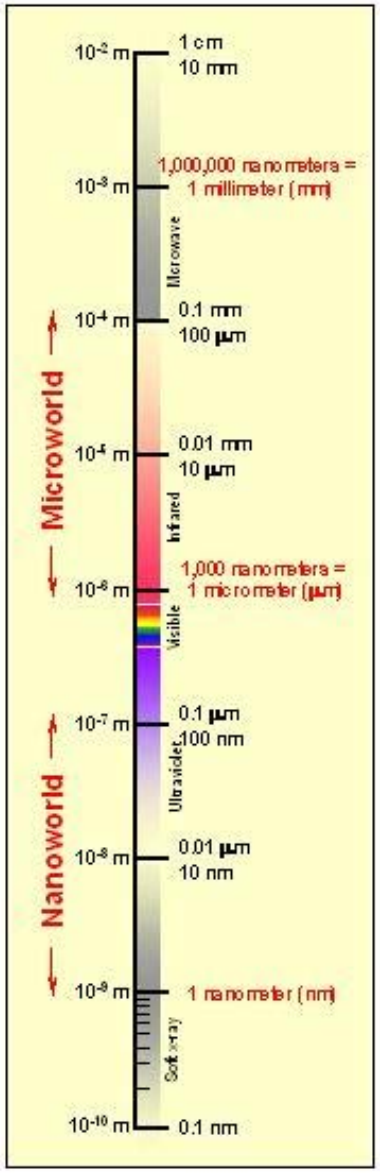

Red blood cells with white cell
~ 2-5 µm


~10 nm diameter

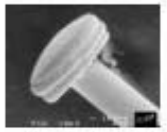

ATPsynthase

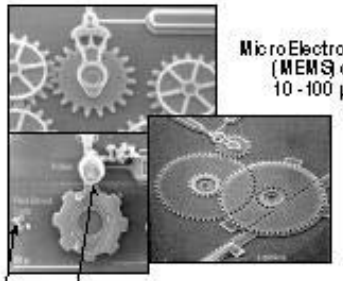

DNA
~2-12 nm diameter


Atoms of silicon
spacing ~tenths of nm

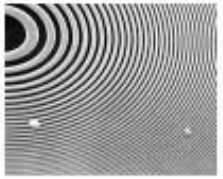


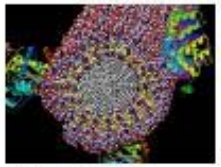
Things Manmade

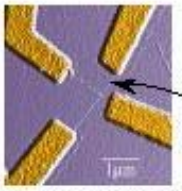

Head of a pin
1-2 mm

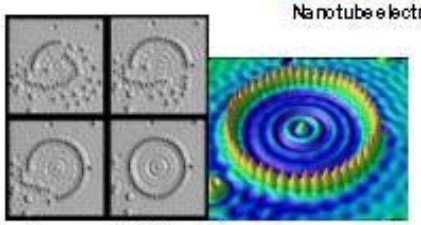

MicroElectroMechanical (MEMS) devices
10 -100 µm wide

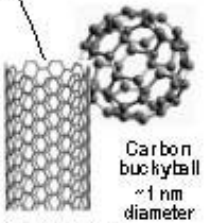
Pollen grain
Red blood cells


Zone plate x-ray "lens"
Outer ring spacing ~35 nm


Self-assembled,
Nature-inspired structure
Many 10s of nm

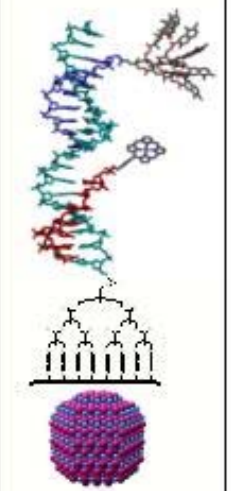

Nanotube electrode


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.

