Nano Innovation 2020
Rome, 15-18 September
Conference & Exhibition

Le nanotecnologie e i nanomateriali

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UNIVERSITÀ DI PARMA

imem

Rome, 15 - 18 September 2020
Next NanoInnovation Conference

Nanotechnology 101

"Nanoscience is the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale"[1].

Outline

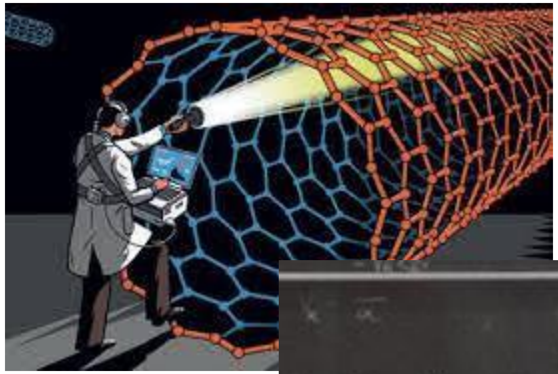
1) Quantum effects 101

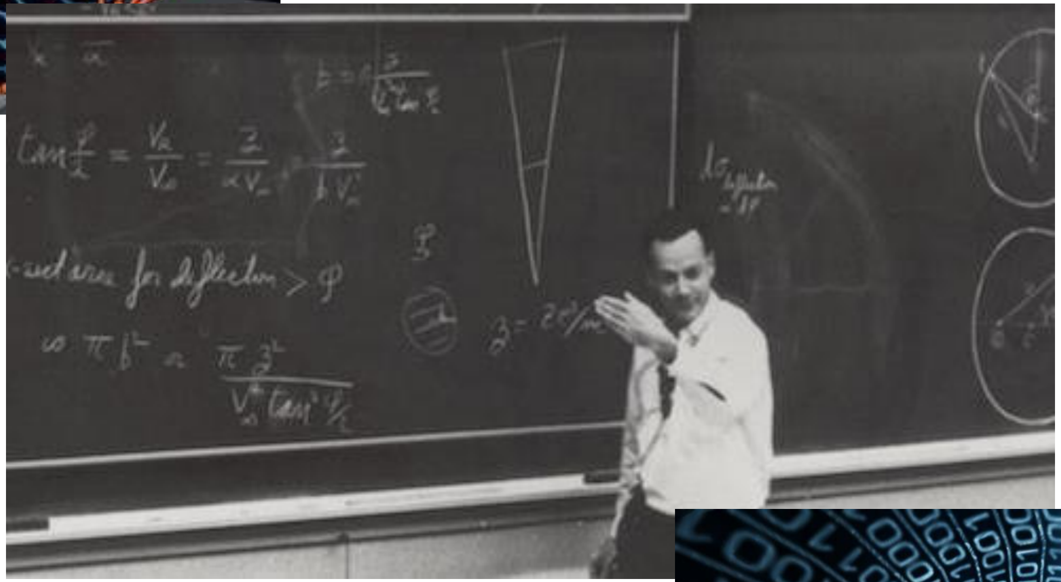
2) Historical perspective

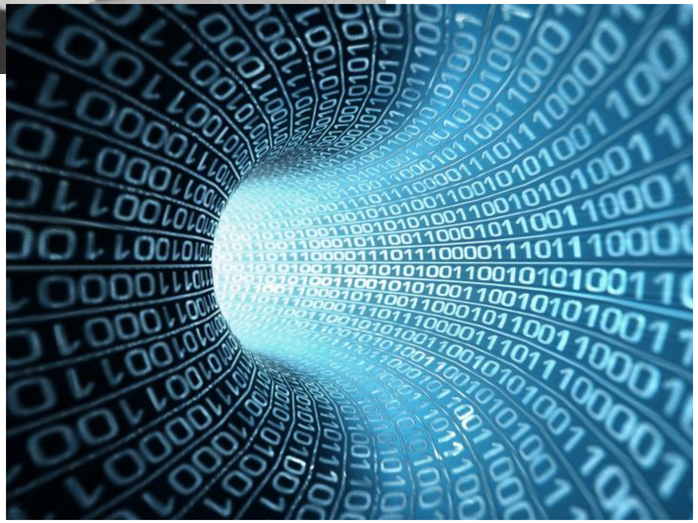
3) Mimicking the Nature

4) Manufacturing and characterization of Nano-devices

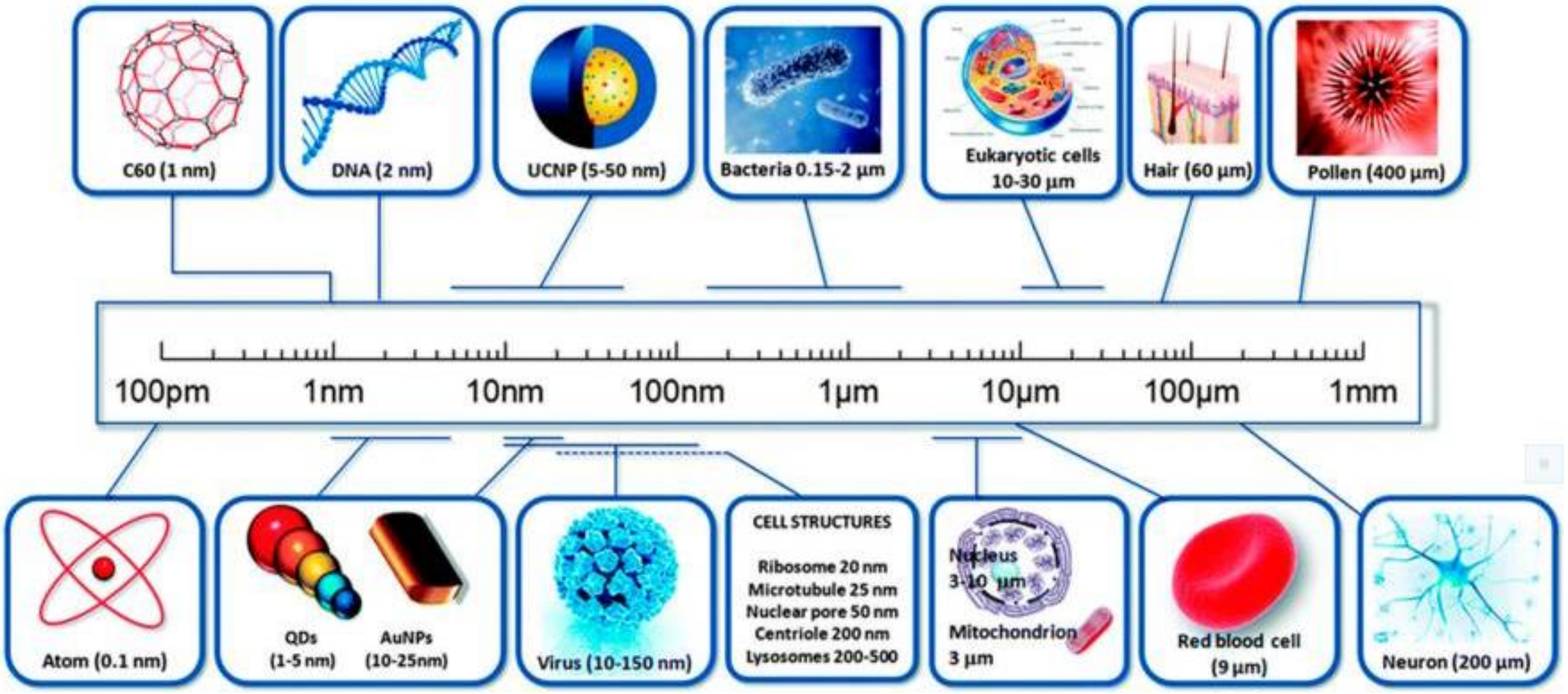
5) Applications



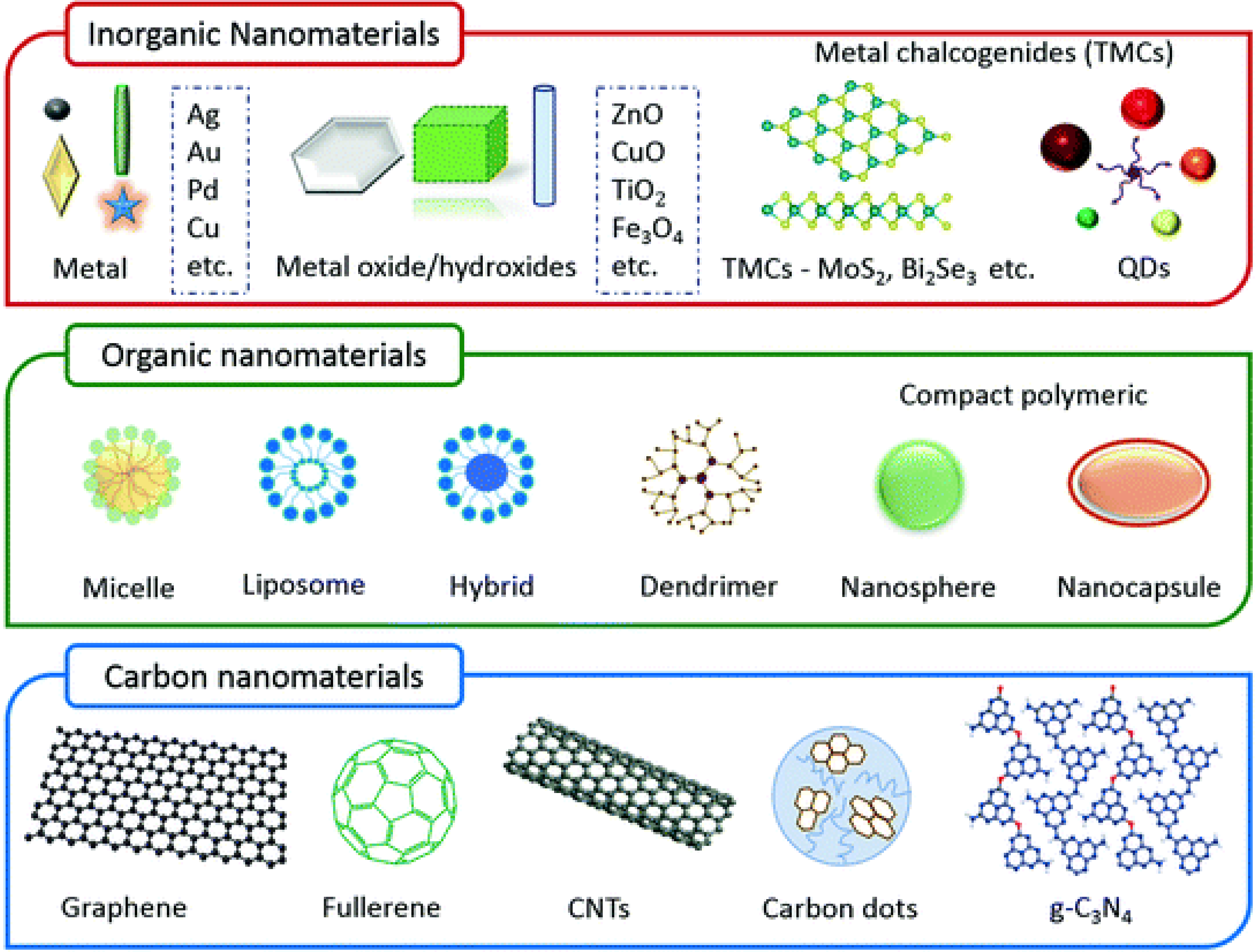




A matter of scale

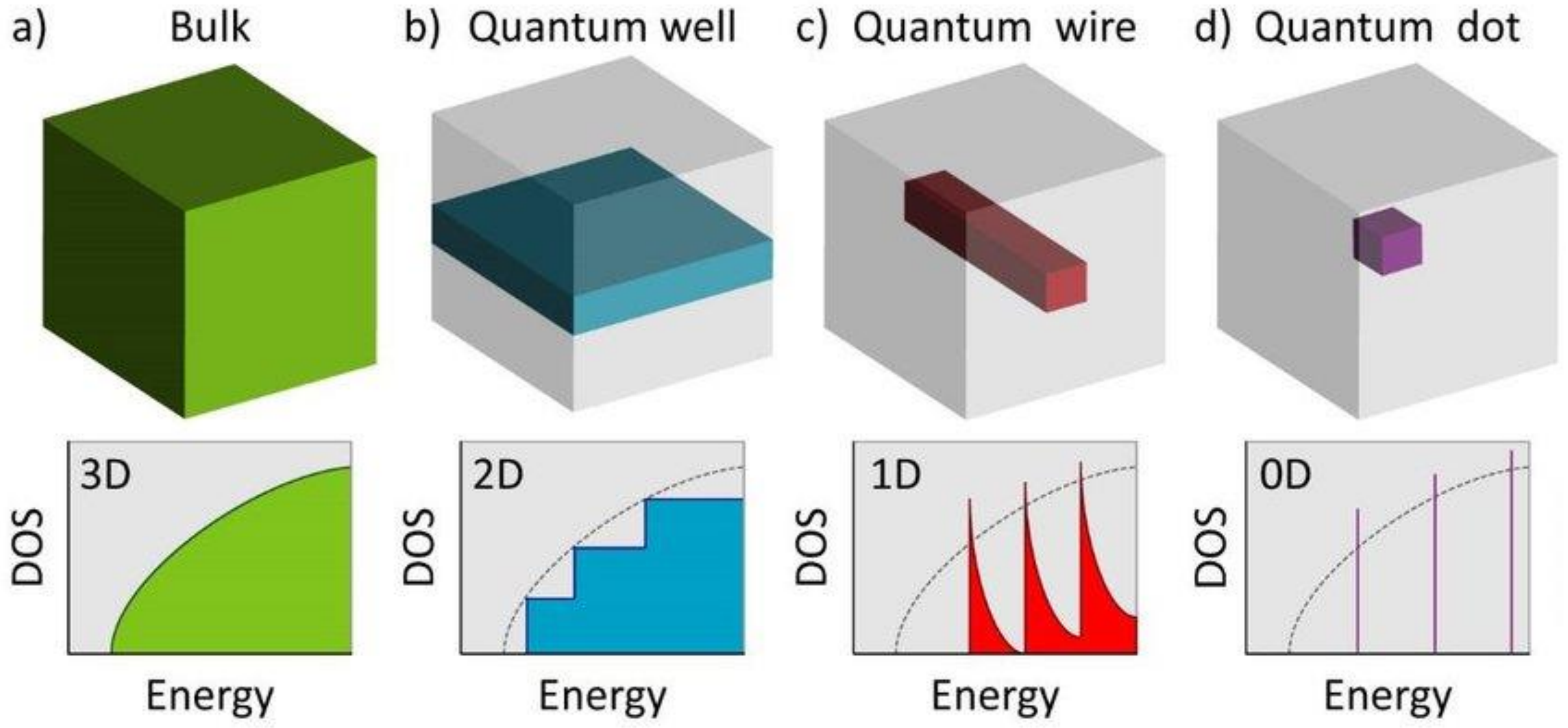


"Nanoscience is the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale"[1].



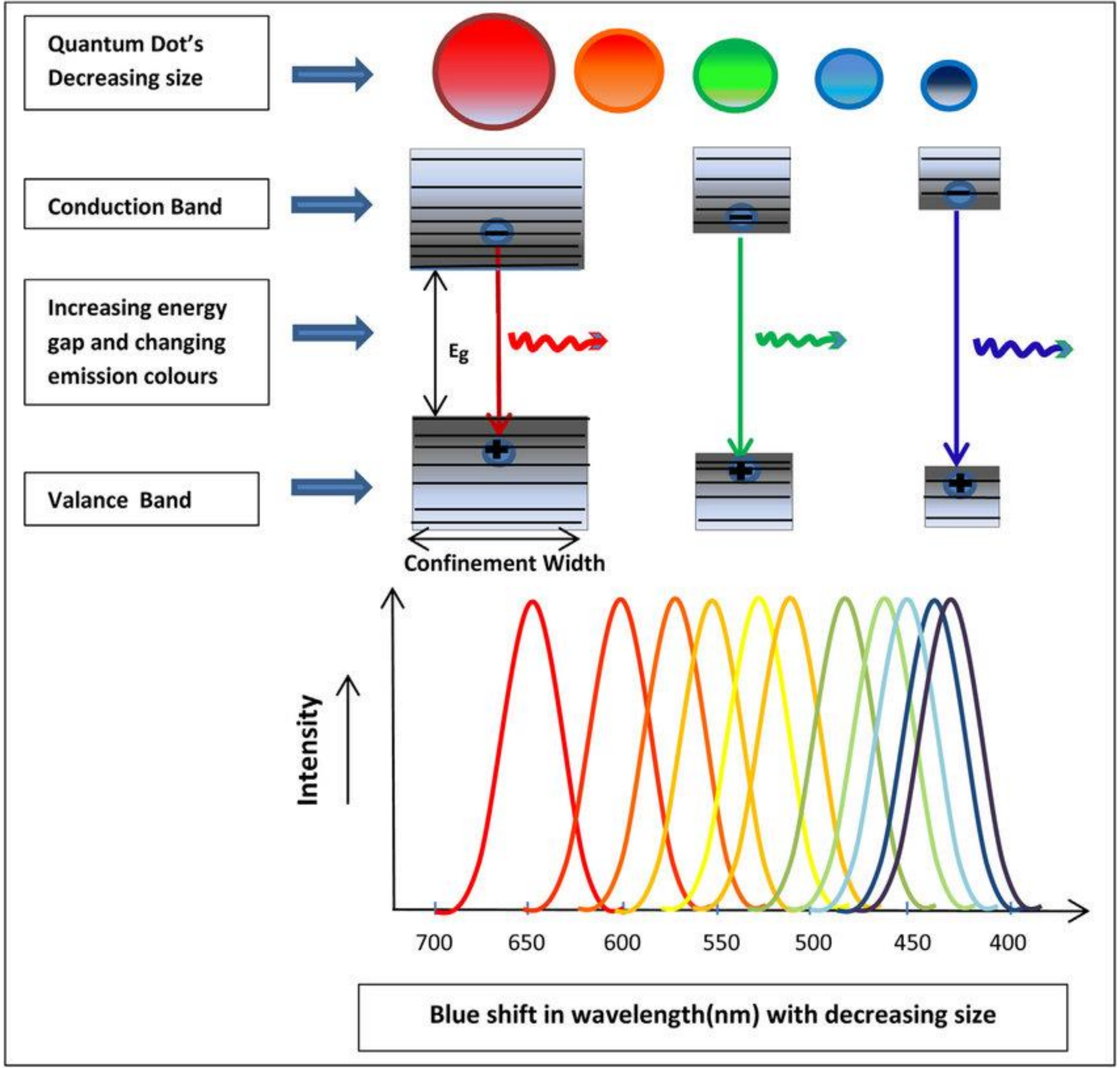
Inorganic Nanomaterials
Metal chalcogenides (TMCs)
Ag
Au
Pd
Cu
etc.
Metal
Metal oxide/hydroxides
ZnO
CuO
TiO_2
Fe_3O_4
etc.
TMCs - MoS_2, Bi_2Se_3 etc.
QDs
Organic nanomaterials
Compact polymeric
Micelle
Liposome
Hybrid
Dendrimer
Nanosphere
Nanocapsule
Carbon nanomaterials
Graphene
Fullerene
CNTs
Carbon dots
$g\text{-}C_3N_4$

