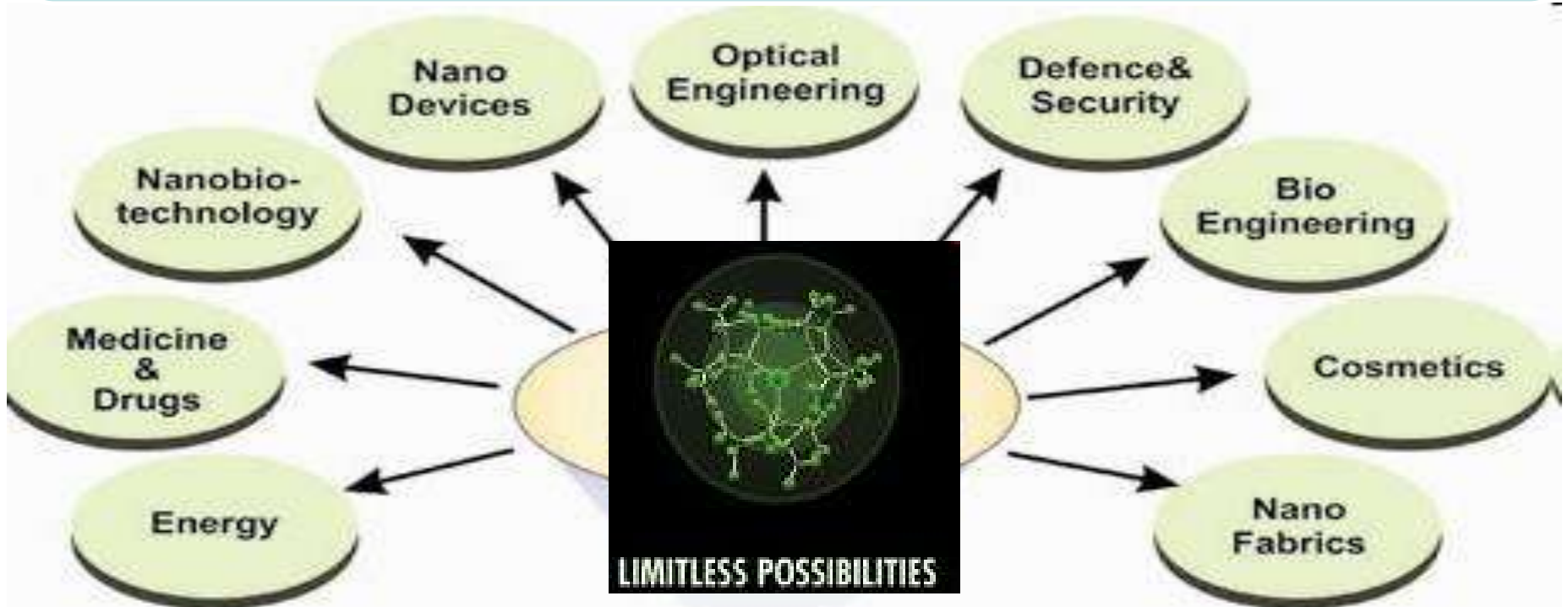


NANOTECHNOLOGY



**Multilayered Nanoparticles for Drug/Gene
Delivery in Nanomedicine**

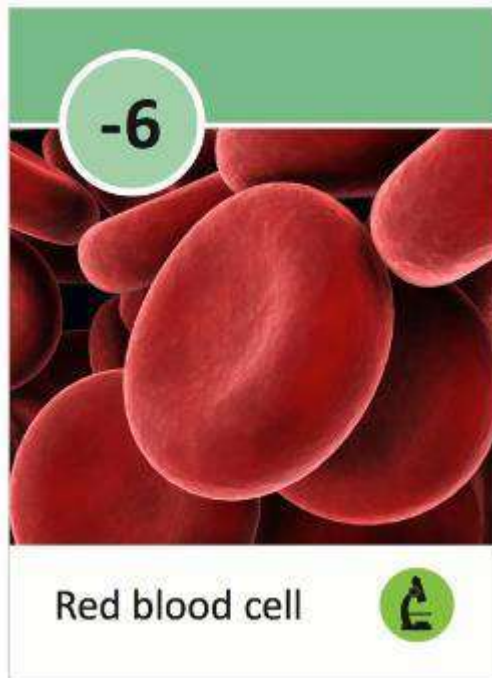
- Dr. Rajeshwara Achur

How Big is a Nanometer?