There's plenty of room at the bottom

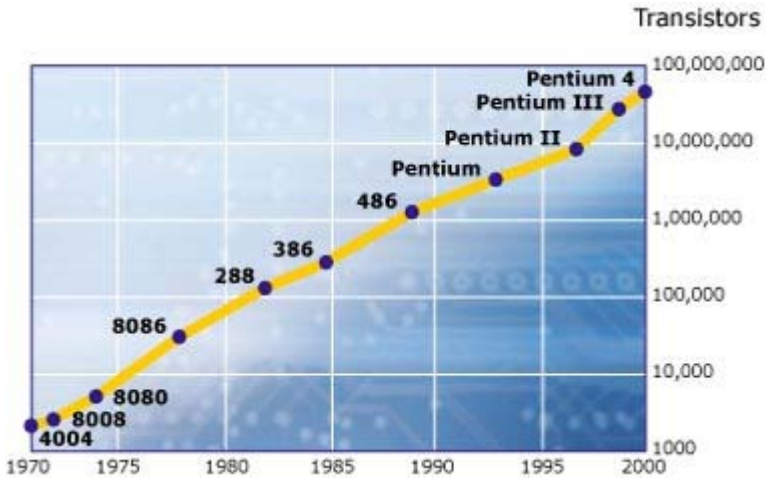
"What would happen if we could arrange the atoms one by one the way we want them?"
Richard P. Feynman, 1960

Photo courtesy of The Archives, California Institute of Technology.

SEMICONDUCTOR INDUSTRY: CONSTANTLY CONCERN ABOUT MAKING DEVICES SMALLER

MEMS MicroElectroMechanic Device – car industry, air bag control

MOORE' S LAW


Transistors
100,000,000
10,000,000
1,000,000
100,000
10,000
1000
Pentium 4
Pentium III
Pentium II
Pentium
486
386
288
8086
8080
8008
4004
1970
1975
1980
1985
1990
1995
2000

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NANOMEDICINE: AN UPCOMING NEW COSTUMER

NANOROBOTS – therapy and diagnosis (theragnosis)

TO SUMMARIZE:

NANOTECHNOLOGY COVERS MANY FIELDS, SUCH AS BIOLOGY, CHEMISTRY, PHYSICS, MATERIALS SCIENCE, MECHANICAL AND ELECTRONIC ENGINEERING, MEDICINE

NANOTECHNOLOGY DRAWS THE LINE BETWEEN MACRO (AND MICRO) AND THE ATOMS

NANOTECHNOLOGY IS THE ULTIMATE SCIENTIFIC QUEST WHERE EVERY STRUCTURE (OR PROPERTY) IS DESIGN AT A MOLECULAR LEVEL

NANOMATERIALS IN ART: EVEN THOUGH NANO HAVE BEEN AROUND SINCE THE ANCIENT ROME, THERE MAKING WAS NOT INTENTIONAL

Lycurgus cup, 4th century AD

NANOMATERIALS IN ART: EVEN THOUGH NANO HAVE BEEN AROUND SINCE THE ANCIENT ROME, THERE MAKING WAS NOT INTENTIONAL

Roman gold-glass, 4th century AD

Syrian gold-glass, 9th-10th century AD

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Royal Gold Cup, 1370-1380 AD

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Ceramic luster, Valencia, 1470-1500

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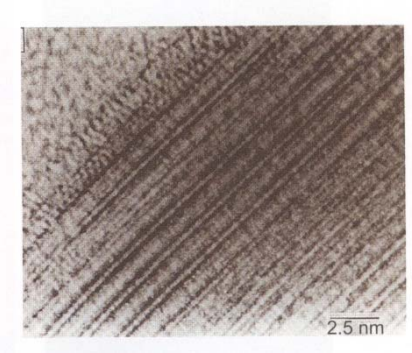
Cathedral Saint-Gatien de Tours