A matter of scale

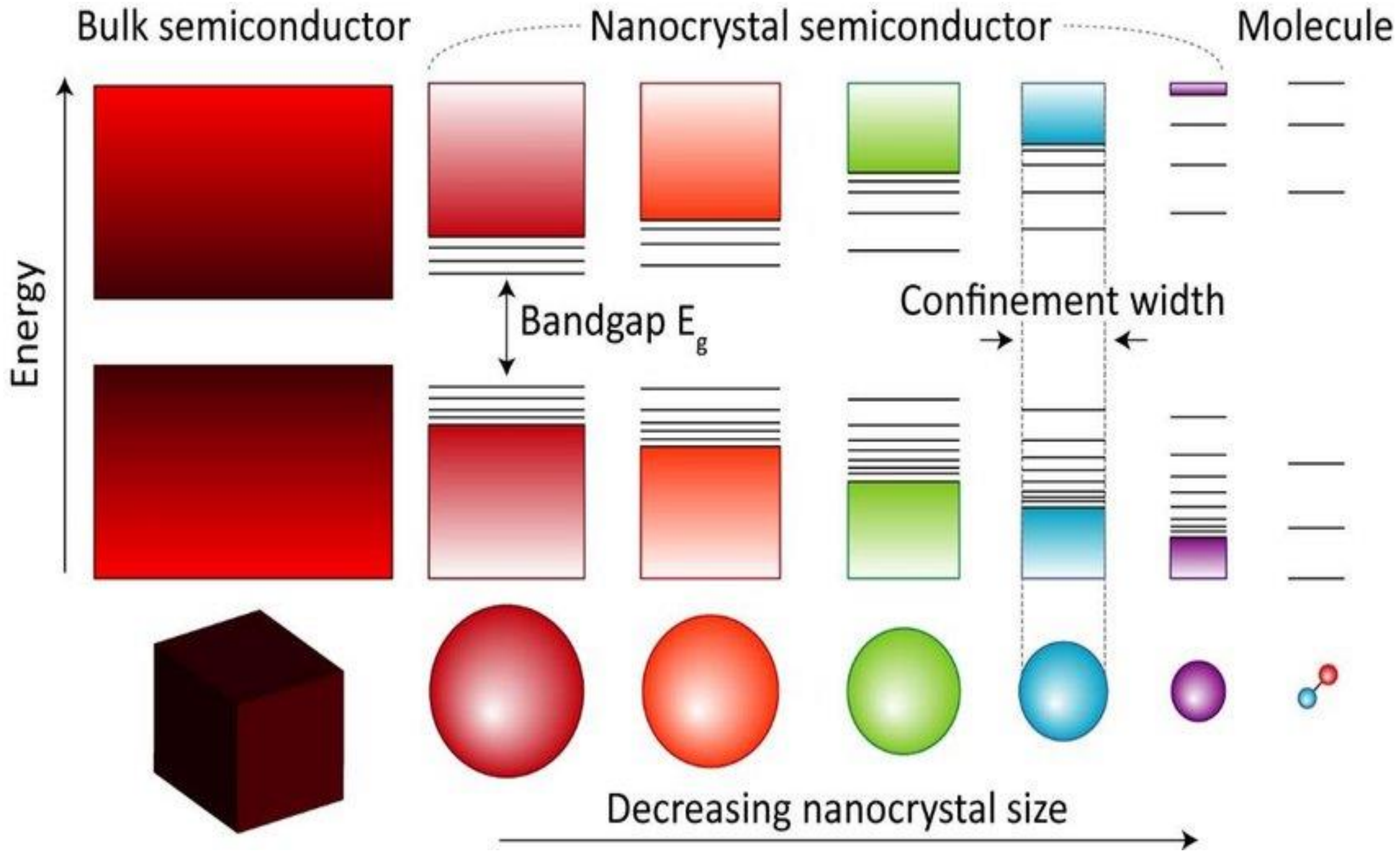


Quantum confinement affects electronic and optical properties

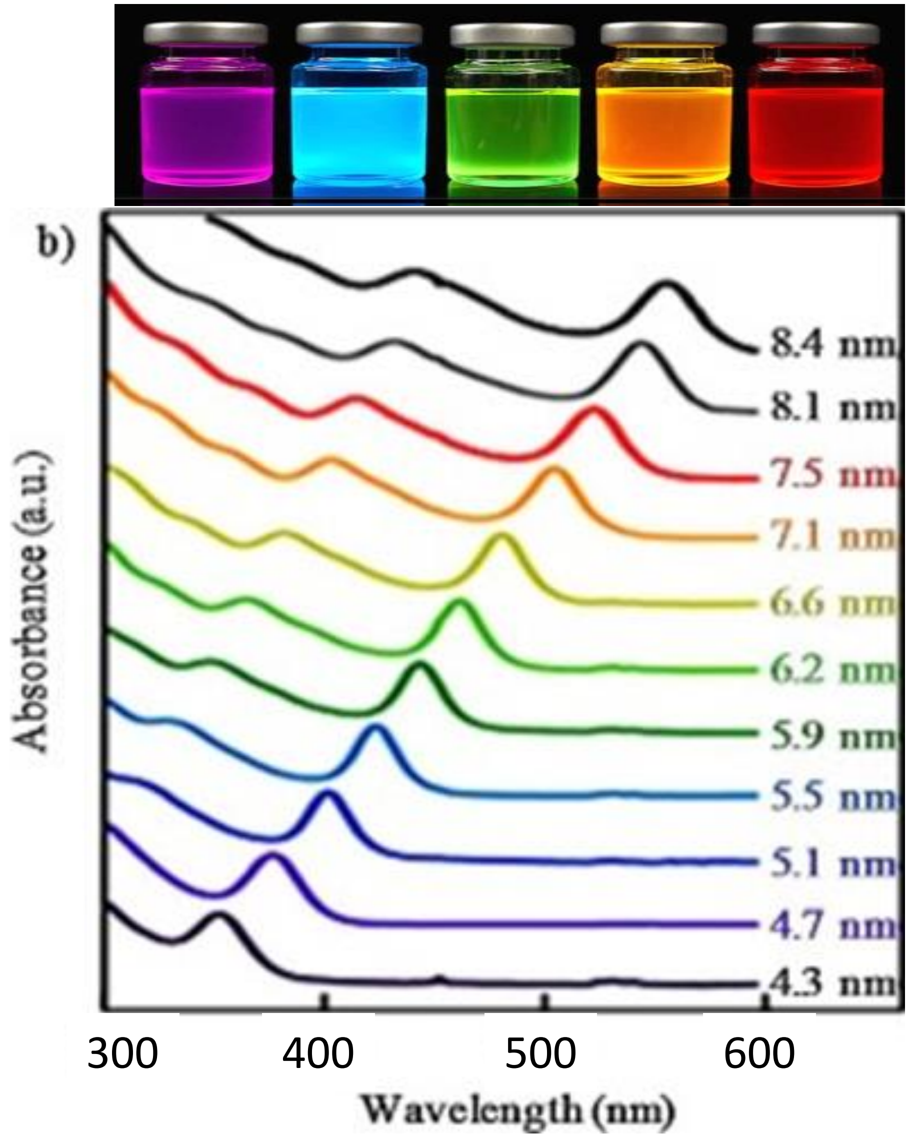
A matter of scale



A matter of scale



CdS quantum Dots



Quantum confinement affects electronic and optical properties

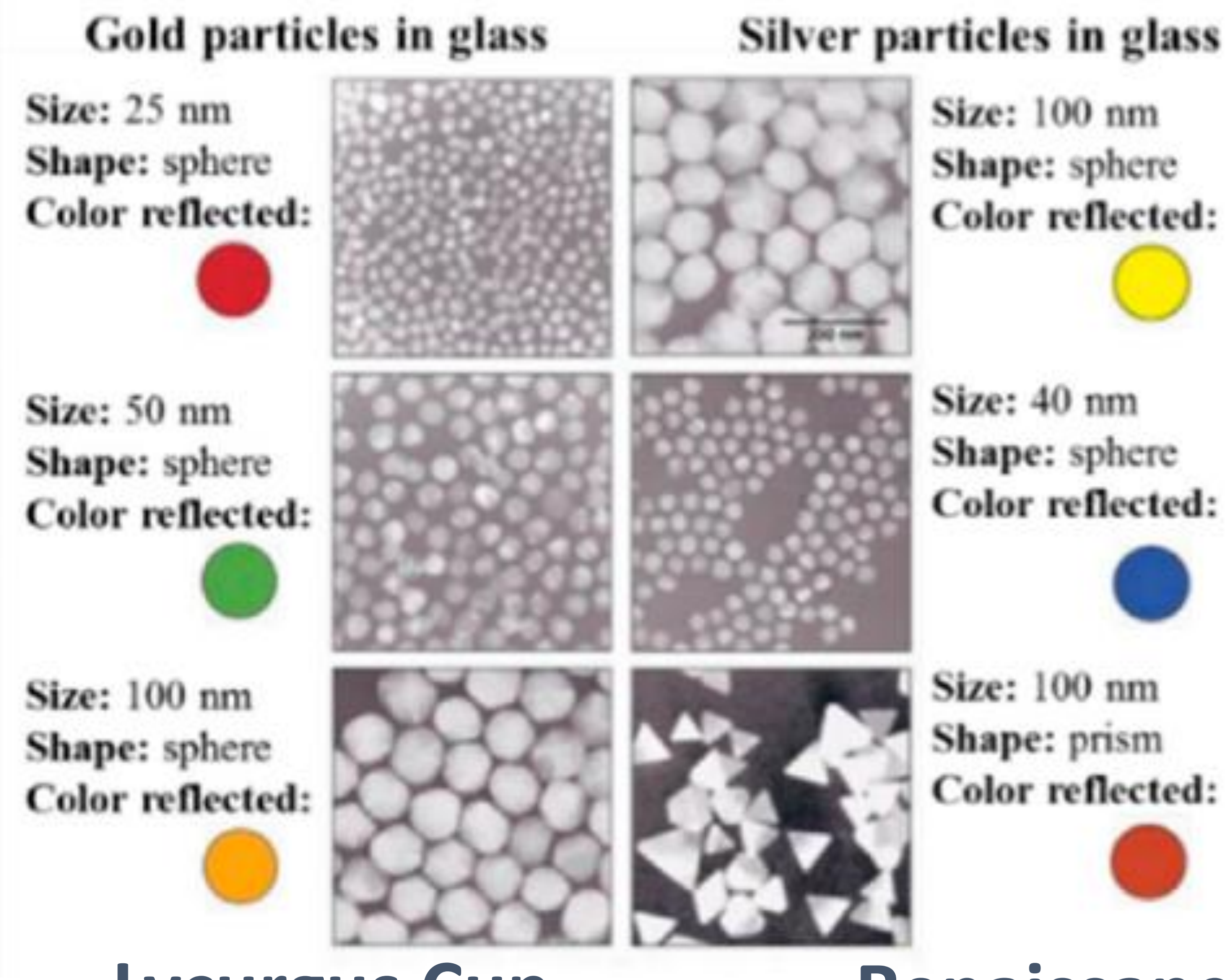
A brief history of nanotechnology

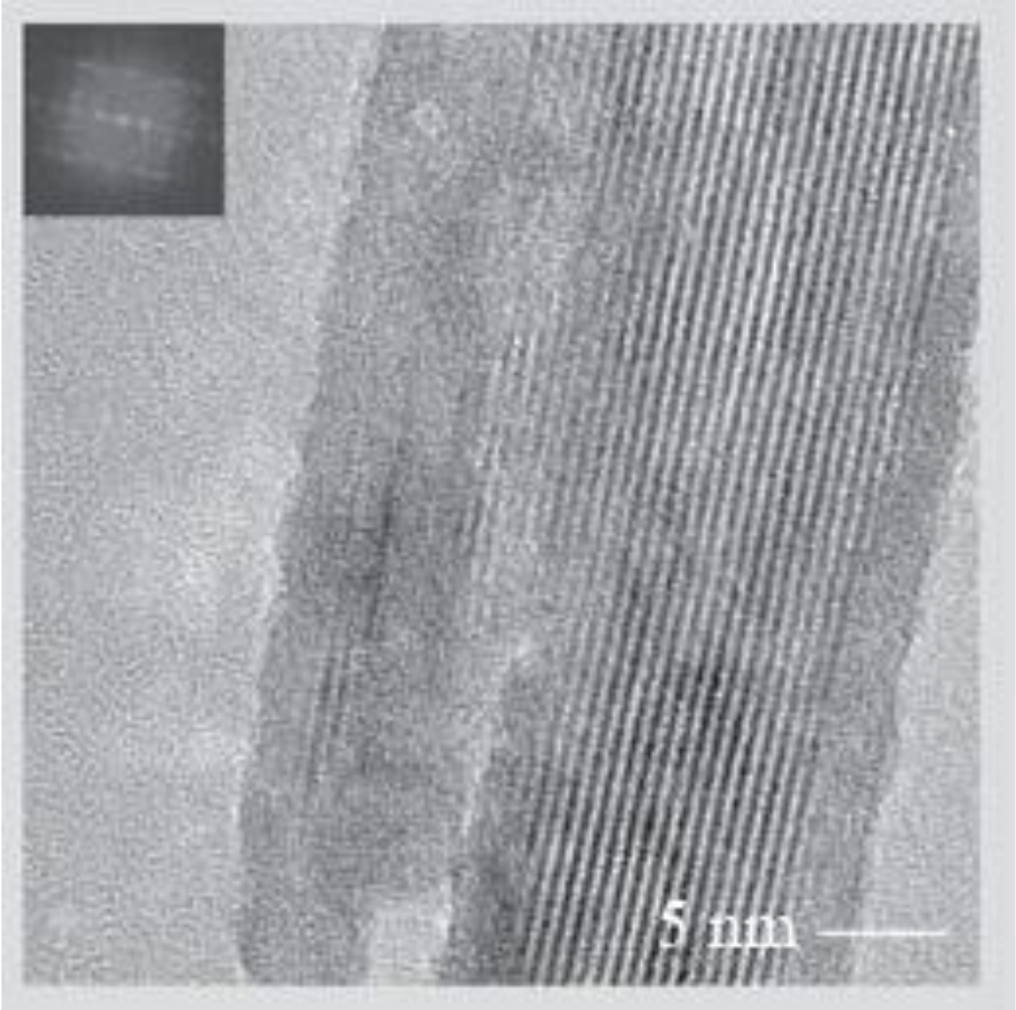
Lycurgus Cup
IV Century

Renaissance Art
XV Century

Damascus Blade
XII Century

A brief history of nanotechnology





Reibold, M., et al. "Carbon Nanotubes in an Ancient Damascus Sabre." Nature 444 (2006).

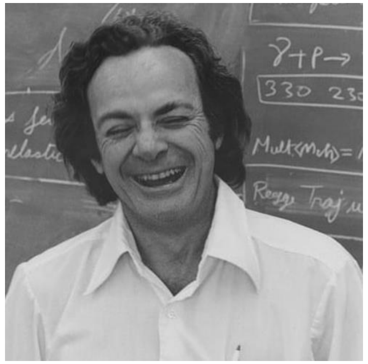
Lycurgus Cup
IV Century

Renaissance Art
XV Century

Damascus Blade
XII Century

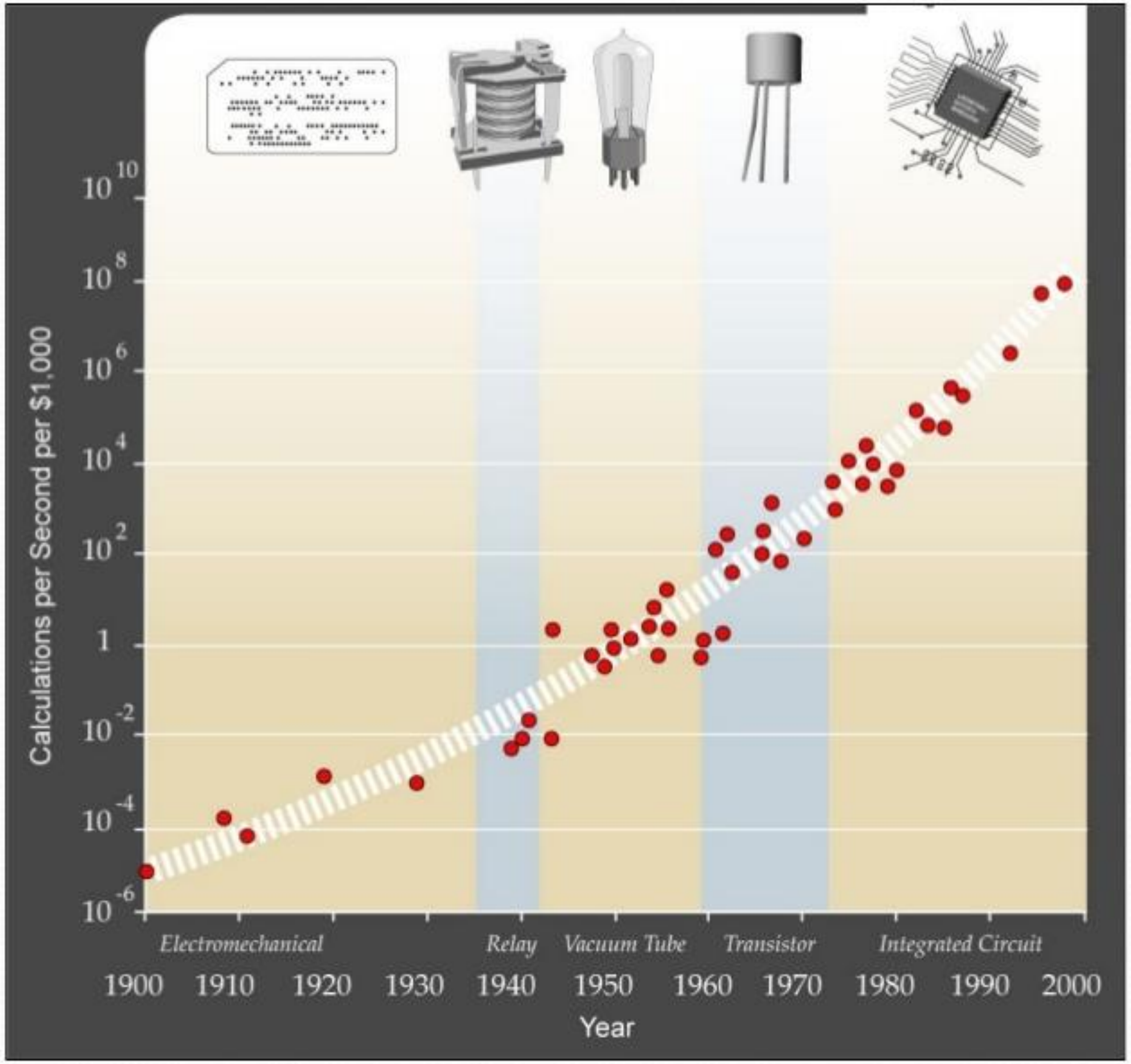
A brief history of nanotechnology

- Scanning electron microscope (1937)
- Transmission electron microscope (1940s)
- Raman Spectroscopy (1930)
- Transistors (1947)
- Resonant Raman Spectroscopy (1950)
- First Integrated Circuits (1959)
- Lasers (1960s)
- CCD (1970s)
- SERS (1974)
- Scanning tunnelling microscope (1981)
- Quantum dots (1993)



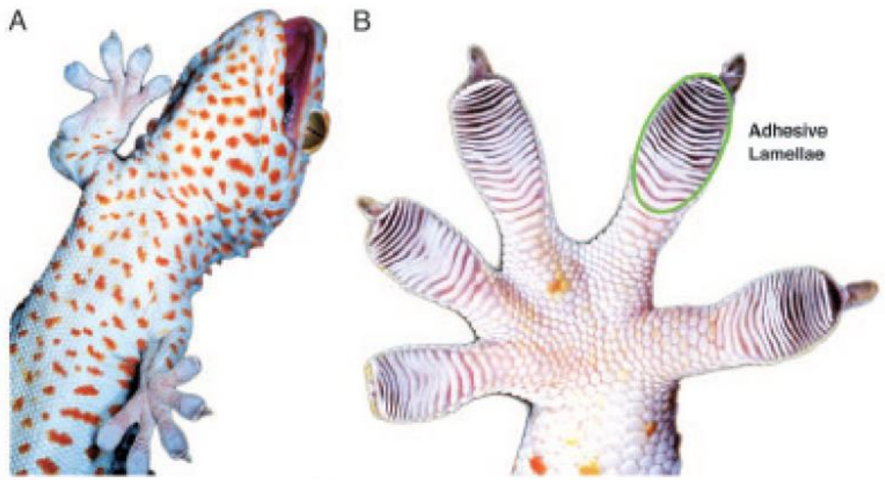
“What I want to talk about is the problem of manipulating and controlling things on a small scale.”