Prefixes for SI Units			
ol		Meaning	Notation
		1,000,000,000,000,000,000.	1.E+18
		1,000,000,000,000,000.	1.E+15
		1,000,000,000,000.	1.E+12
		1,000,000,000.	1.E+09
		1,000,000.	1.E+06
		1,000.	1.E+03
		100.	1.E+02
		10.	1.E+01
		1.	1.E+00
		.1	1.E-01
		.01	1.E-02
		.001	1.E-03
		.000001	1.E-06
		.000000001	1.E-09
		.0000000000001	1.E-12
		.00000000000000001	1.E-15
		.0000000000000000001	1.E-18
centi-	c	.01	1.E-02
milli-	m	.001	1.E-03
micro-	μ	.000001	1.E-06
nano-	n	.000000001	1.E-09
pico-	p	.0000000000001	1.E-12
femto-	f	.00000000000000001	1.E-15
atto-	a	.0000000000000000001	1.E-18

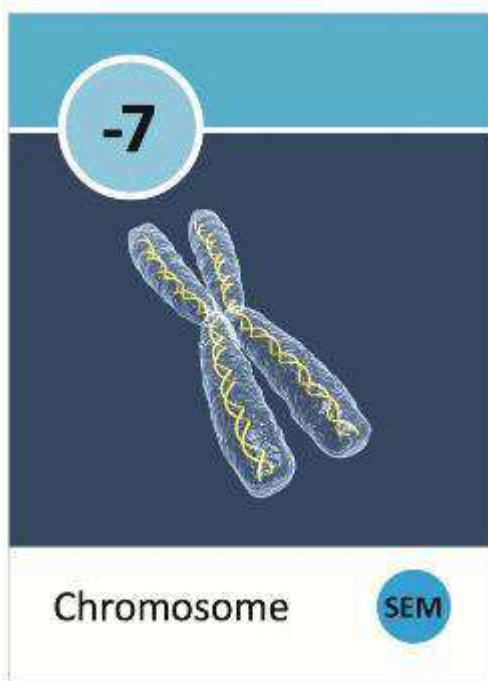
How Big is a Nanometer?



Prefixes for SI Units		
	Meaning	Notation
	1,000,000,000,000,000,000.	1.E+18
	1,000,000,000,000,000.	1.E+15
	1,000,000,000,000.	1.E+12
	1,000,000,000.	1.E+09
	1,000,000.	1.E+06
	1,000.	1.E+03
	100.	1.E+02
	10.	1.E+01
	1.	1.E+00
	.1	1.E-01
	.01	1.E-02
	.001	1.E-03
	.000001	1.E-06
	.000000001	1.E-09
	.0000000000001	1.E-12
	.0000000000000001	1.E-15
	.000000000000000001	1.E-18

centi-	c
milli-	m
micro-	μ
nano-	n
pico-	p
femto-	f
atto-	a

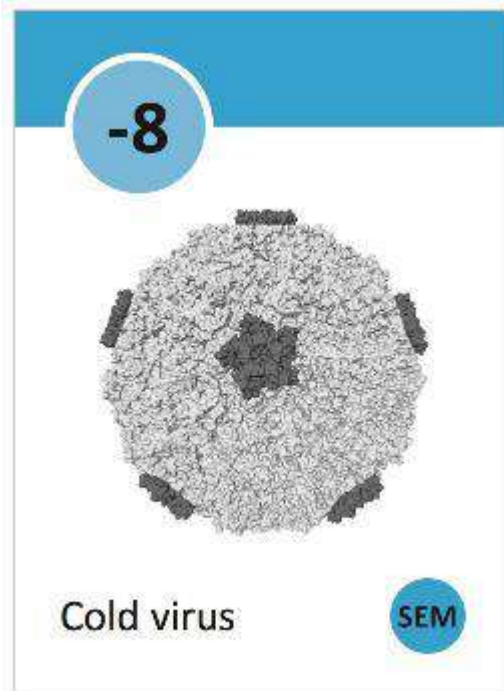
How Big is a Nanometer?