Cathedral Chartres

NANOMATERIALS IN ART: EVEN THOUGH NANO HAVE BEEN AROUND SINCE THE ANCIENT ROME, THERE MAKING WAS NOT INTENTIONAL

Maia blue, Cacaxtla



SEM image palygorskite

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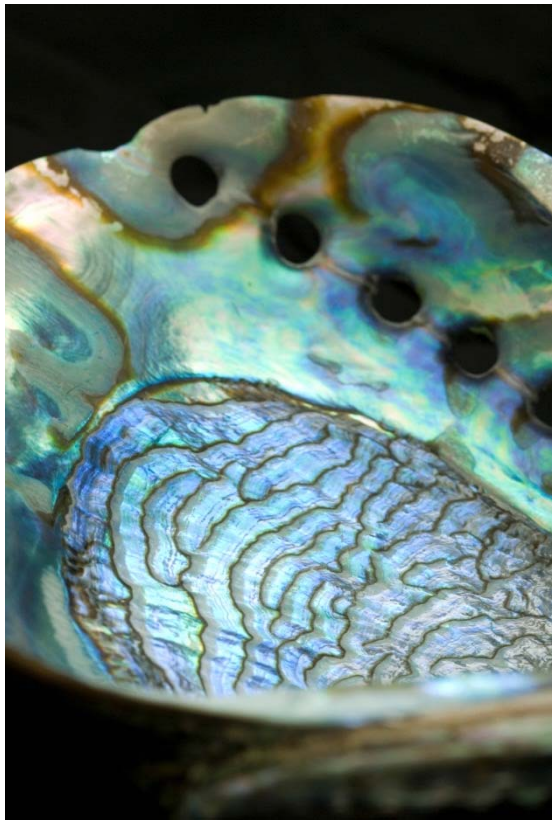
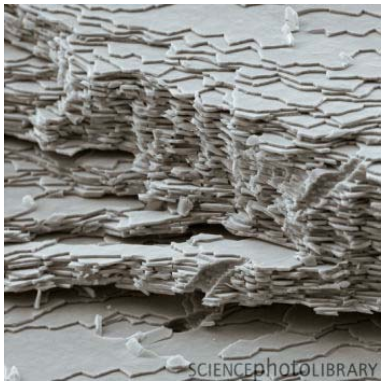
Buon fresco, Buonconsiglio, Trento

NANOMATERIALS IN NATURE: THE FIRST SIGNS OF LIVE ON EARTH OCCURRED 3.8 BILIONS OF YEARS AGO. WE JUST STARTED TRYING TO MIMIC SOME OF THE NATURAL NANOSTRUCTURES NOW.



Abalone



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Mussel

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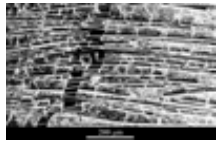
Spider web



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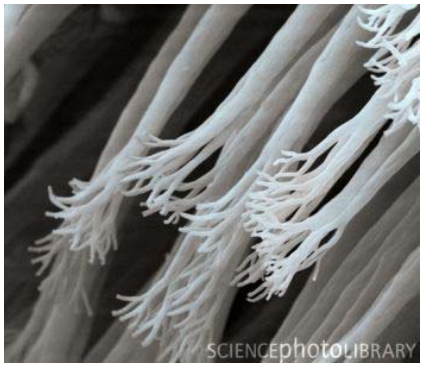

The base of gecko' feet is covered by half a million keratin hairs, 200 nm in diameter.
Each hair produces a force of 10^{-7}N
Half a million of hairs, produce a strong adhesive force of 10 N /cm^2

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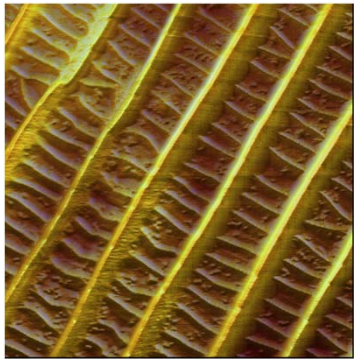
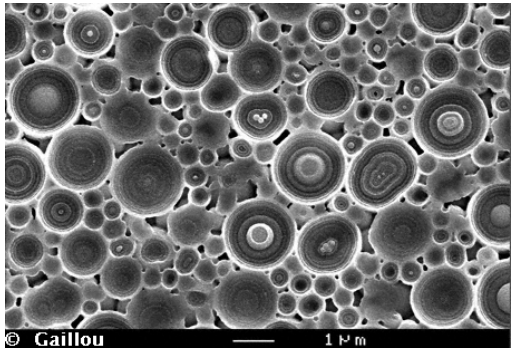
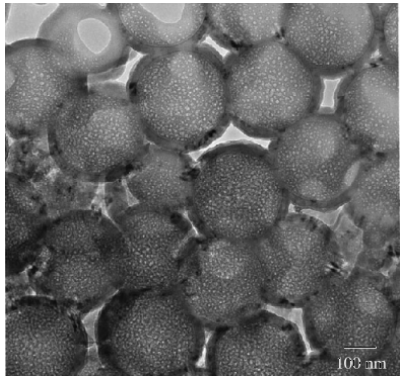