Feynman's 1959 lecture



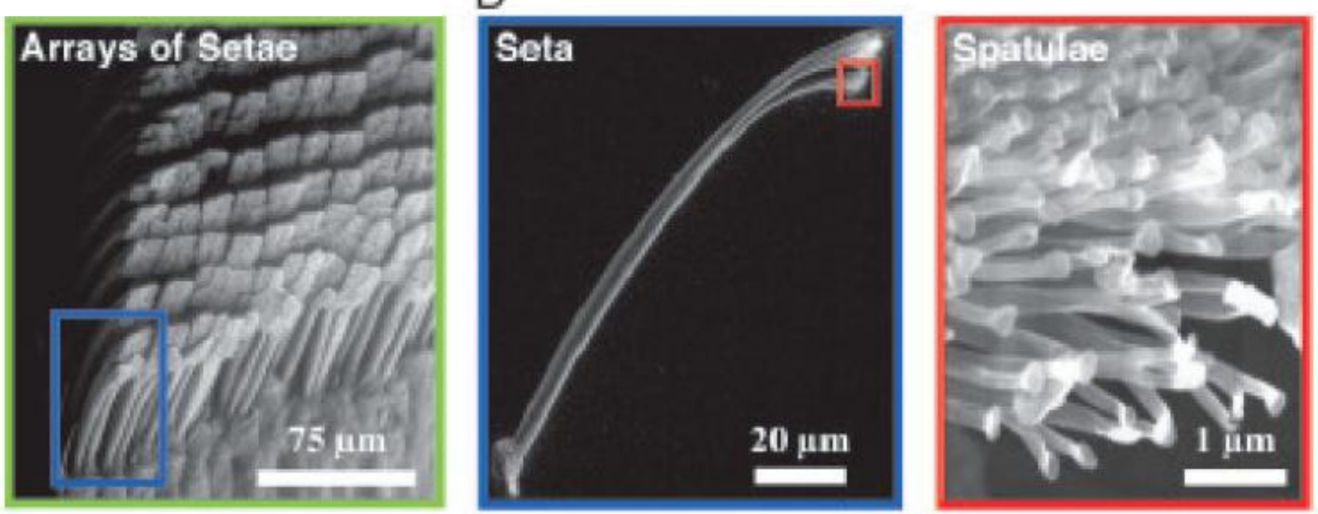
There's Plenty of Room at the Bottom !