Prefixes for SI Units		
	Meaning	Notation
	1,000,000,000,000,000,000.	1.E+18
	1,000,000,000,000,000.	1.E+15
	1,000,000,000,000.	1.E+12
	1,000,000,000.	1.E+09
	1,000,000.	1.E+06
	1,000.	1.E+03
	100.	1.E+02
	10.	1.E+01
	1.	1.E+00
	.1	1.E-01
	.01	1.E-02
	.001	1.E-03
	.000001	1.E-06
	.000000001	1.E-09
	.0000000000001	1.E-12
	.0000000000000001	1.E-15
	.000000000000000001	1.E-18

centi-	c		
milli-	m		
micro-	μ		
nano-	n		
pico-	p		
femto-	f		
atto-	a		


How Big is a Nanometer?




Prefixes for SI Units			
	Meaning	Notation	
	1,000,000,000,000,000,000.	1.E+18	
	1,000,000,000,000,000.	1.E+15	
	1,000,000,000,000.	1.E+12	
	1,000,000,000.	1.E+09	
	1,000,000.	1.E+06	
	1,000.	1.E+03	
	100.	1.E+02	
	10.	1.E+01	
	1.	1.E+00	
	.1	1.E-01	
	.01	1.E-02	
	.001	1.E-03	
micro-	μ	.000001	1.E-06
nano-	n	.000000001	1.E-09
pico-	p	.000000000001	1.E-12
femto-	f	.0000000000000001	1.E-15
atto-	a	.000000000000000001	1.E-18

How Big is a Nanometer?

-9



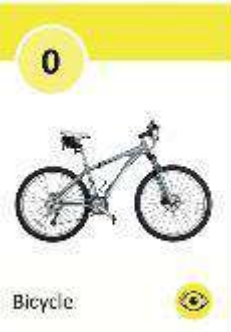
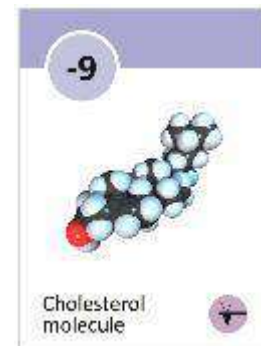
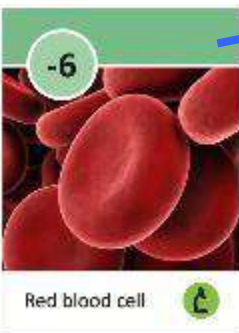
Cholesterol molecule



Prefixes for SI Units		
	Meaning	Notation
	1,000,000,000,000,000,000.	1.E+18
	1,000,000,000,000,000.	1.E+15
	1,000,000,000,000.	1.E+12
	1,000,000,000.	1.E+09
	1,000,000.	1.E+06
	1,000.	1.E+03
	100.	1.E+02
	10.	1.E+01
	1.	1.E+00
	.1	1.E-01
centi-	c	.01
milli-	m	.001
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nano-	n	.000000001
pico-	p	.000000000001
femto-	f	.0000000000000001
atto-	a	.000000000000000001

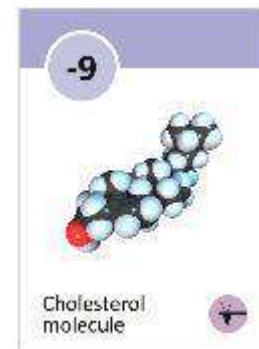
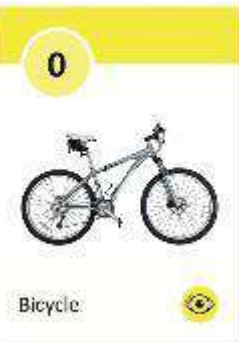
How Big is a Nanometer?

Prefixes for SI Units		
Prefix	Meaning	Notation
giga-	1,000,000,000.	1.E+09
mega-	1,000,000.	1.E+06
kilo-	1,000.	1.E+03
	1.	1.E+00
milli-	.001	1.E-03
micro-	.000001	1.E-06
nano-	.000000001	1.E-09



How Big is a Nanometer?