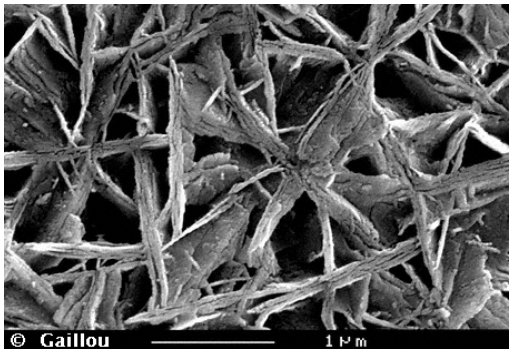
The nanoarchitecture of butterfly wings, which are iridescent, are a great inspiration for many photonic crystals.
A photonic crystal is a dielectric material with periodicity in its dielectric constant (or refractive index). Due to Bragg's reflection light transmission through the material is not possible in a wavelength interval – known as stopband.

NANOMATERIALS IN NATURE: THE FIRST SIGNS OF LIVE ON EARTH OCCURRED 3.8 BILIONS OF YEARS AGO. WE JUST STARTED TRYING TO MIMIC SOME OF THE NATURAL NANOSTRUCTURES NOW.

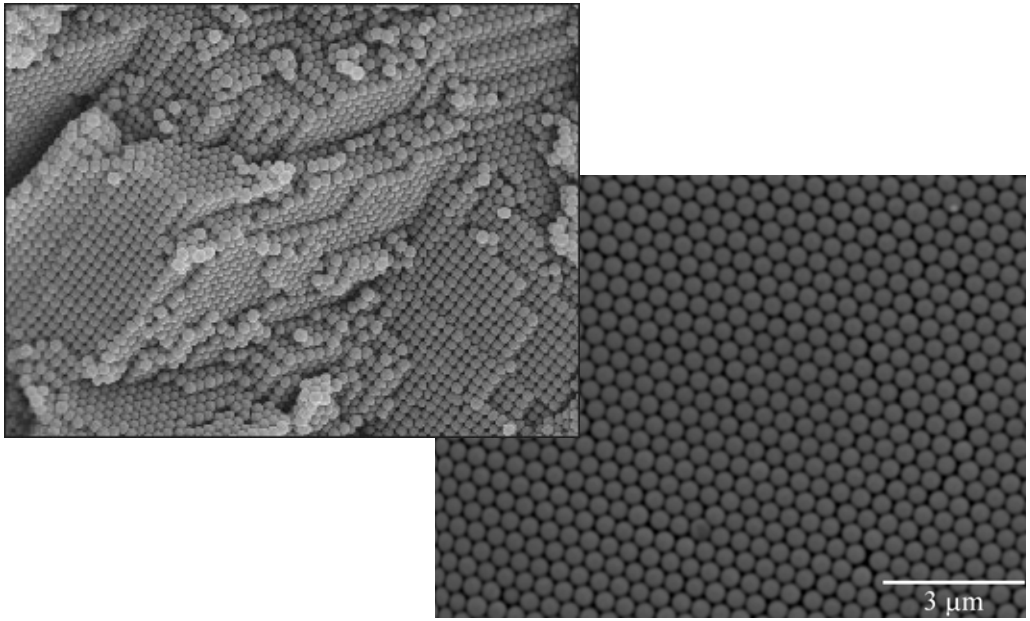
The nanoarchitecture natural opals, which are iridescent, are also a great inspiration for many photonic crystals.

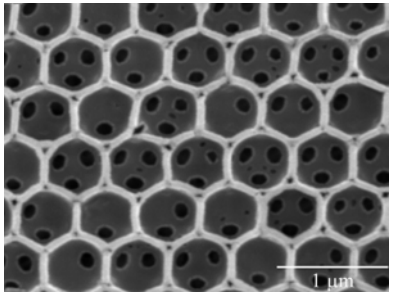






NANOMATERIALS IN NATURE: THE FIRST SIGNS OF LIVE ON EARTH OCCURRED 3.8 BILIONS OF YEARS AGO. WE JUST STARTED TRYING TO MIMIC SOME OF THE NATURAL NANOSTRUCTURES NOW.