Biomemetic: leveraging small-scale interactions



1.000.000 setae

1.000 spatular tips

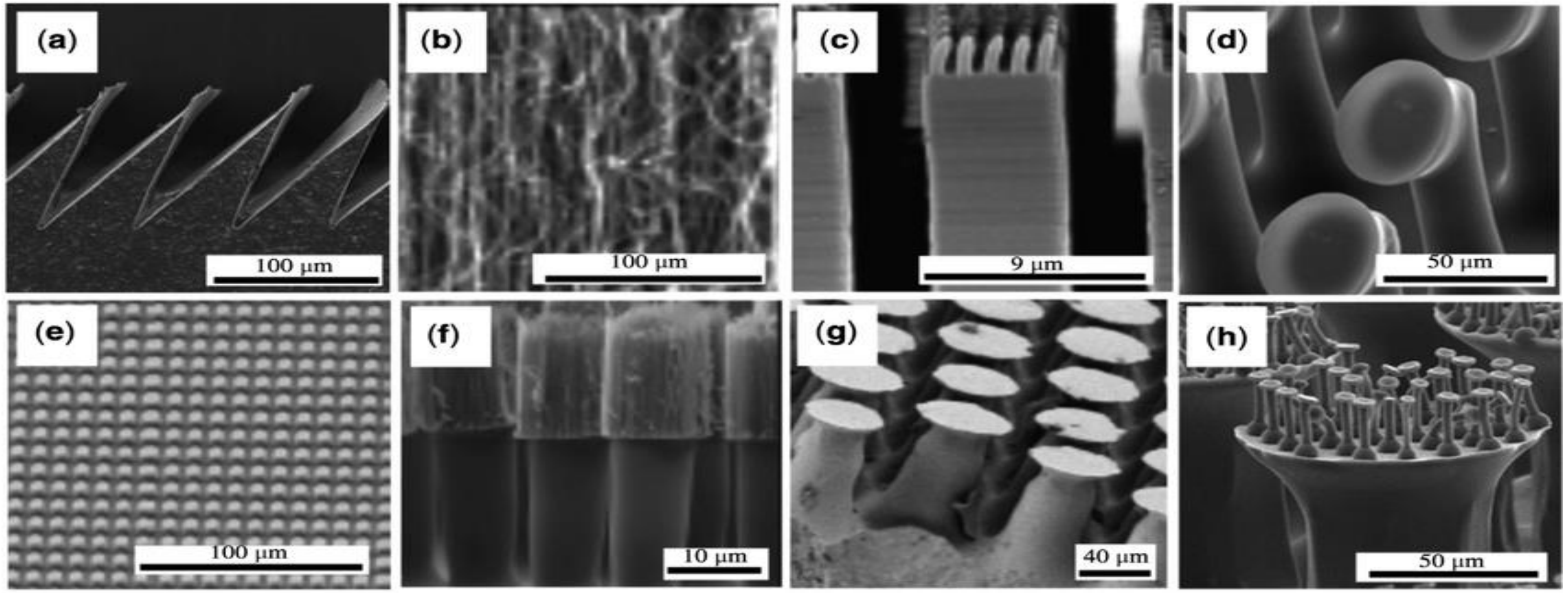


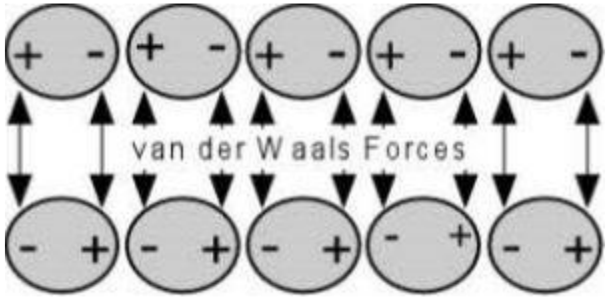
MACRO

MESO

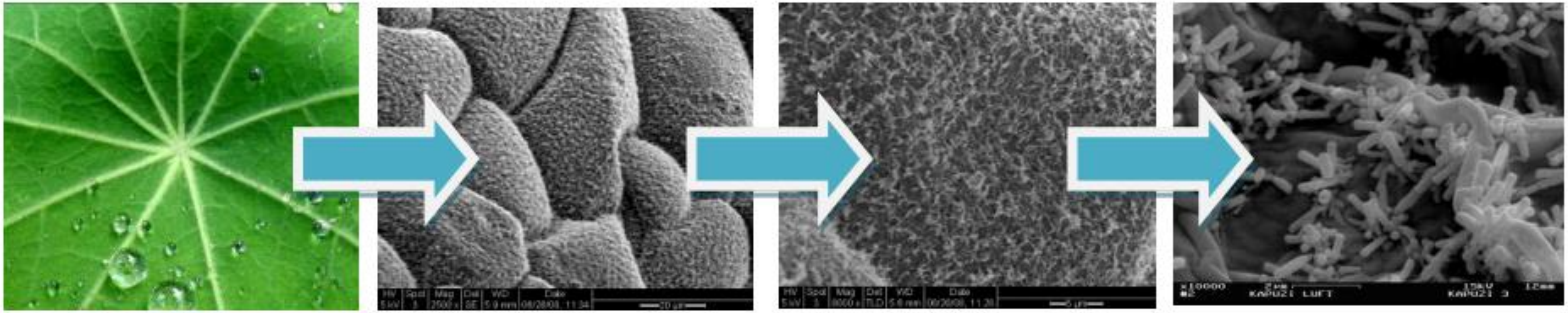
MICRO

NANO

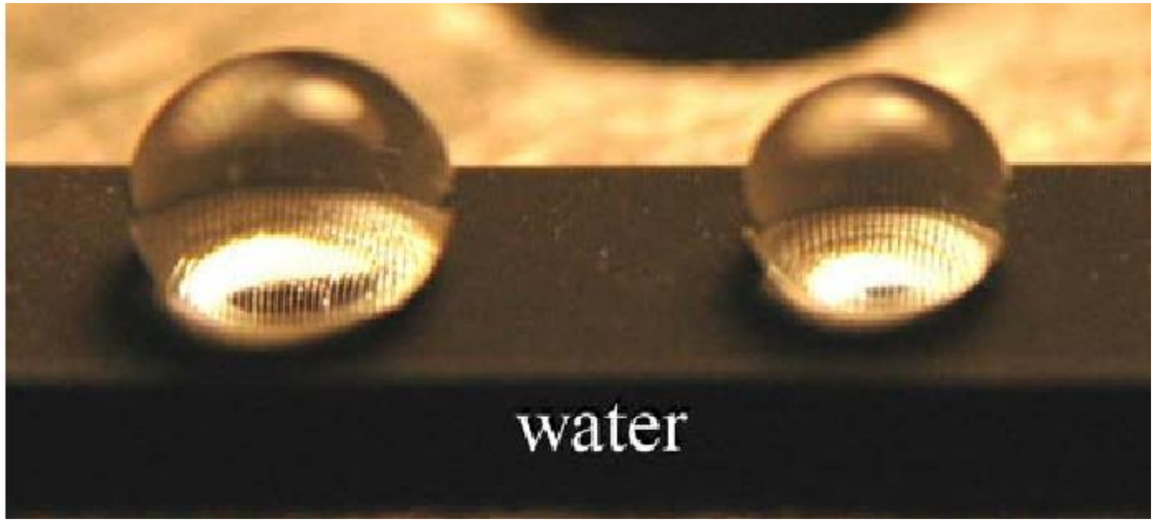


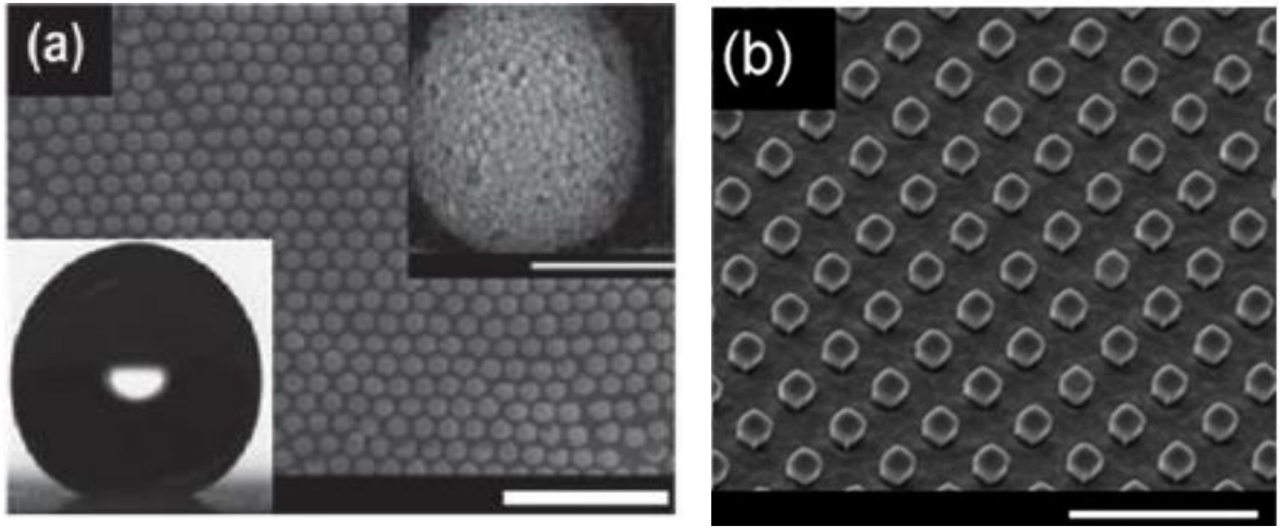


Biomimetic: leveraging small-scale interactions

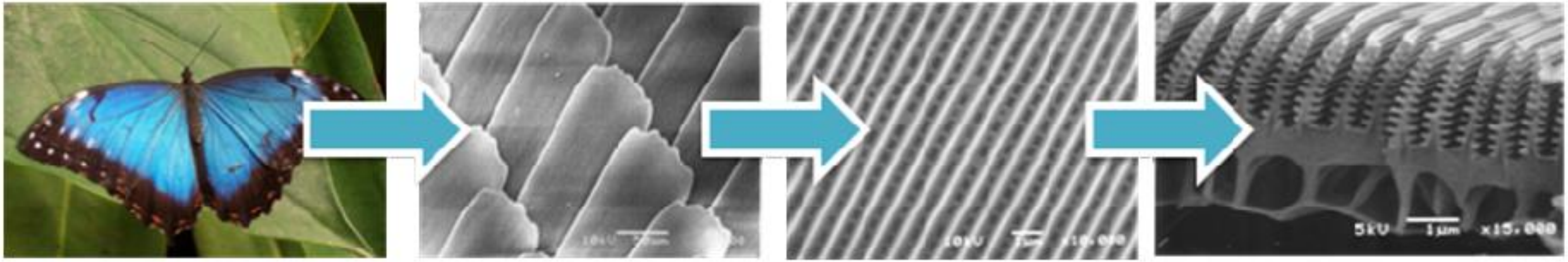


MACRO MESO MICRO NANO

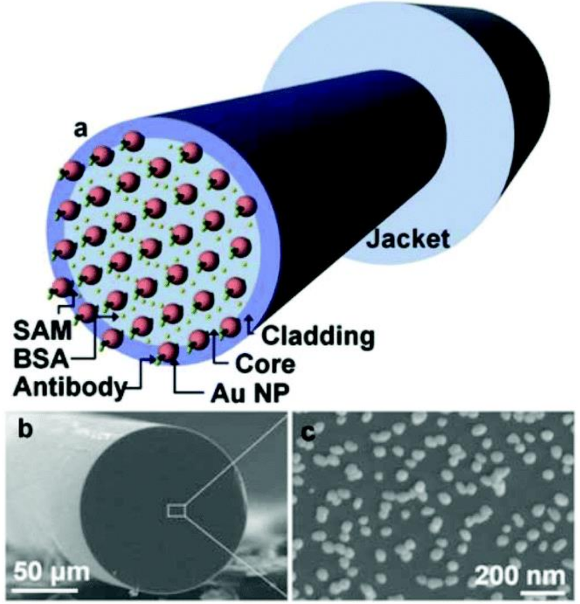


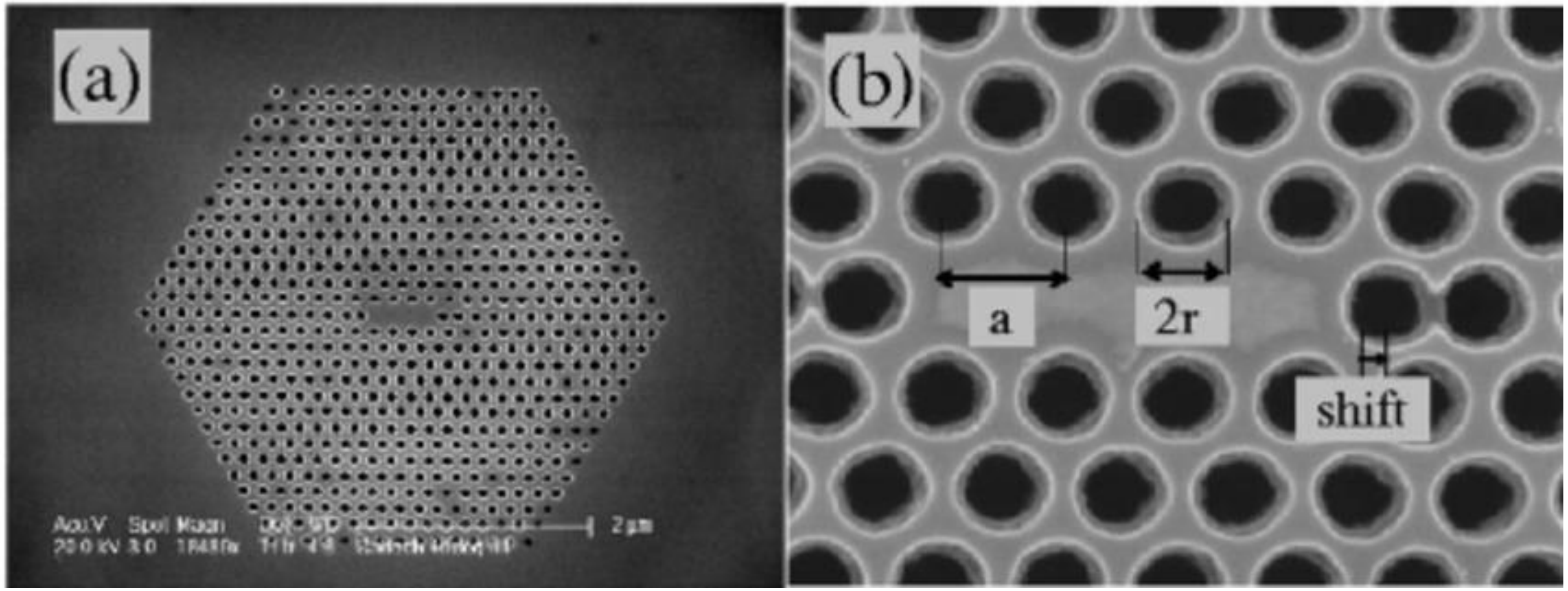


Biomimetic: modulating refractive index

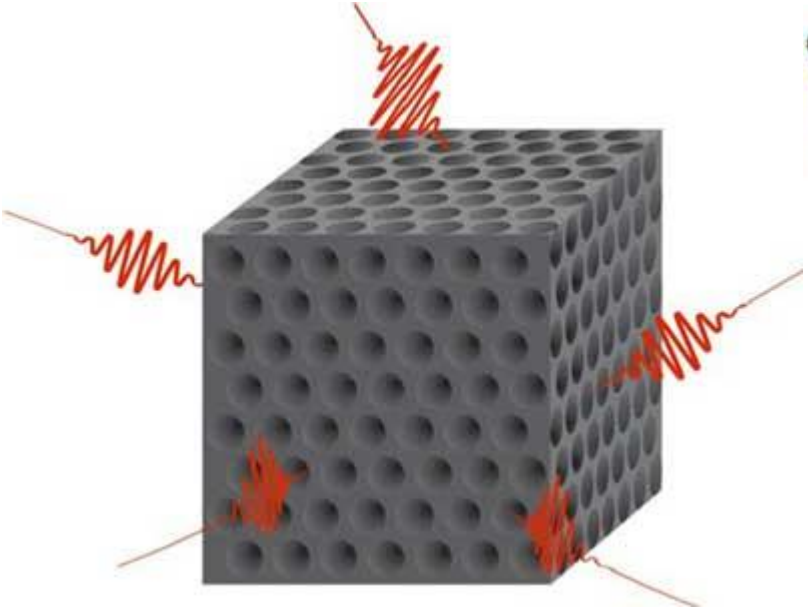


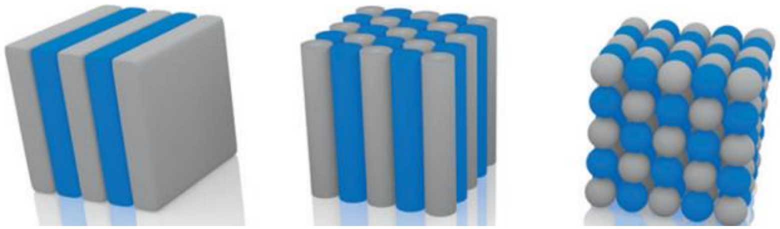
MACRO MESO MICRO NANO

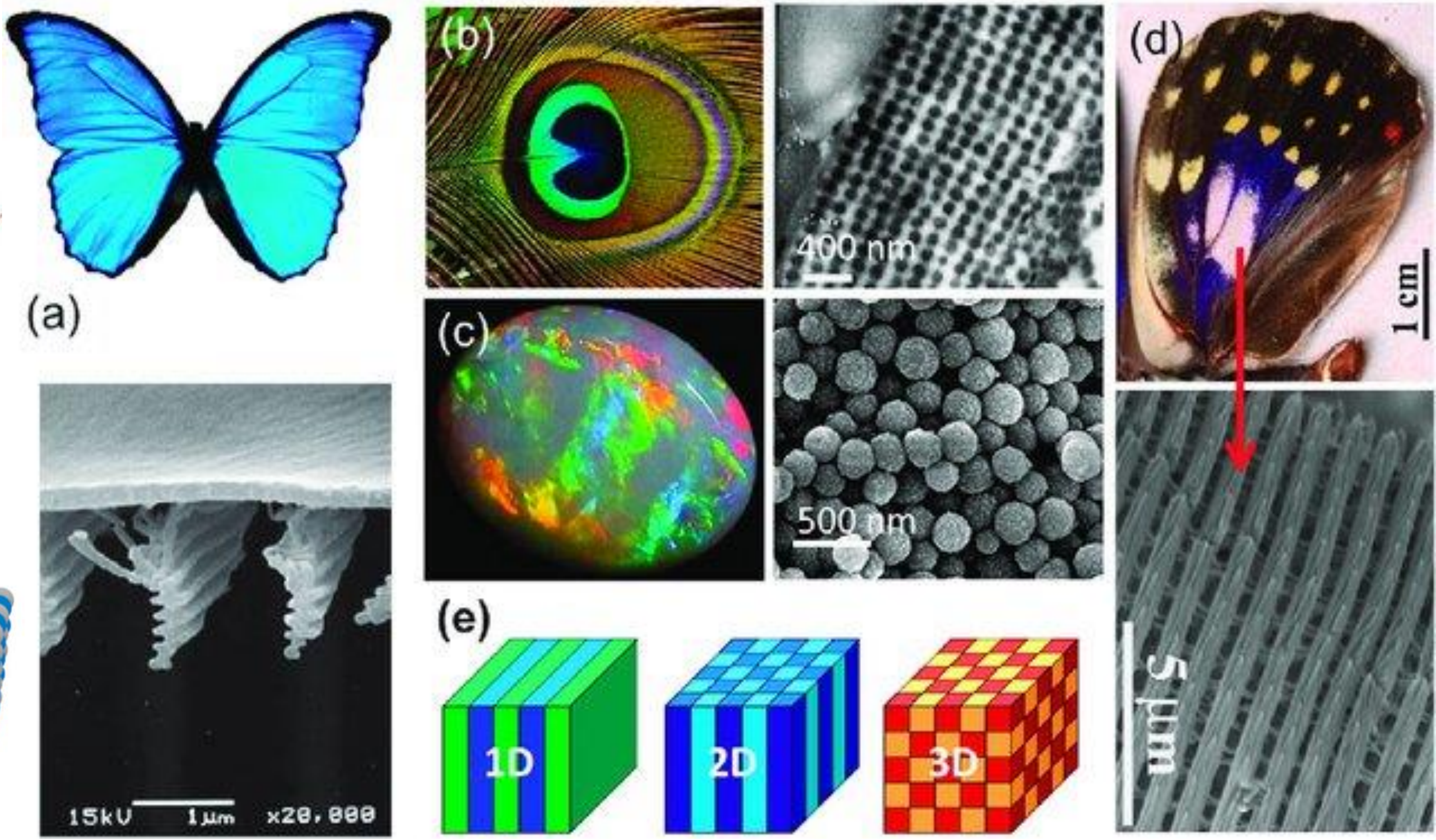


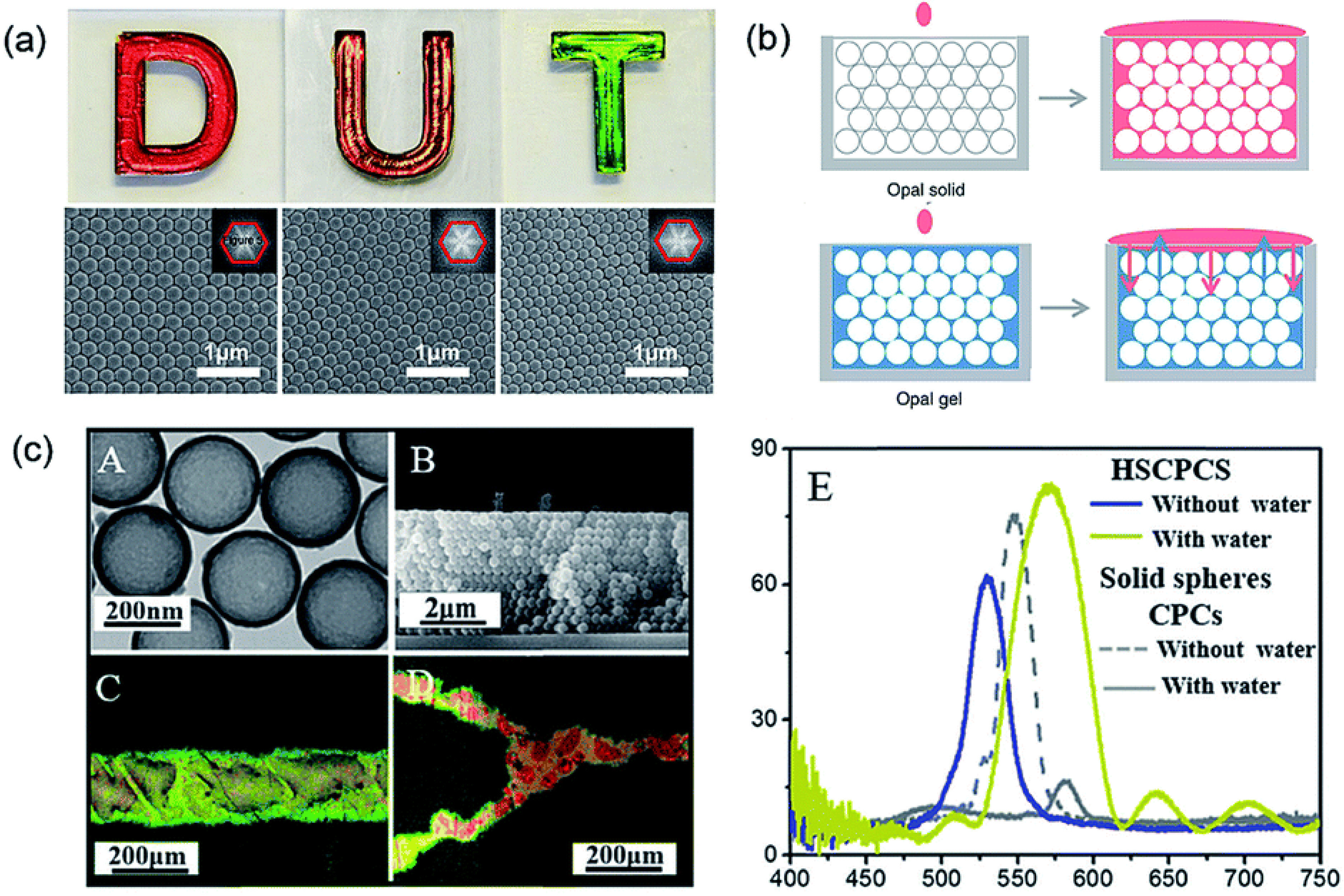


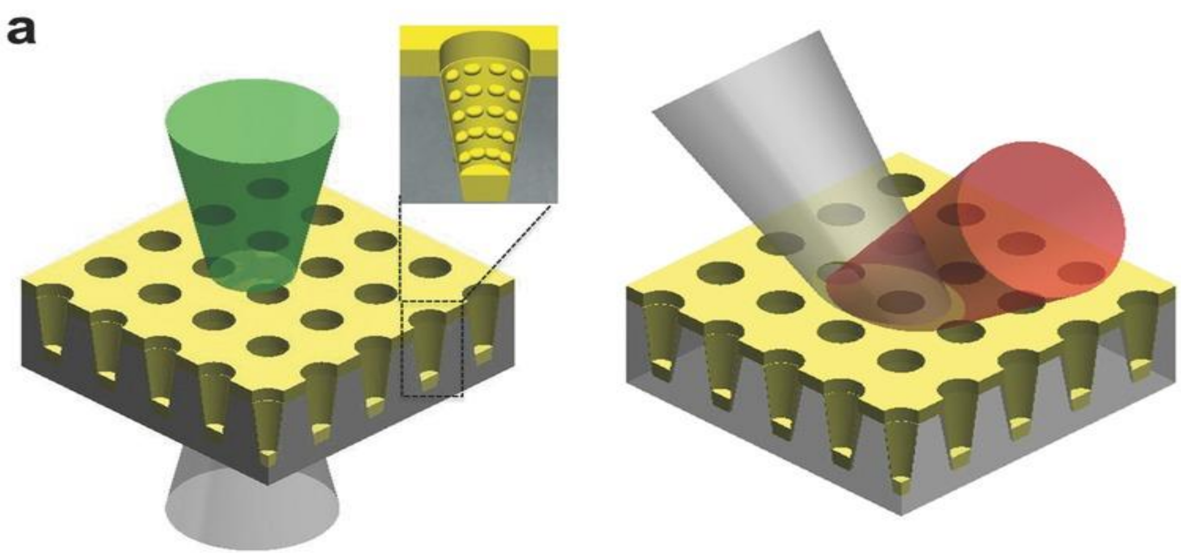
Biomimetic: Photonic crystals

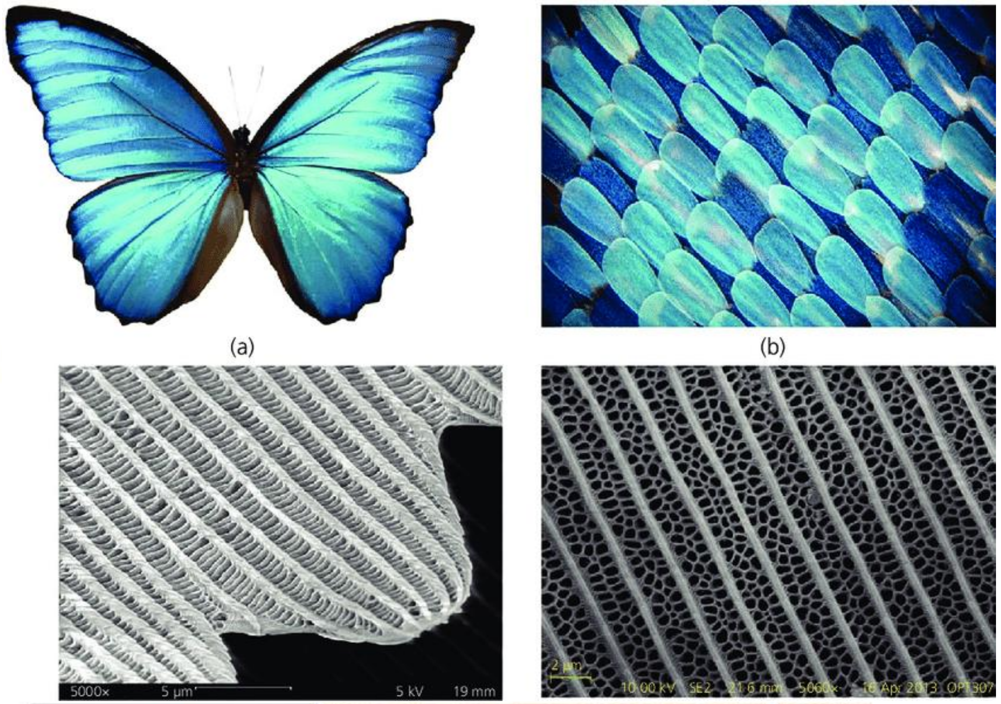


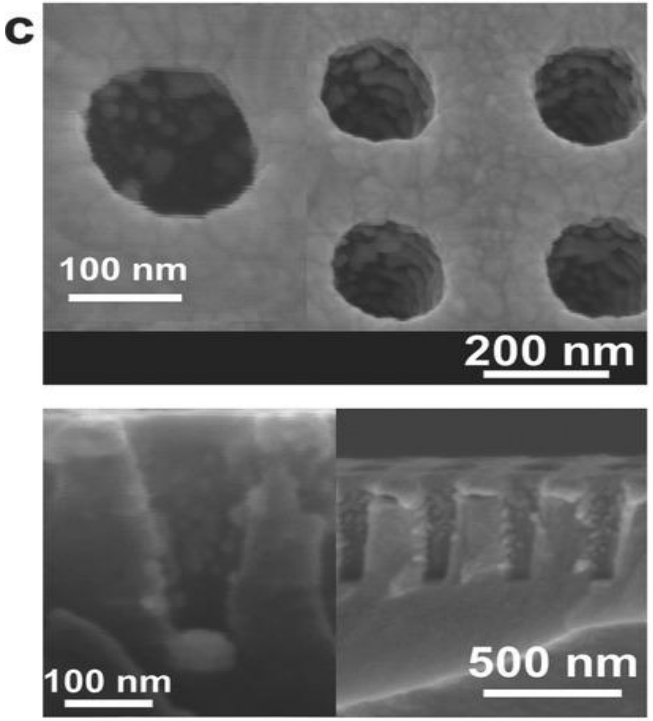


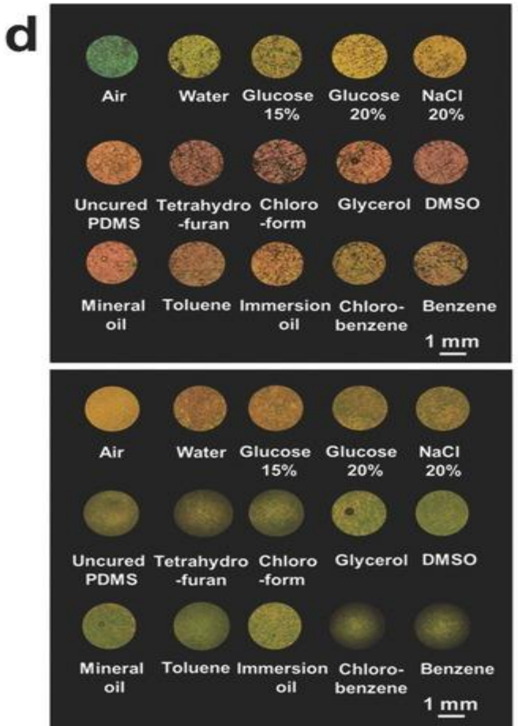


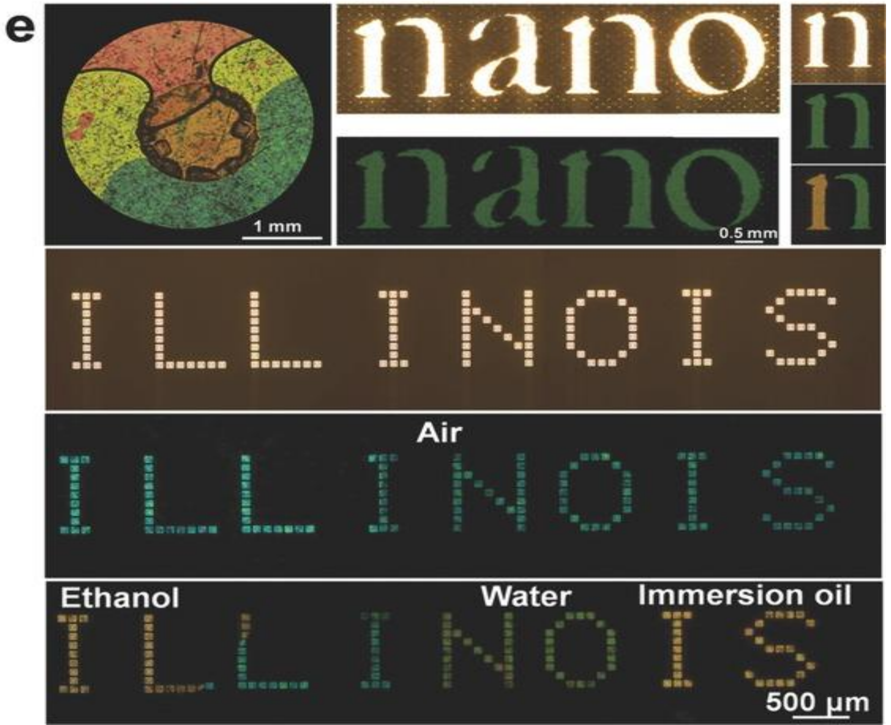

(a)
1μm
1μm
1μm
(b)
Opal solid
Opal gel
(c)
A
200nm
B
2μm
C
200μm
D
200μm
E
HSCPCS
Without water
With water
Solid spheres CPCs
Without water
With water
90
60
30
0
400
450
500
550
600
650
700
750