Prefixes for SI Units		
Prefix	Meaning	Notation
giga-	1,000,000,000.	1.E+09
mega-	1,000,000.	1.E+06
kilo-	1,000.	1.E+03
	1.	1.E+00
milli-	.001	1.E-03
micro-	.000001	1.E-06
nano-	.000000001	1.E-09



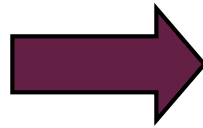
How Big is a Nanometer?

- In the time it takes to read this sentence, your fingernails will have grown approximately one nanometer (1 nm).



How Big is a Nanometer?

- If you could paint a teaspoon of paint one nanometer thick, how much area would it cover?



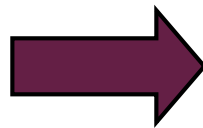
How Big is a Nanometer?

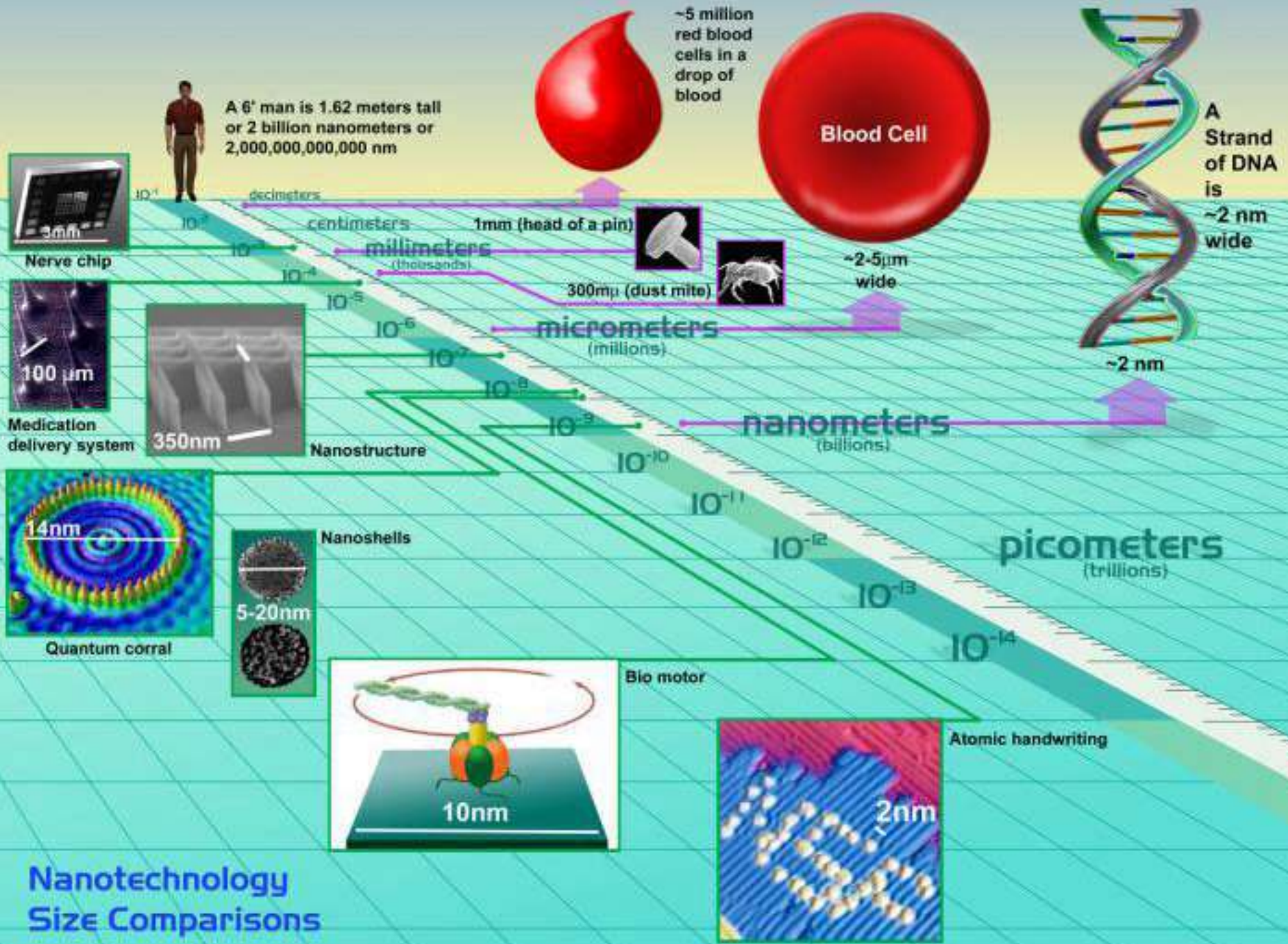
- If you could paint a teaspoon of paint one nanometer thick, how much area would it cover?