Artificial opals: (a) and (b) resulting from self-assembly of PS nanoparticles and (c) inverse opals, resulting from heat or chemical removing of PS spheres.

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The water skater is able to land or slide over the surface of water. Its legs are lined with very fine hairs which end in nanonotches, making them superhydrophobic.

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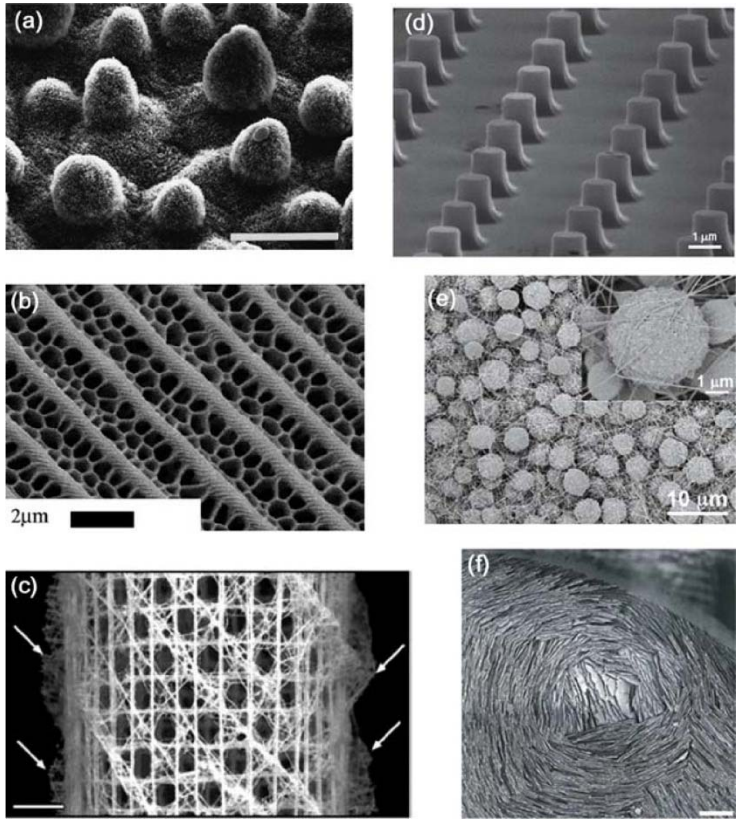
Several man-made surfaces have been developed using nanoarchitecture at different levels to produce superhydrophobia in the final product.



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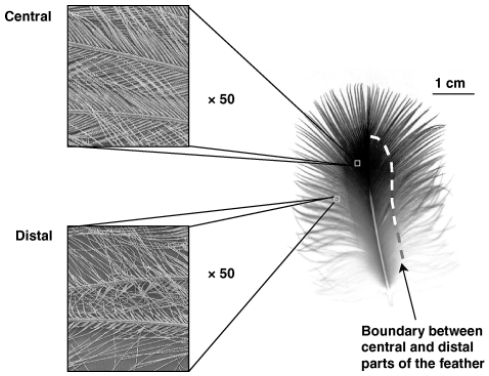

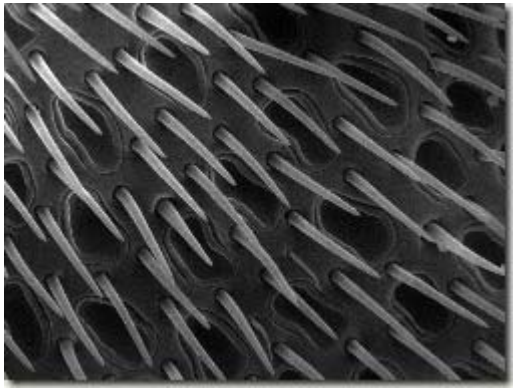

The feathers of several birds reveal a nanostructure of nanospines and nanobarbs, which are responsable for superhydrophobia.