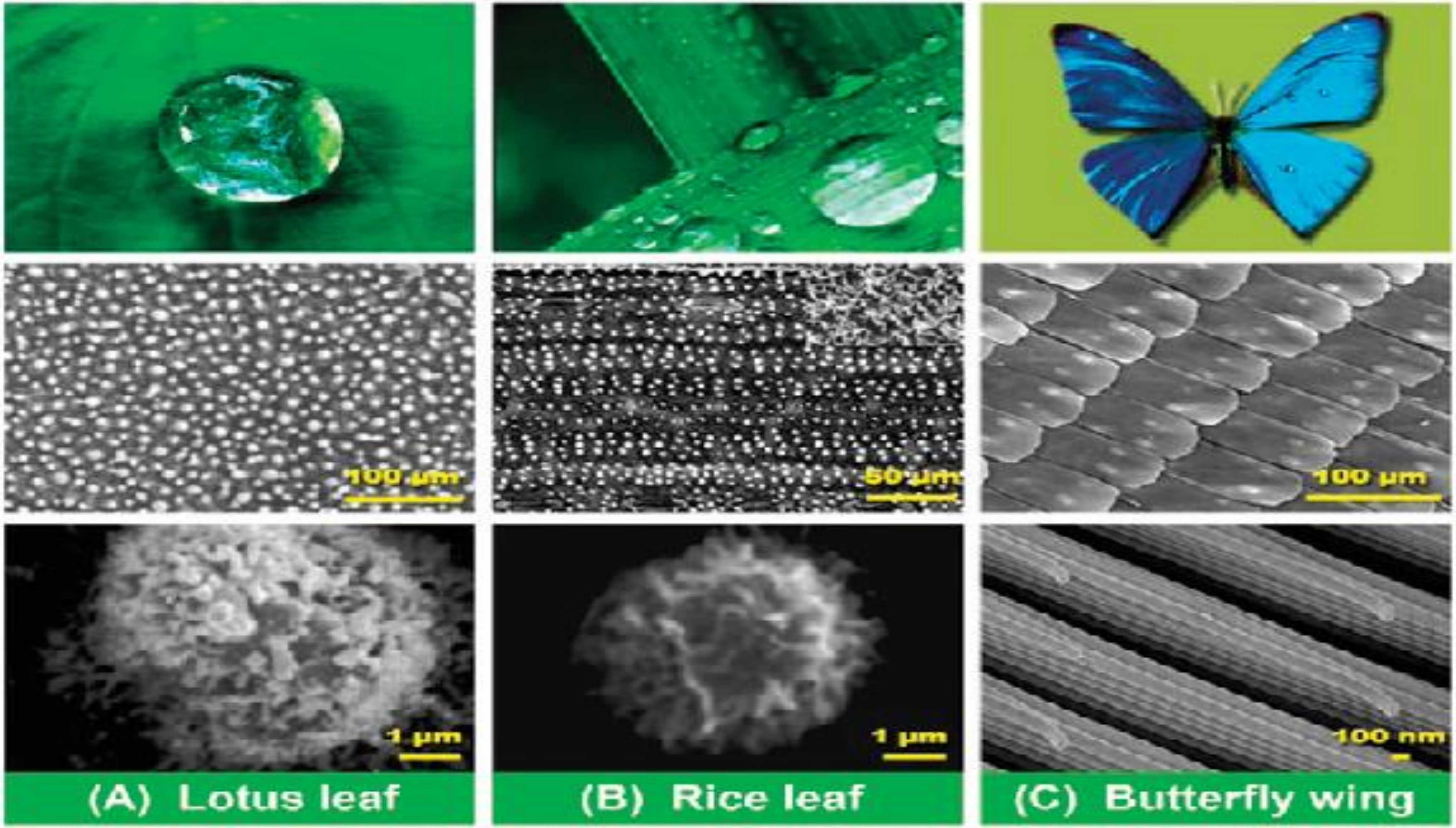

a

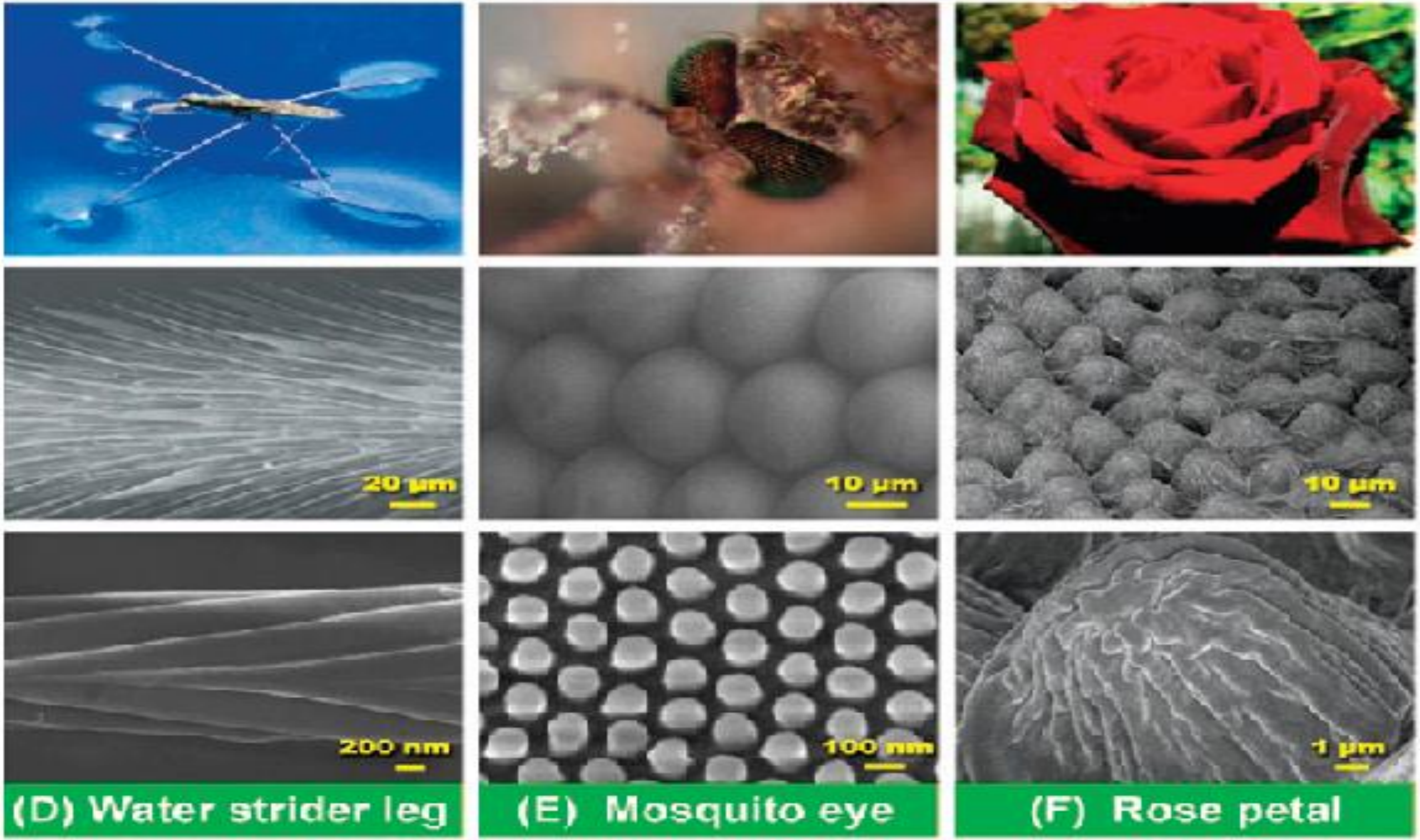

(a)
(b)
5000× 5 μm 5 kV 19 mm

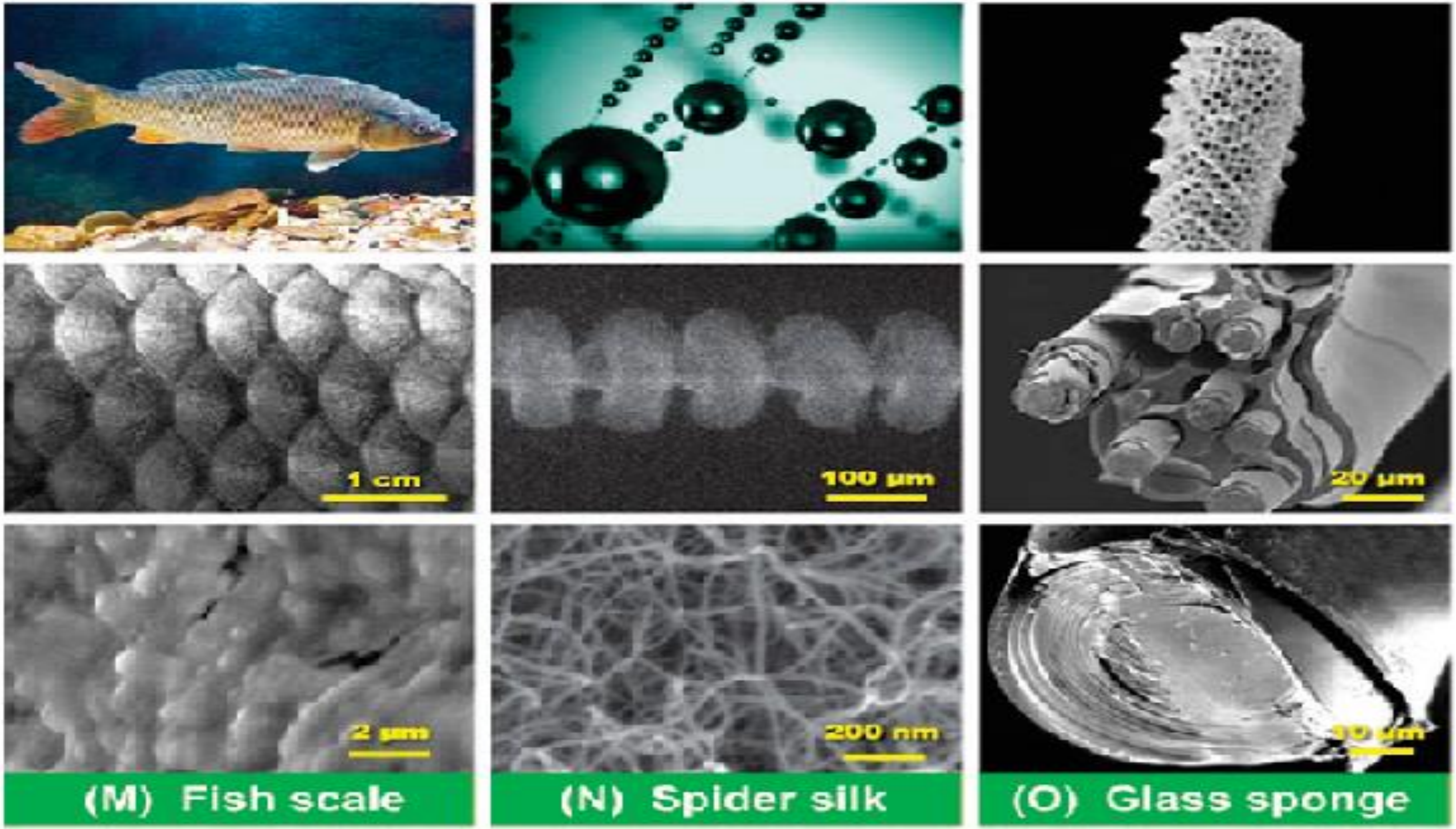

c
100 nm
200 nm
100 nm
500 nm


d
Air
Water
Glucose 15%
Glucose 20%
NaCl 20%
Uncured PDMS
Tetrahydro -furan
Chloro -form
Glycerol
DMSO
Mineral oil
Toluene
Immersion oil
Chloro- benzene
Benzene
1 mm
Air
Water
Glucose 15%
Glucose 20%
NaCl 20%
Uncured PDMS
Tetrahydro -furan
Chloro -form
Glycerol
DMSO
Mineral oil
Toluene
Immersion oil
Chloro- benzene
Benzene
1 mm


e
1 mm
nano
nano
0.5 mm
n
n
n
ILLINOIS
Air
ILLINOIS
Ethanol
Water
Immersion oil
ILLINOIS
500 μm

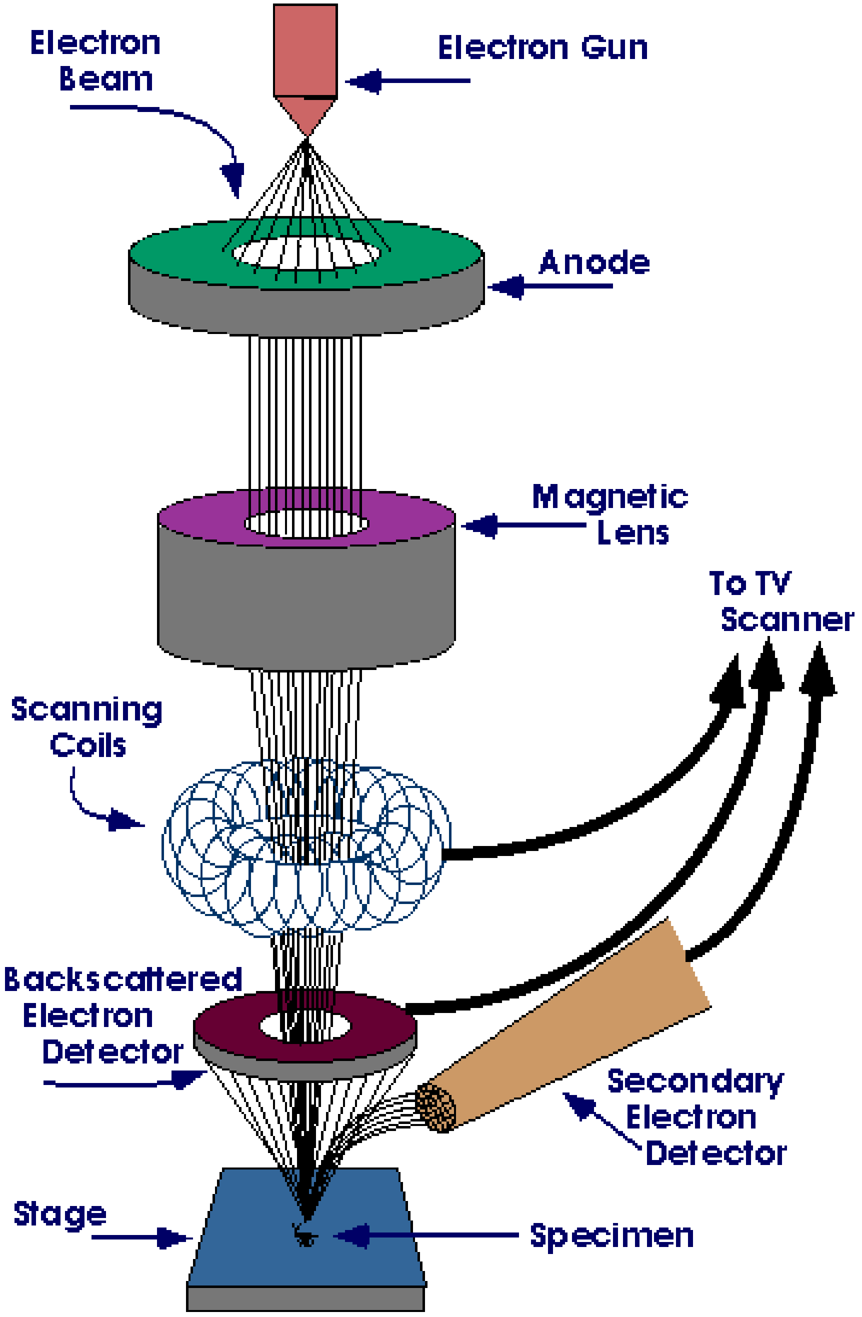

100 µm
50 µm
100 µm
1 µm
1 µm
100 nm
(A) Lotus leaf
(B) Rice leaf
(C) Butterfly wing


20 µm
10 µm
10 µm
200 nm
100 nm
1 µm
(D) Water strider leg
(E) Mosquito eye
(F) Rose petal


1 cm
100 µm
20 µm
2 µm
200 nm
10 µm
(M) Fish scale
(N) Spider silk
(O) Glass sponge

How do we “see” nanostructures ? Microscopy!

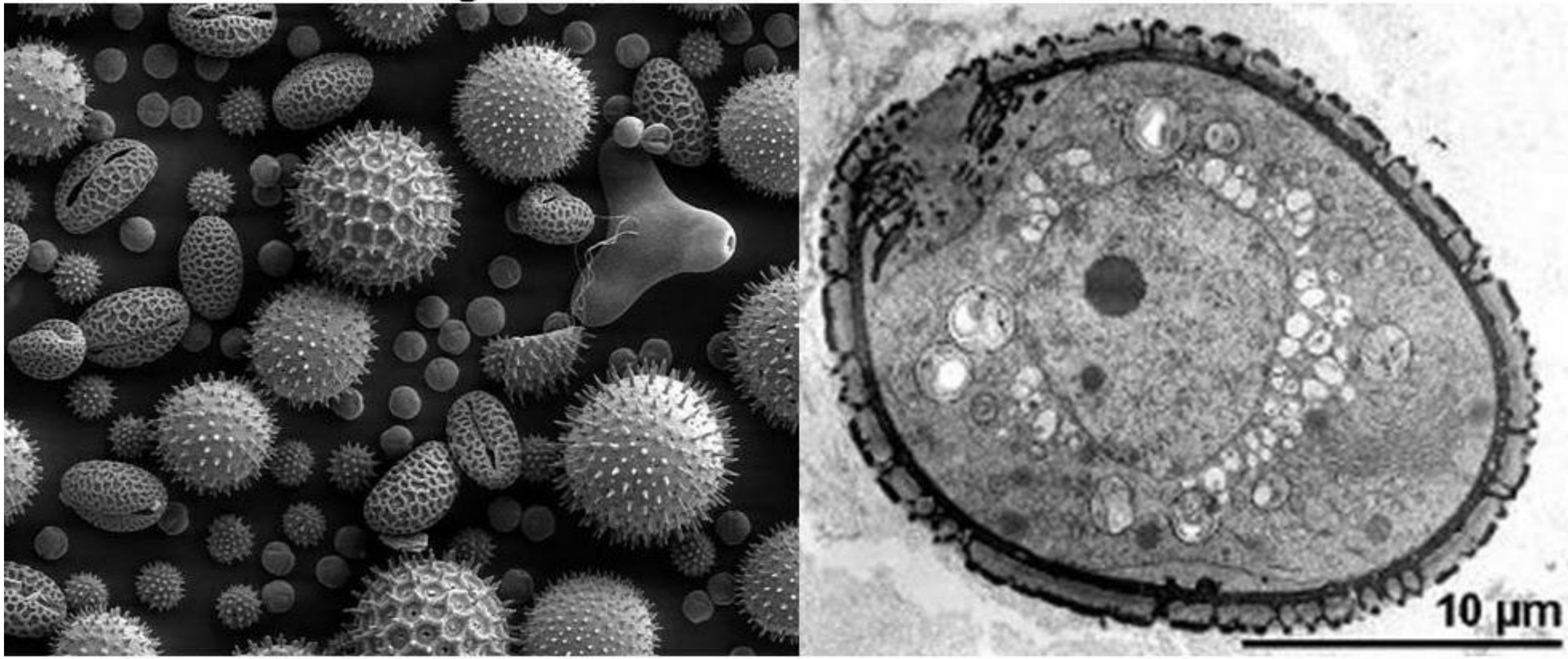
Using electrons – instead of visible photons - allows to dig deeper into the nanoworld



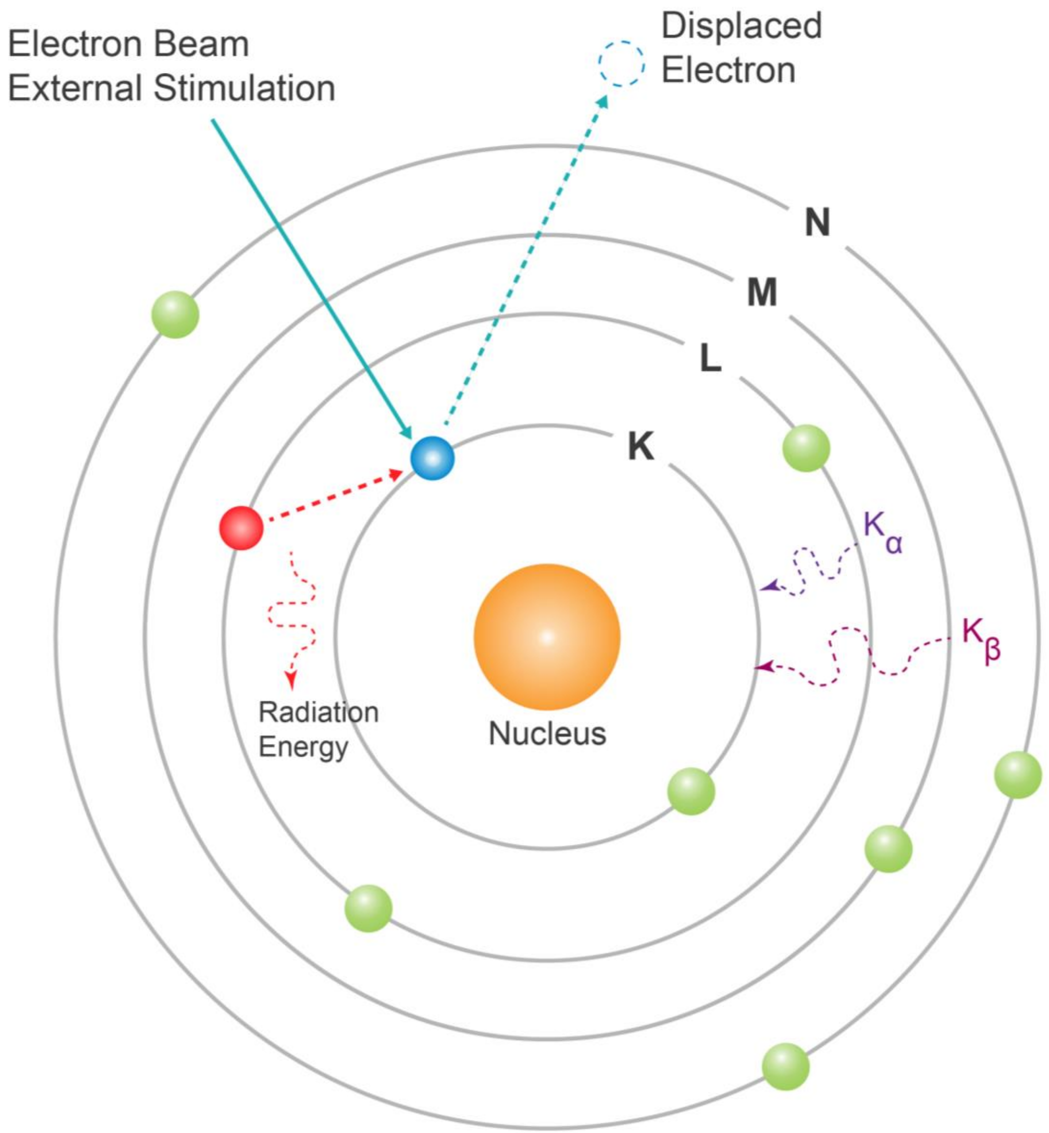
How do we “see” nanostructures ? Microscopy!

«S» is for scanning
«T» is for transmission

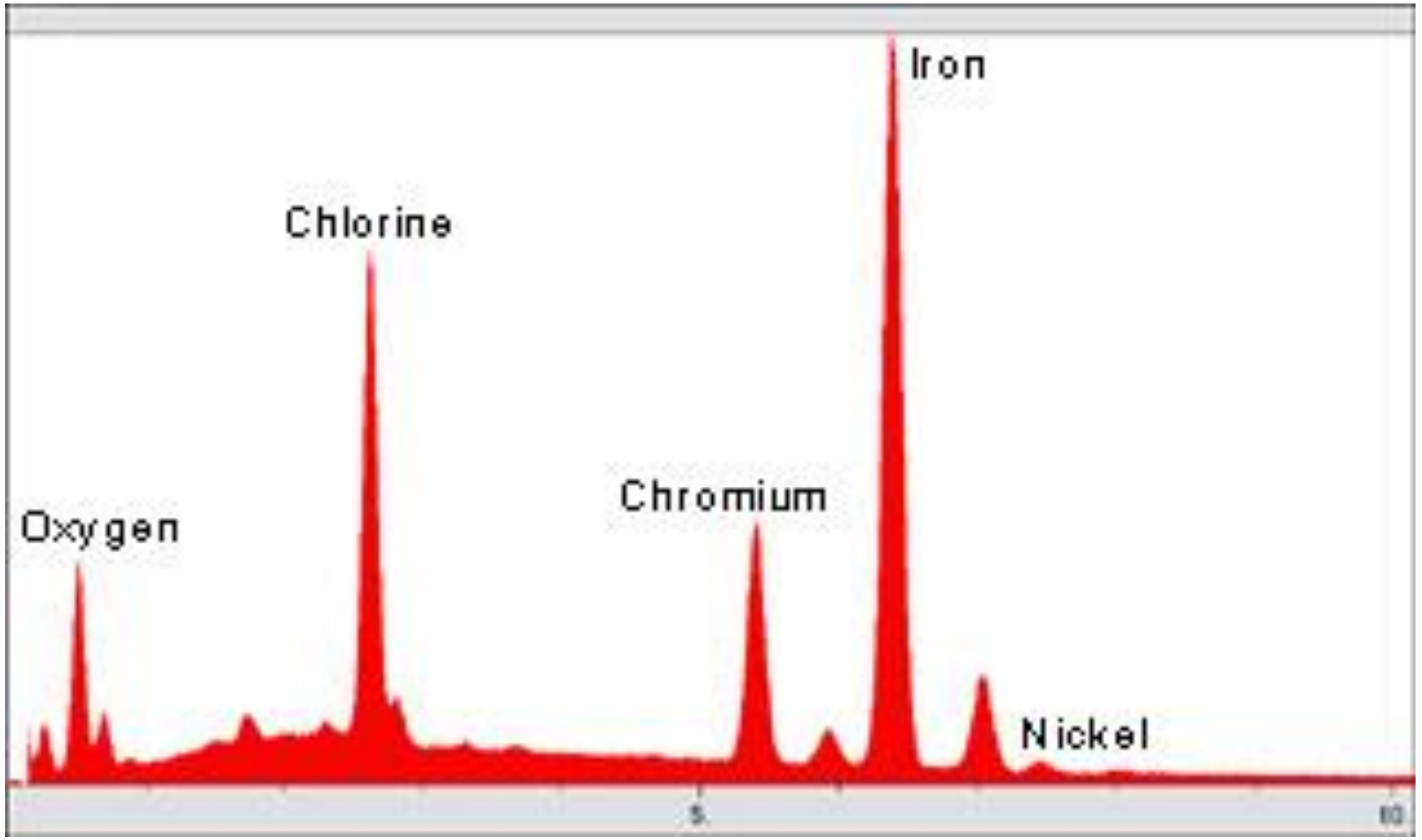
Pollen grain under SEM and TEM



How do we “see” nanostructures ? Spectroscopy!

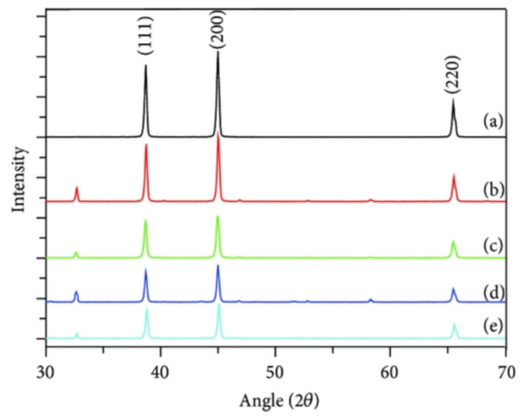


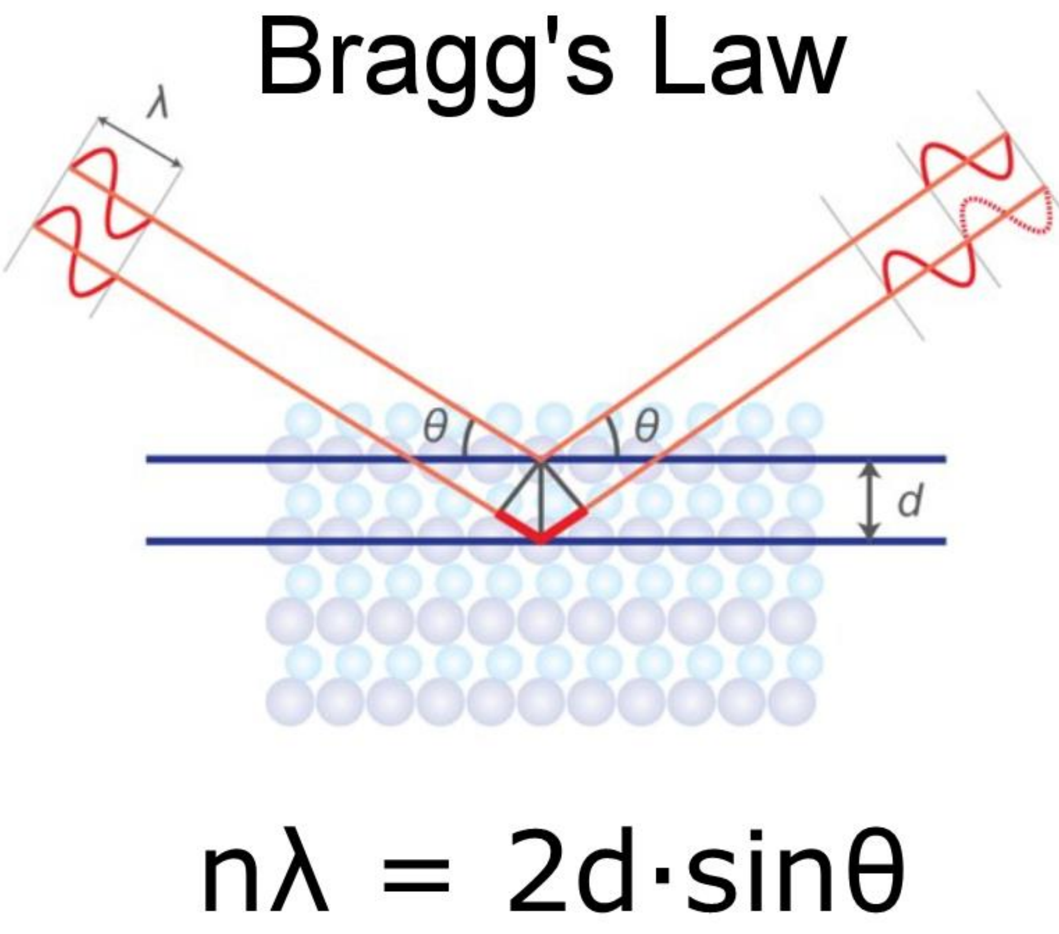
Every atom is unique…

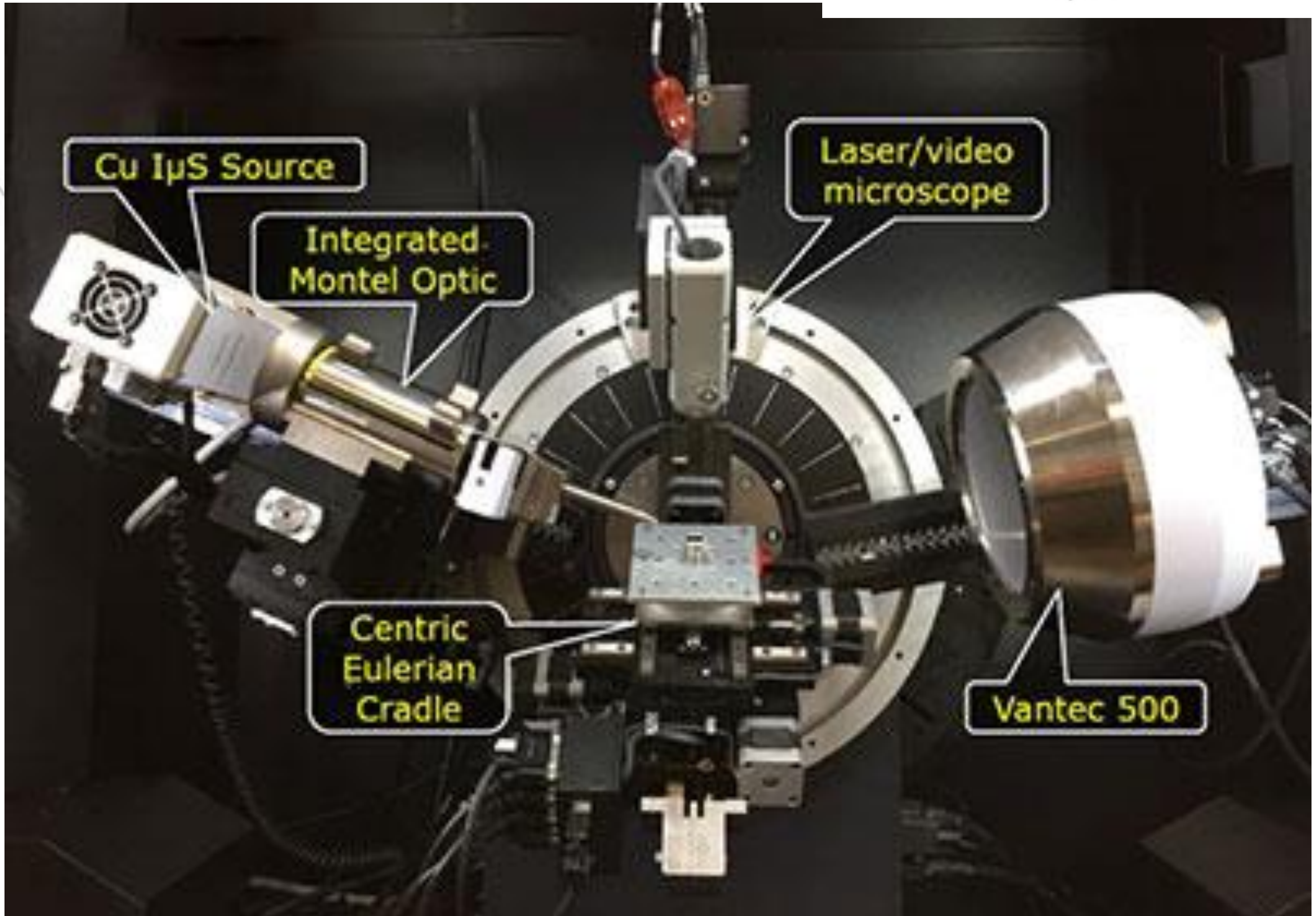


How do we “see” nanostructures ? XRD!

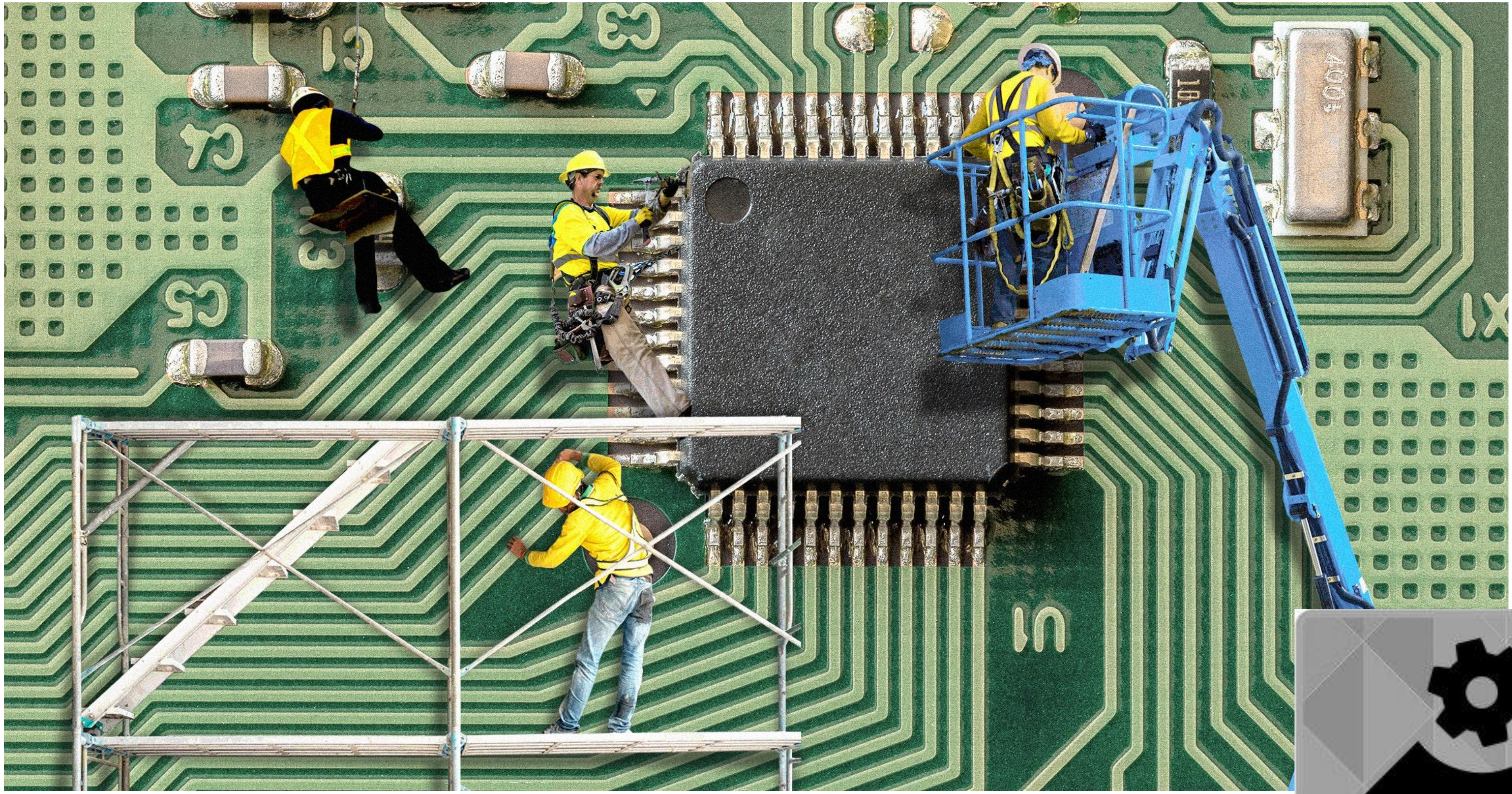
Scattering of incident photons by an ordered array of atoms

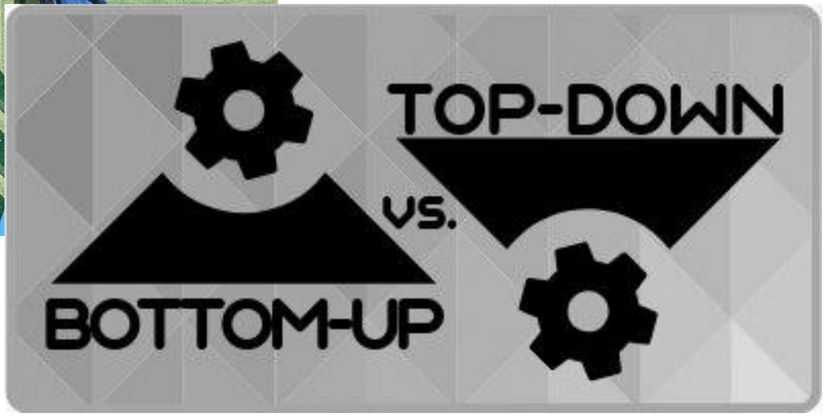




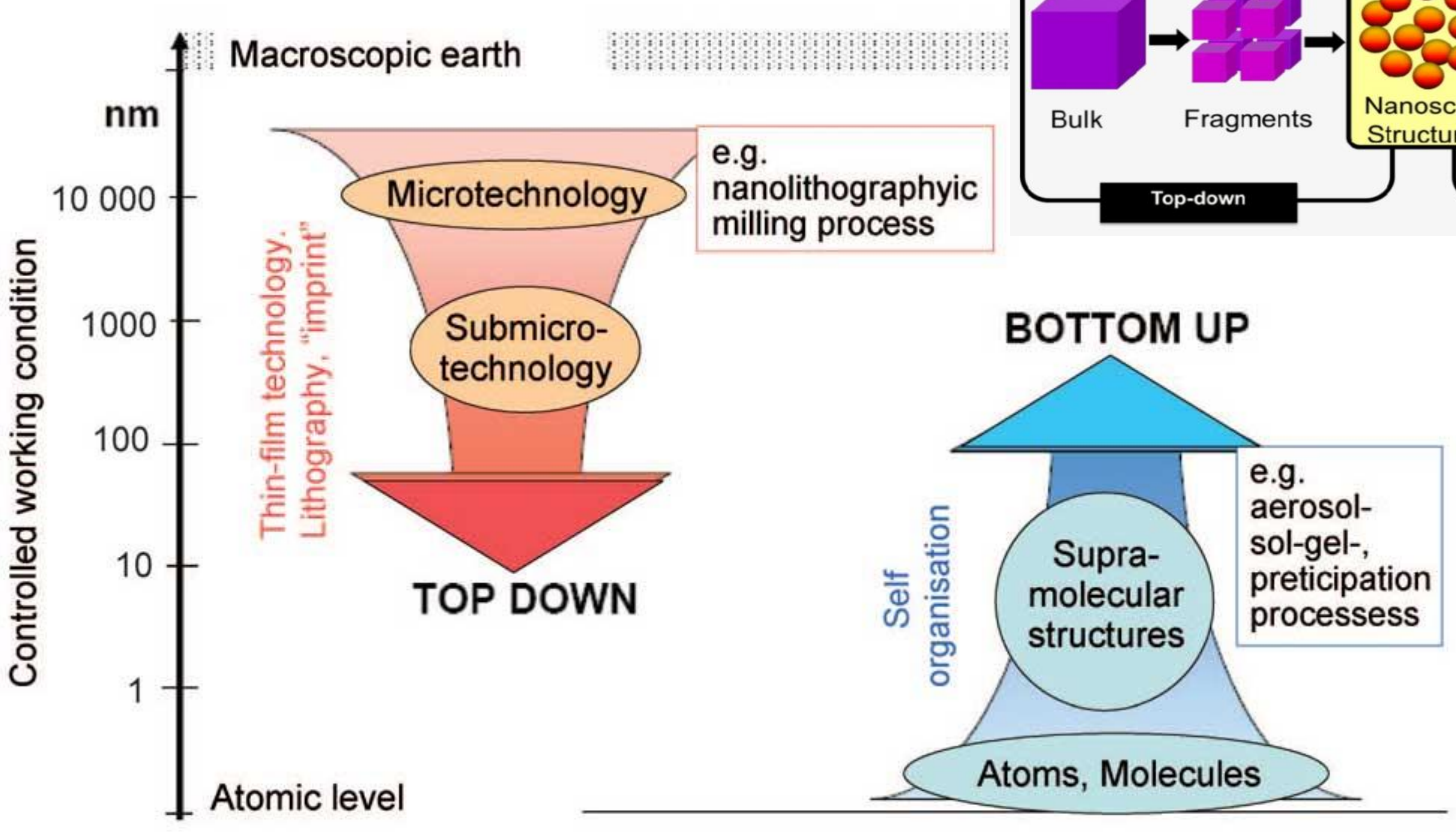


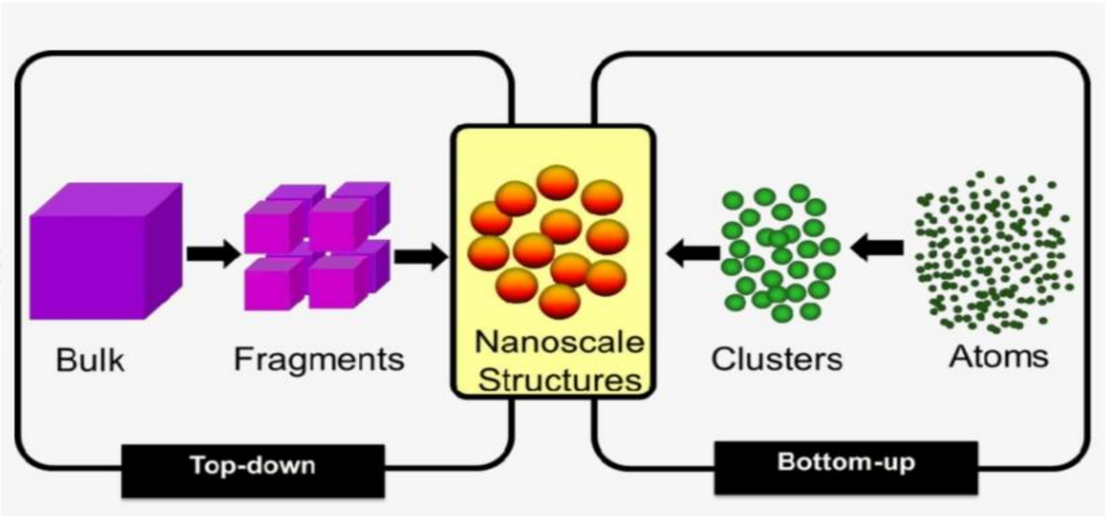
How do we create nanostructures ?



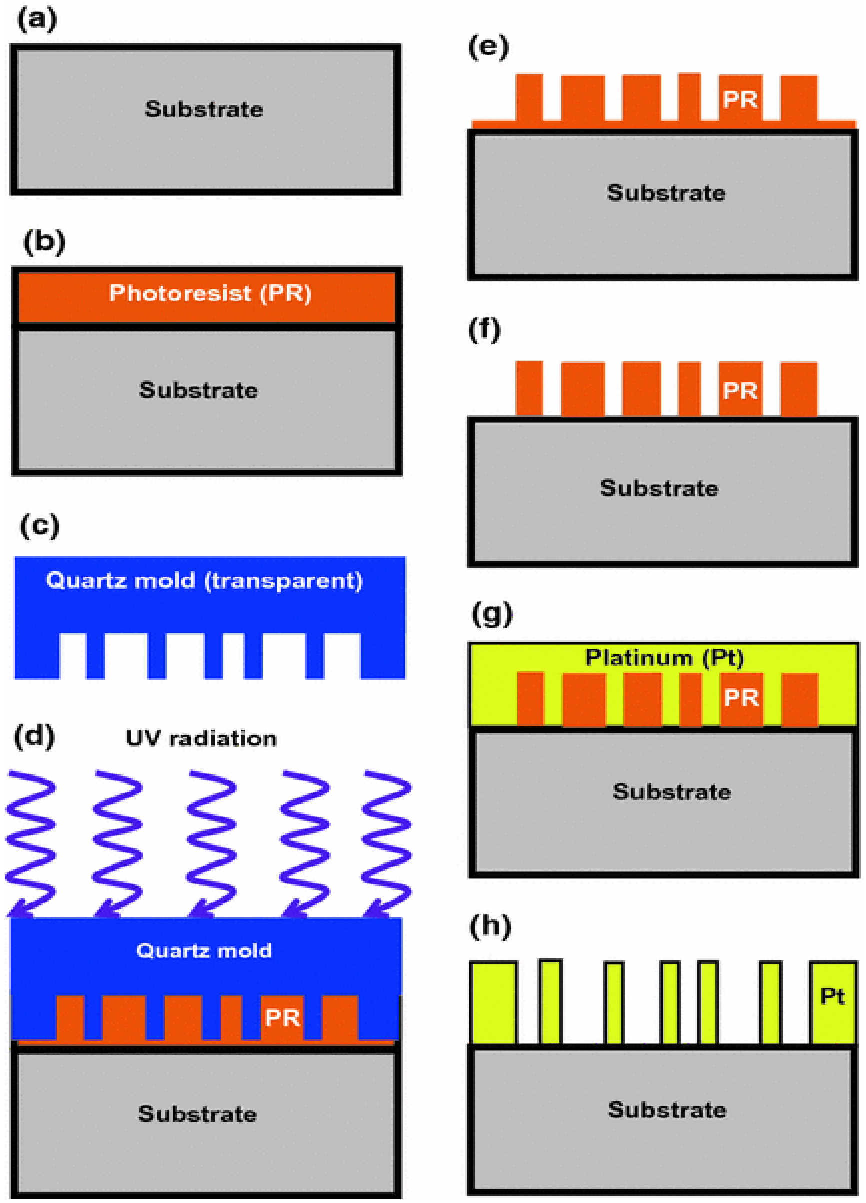


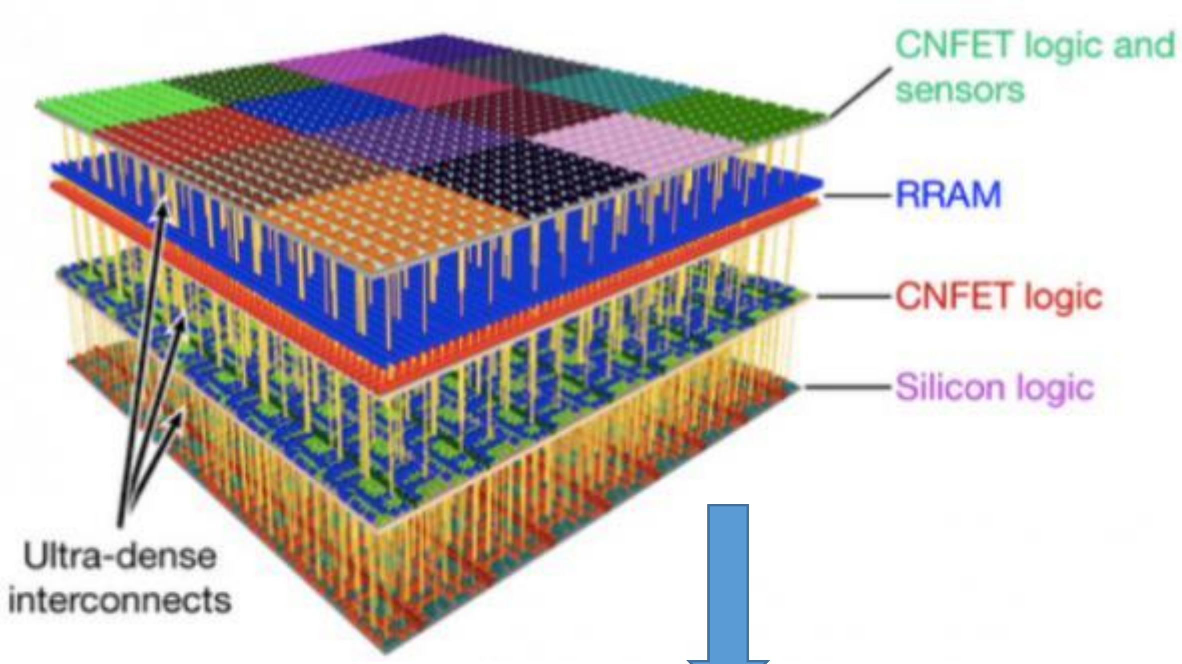
How do we create nanostructures ?

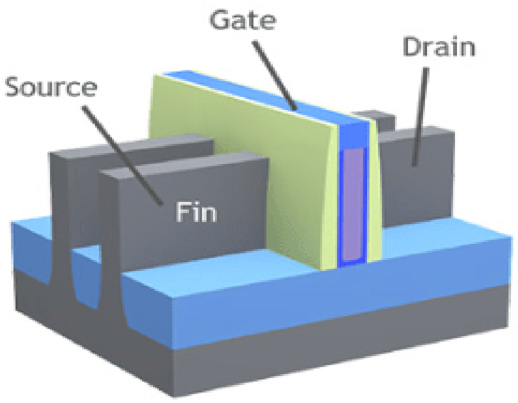




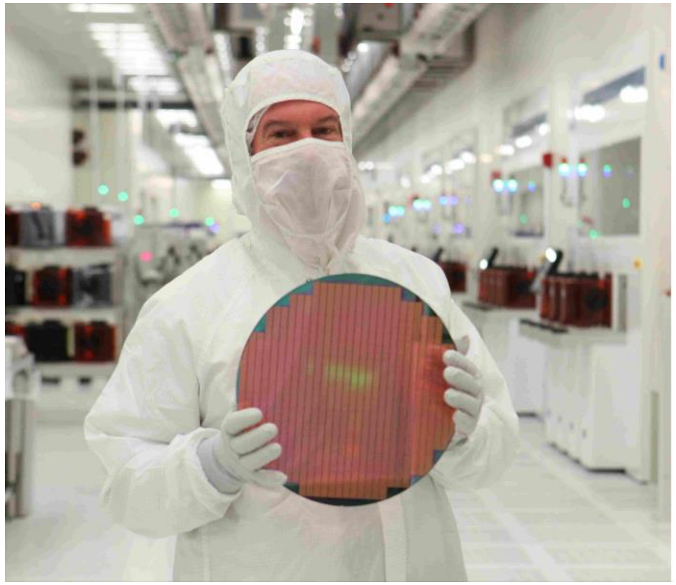
Top Down


(a)
Substrate
(b)
Photoresist (PR)
Substrate
(c)
Quartz mold (transparent)
(d)
UV radiation
Quartz mold
PR
Substrate
(e)
PR
Substrate
(f)
PR
Substrate
(g)
Platinum (Pt)
PR
Substrate
(h)
Pt
Substrate


CNFET logic and sensors
RRAM
CNFET logic
Silicon logic
Ultra-dense interconnects


Gate
Drain
Source
Fin


3
SAMSUNG
5

SOKUDO


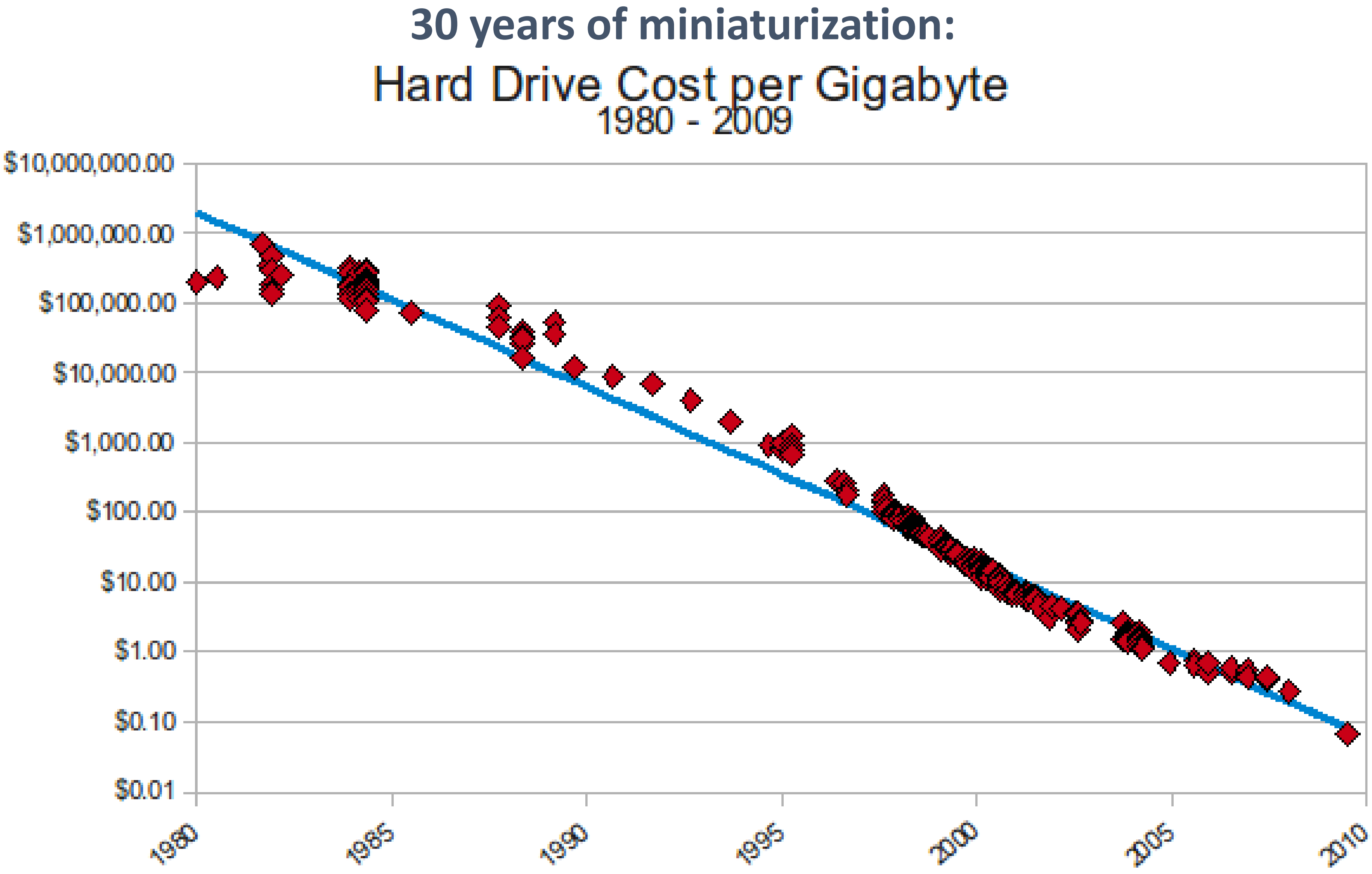
1982

675 Mb = $70,000

128Gb = $13,300,000

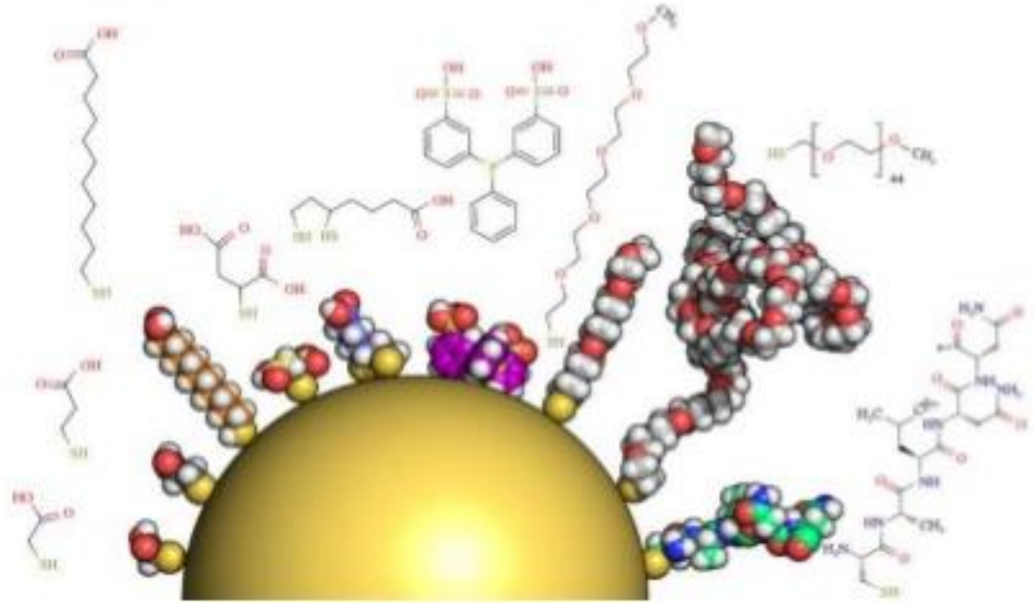
2020

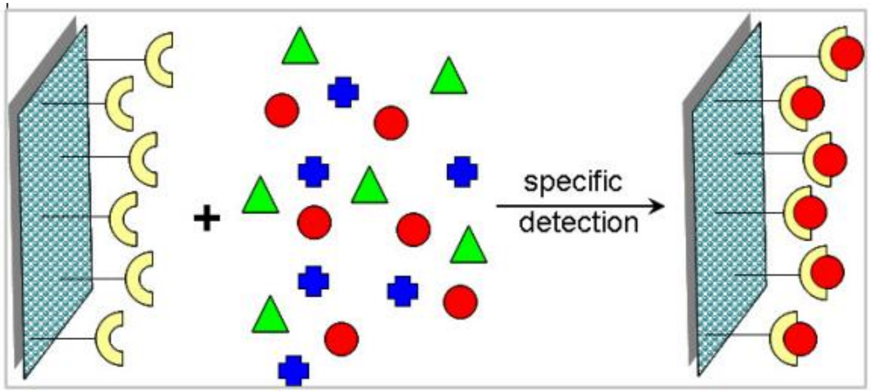
128Gb = $19



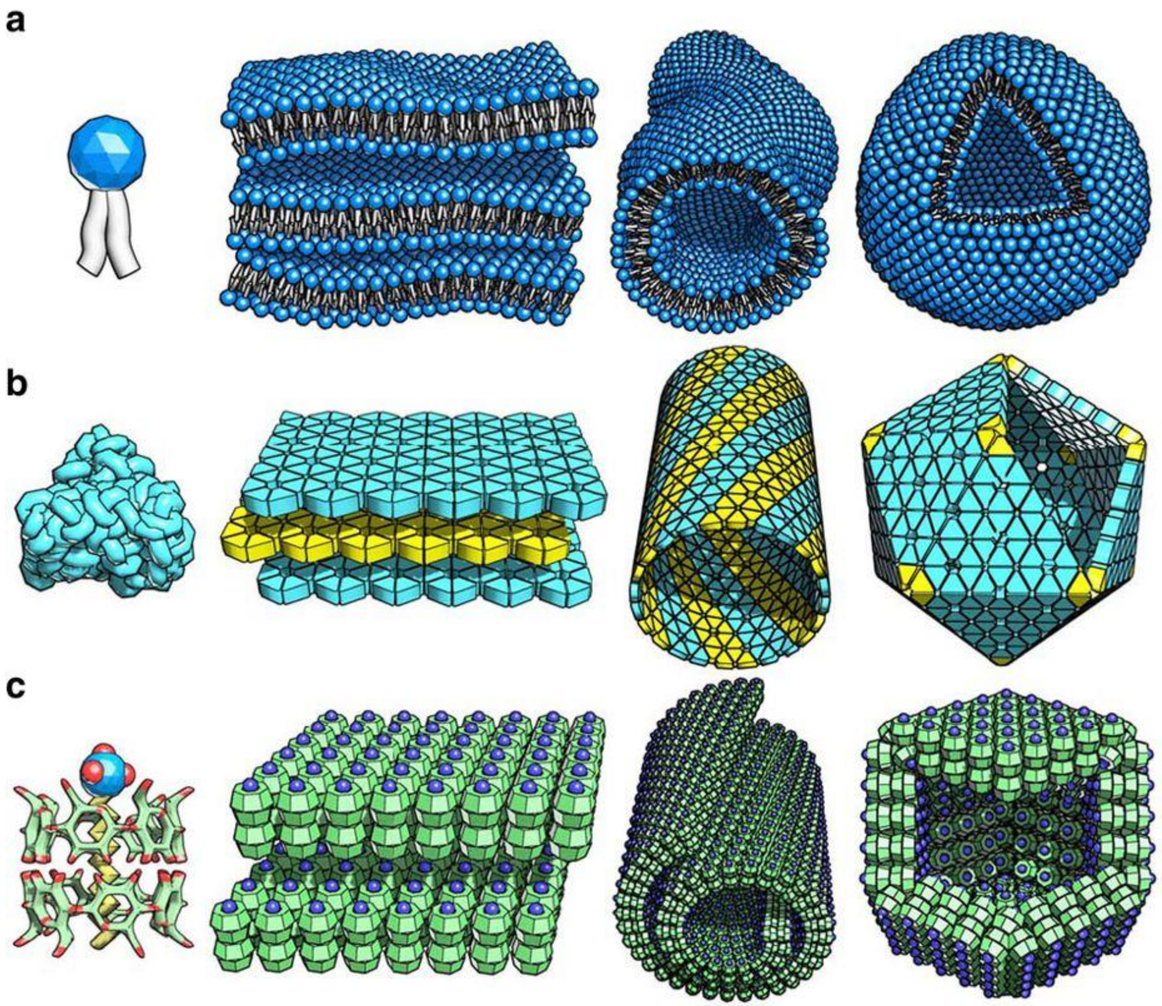
Bottom Up

- The surface coating of nanoparticles determines many of their physical and chemical properties, notably stability, solubility, and targeting. A coating that is multivalent or polymeric confers high stability.

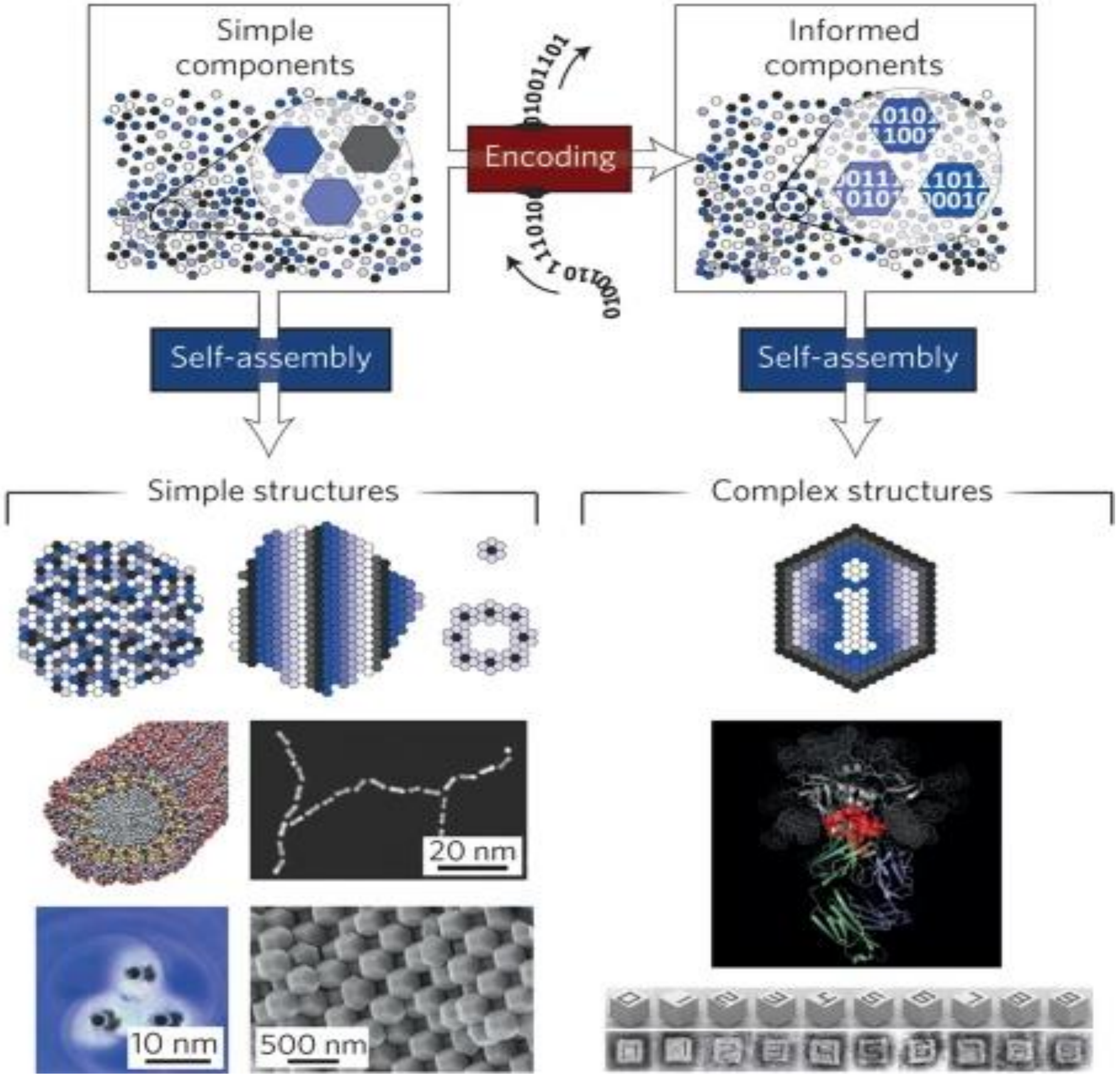


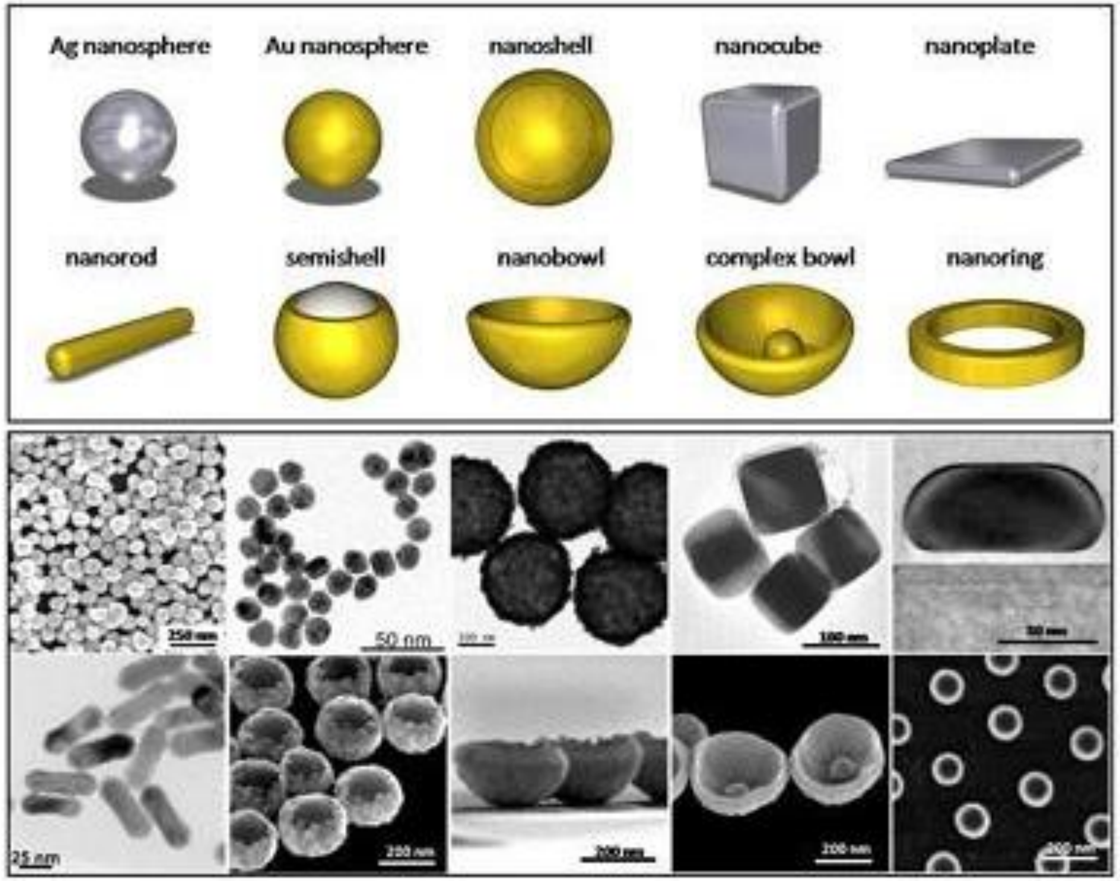


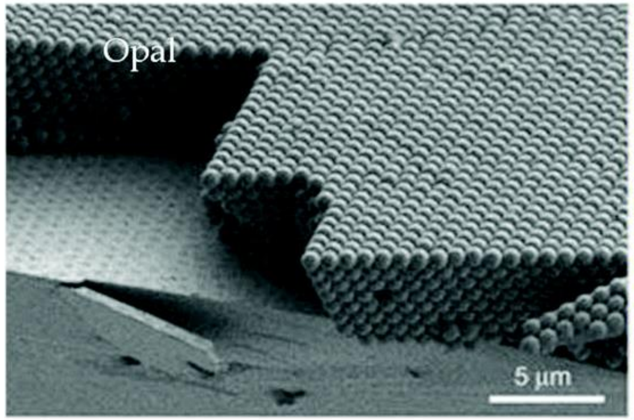
Building complex structures…
…from scratches

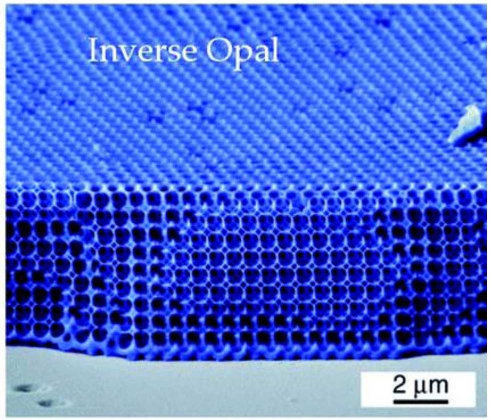


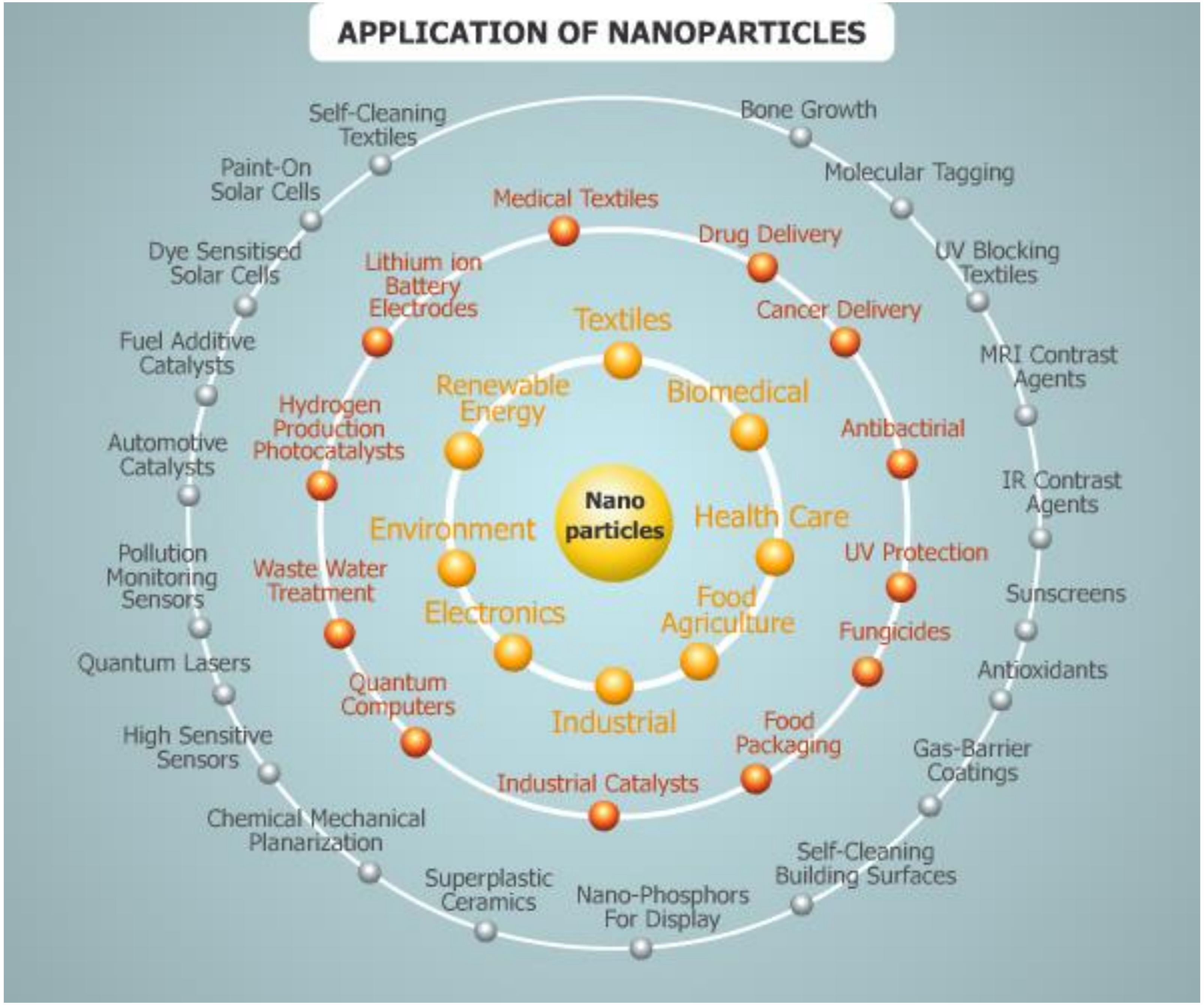
Bottom Up


Simple components
Encoding
Informed components
Self-assembly
Self-assembly
Simple structures
Complex structures
20 nm
10 nm
500 nm

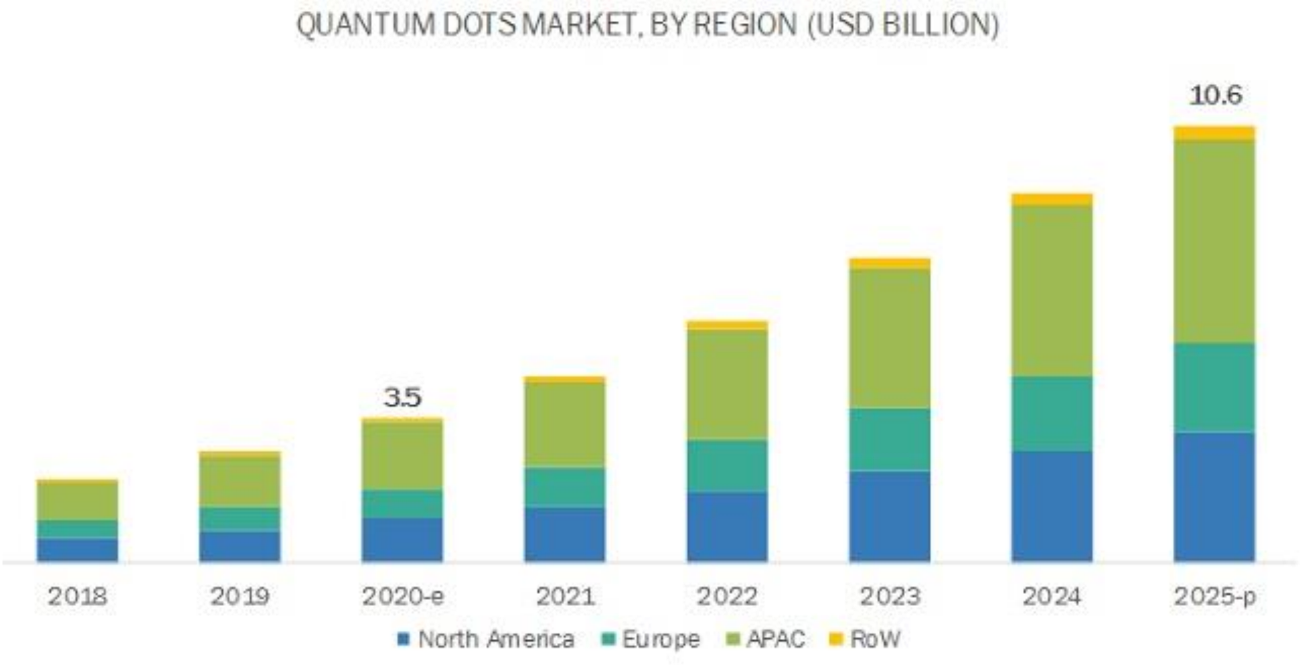

Ag nanosphere
Au nanosphere
nanoshell
nanocube
nanoplate
nanorod
semishell
nanobowl
complex bowl
nanoring
50 nm
25 nm


Opal
5 μm


Inverse Opal
2 μm

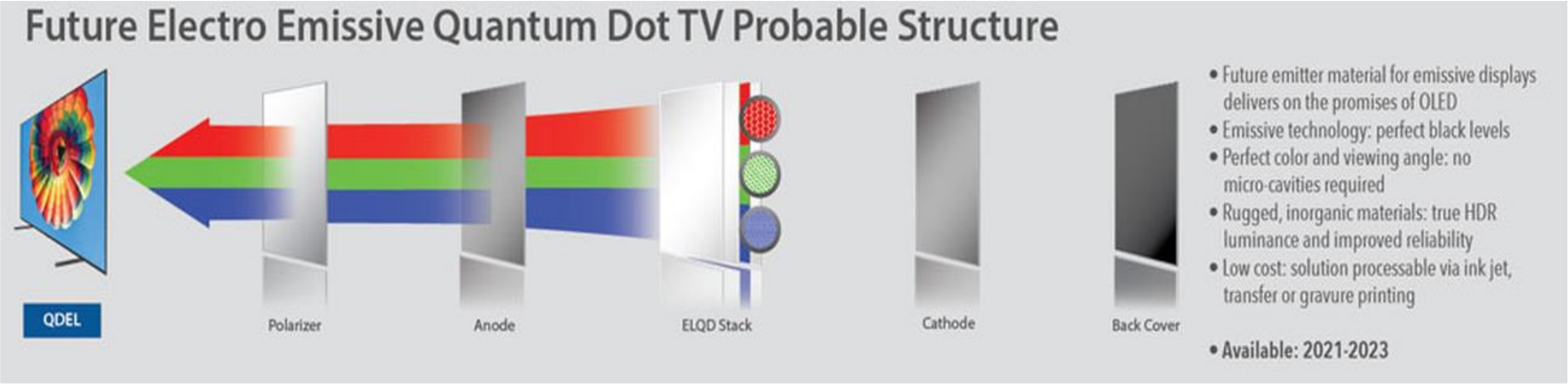

APPLICATION OF NANOPARTICLES
Nano particles
Textiles
Biomedical
Health Care
Food Agriculture
Industrial
Electronics
Environment
Renewable Energy
Medical Textiles
Drug Delivery
Cancer Delivery
Antibactirial
UV Protection
Fungicides
Food Packaging
Industrial Catalysts
Quantum Computers
Waste Water Treatment
Hydrogen Production Photocatalysts
Lithium ion Battery Electrodes
Bone Growth
Molecular Tagging
UV Blocking Textiles
MRI Contrast Agents
IR Contrast Agents
Sunscreens
Antioxidants
Gas-Barrier Coatings
Self-Cleaning Building Surfaces
Nano-Phosphors For Display
Superplastic Ceramics
Chemical Mechanical Planarization
High Sensitive Sensors
Quantum Lasers
Pollution Monitoring Sensors
Automotive Catalysts
Fuel Additive Catalysts
Dye Sensitised Solar Cells
Paint-On Solar Cells
Self-Cleaning Textiles

Applications: Displays

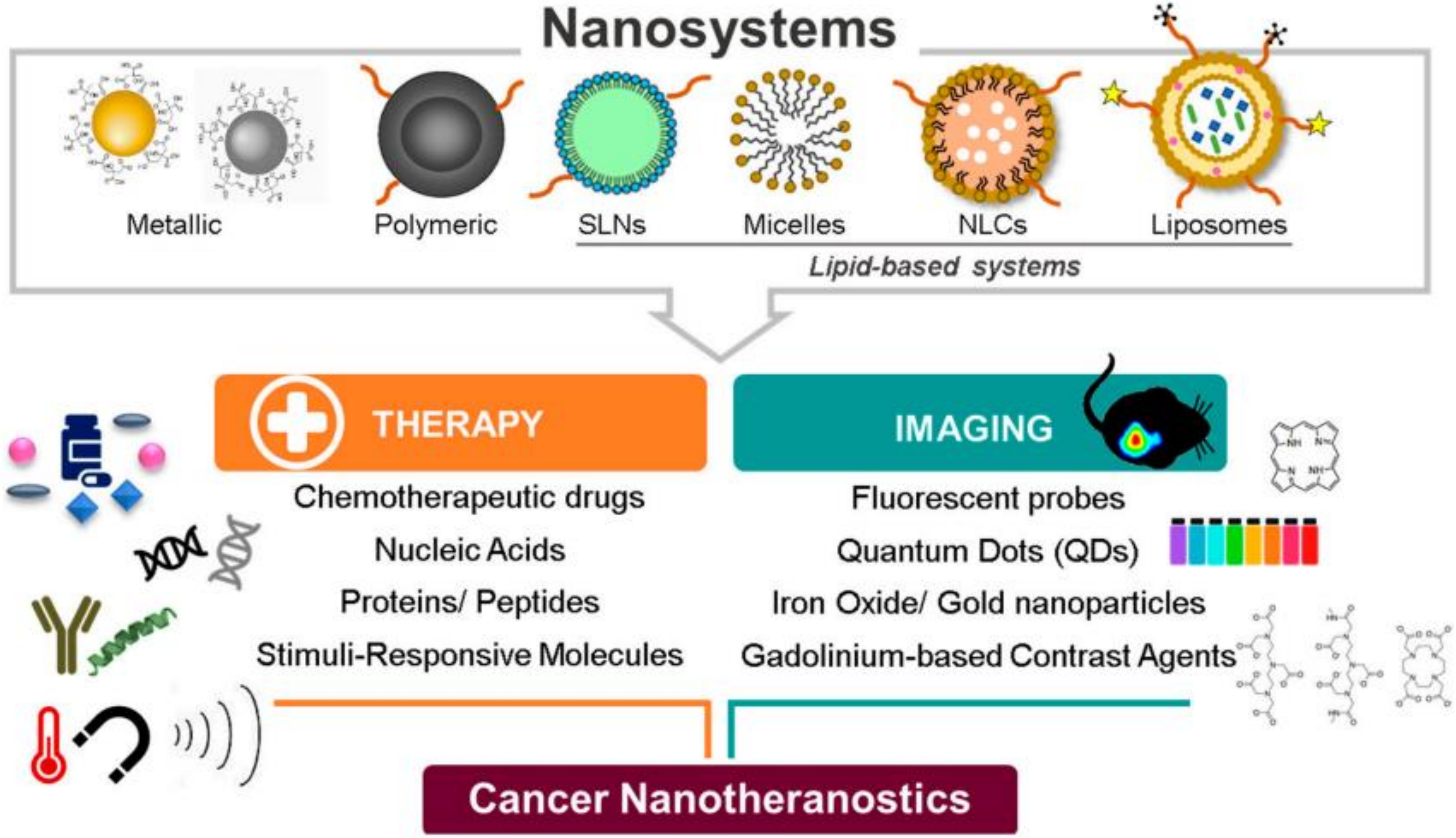


e-estimated; p-projected

Source: Industry Expert, Secondary Research, and MarketsandMarkets Analysis



Applications: Nanomedicine



Applications: an "average" mobile phone

1) QDOT Display
Trillions of Cd, Zn, In based nanoparticles
Anti-reflecting, anti-scratch, hydrohobic coatings

2) ARM CPU
170 *million* 7nm transistors per square mm
10 *billion* transistors inside

3) 20+ Mpixel Camera
Millions of 14nm FinFET technology

4) Wireless ICs (power amplifiers)
Thousands of GaAs and SiGe transistors

6) Battery / Capacitors
Nanostructured Li electrodes
Nanostructured metal-oxides electrodes

7) Various
Gold, silver, rare earths… *lead and mercury*!