How Big is a Nanometer?

- To cover a football field with a 1 nm thick layer of paint, you would need just **1 teaspoon** of paint!







Cat
~ 0.3 m



Monarch butterfly
~ 0.1 m



Dust mite
300 μm



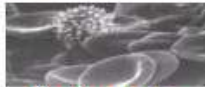
Bee
~ 15 mm



Human hair
~ 50 μm wide



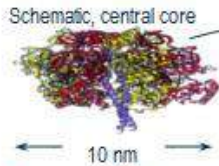
Staphylococcus = 1 μm



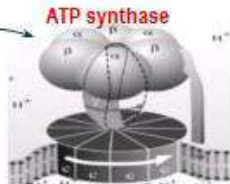
Red blood cells
with white cell
~ 2-5 μm



Ebolavirus
Diameter 50nm,
length 1000nm



Schematic, central core
10 nm



ATP synthase

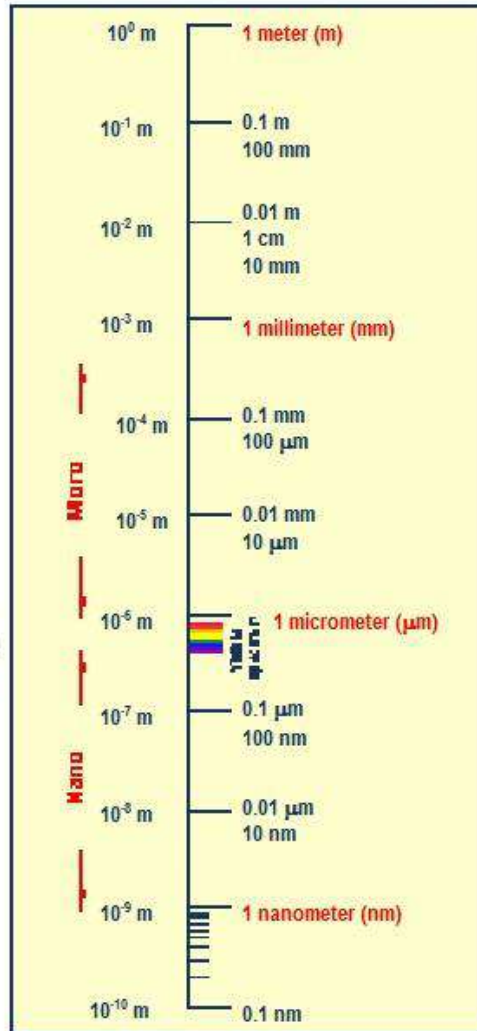


DNA
~ 2 nm wide



Atoms of silicon
spacing ~ tenths of nm

SELF ASSEMBLY



MINIATURIZATION



Objects fashioned from
metals, ceramics, glasses, polymers ...



Head of a pin
1-2 mm



Printed circuit board

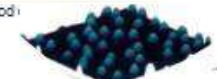
MEMS (MicroElectroMechanical Systems)



10-100 μm wide



Indium arsenide
quantum dot



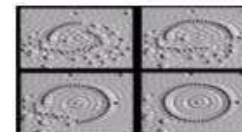
Quantum dot array --
germanium dots on silicon



Smallest
feature size
on a computer
Chip (2005)



Self-assembled
"mushroom"

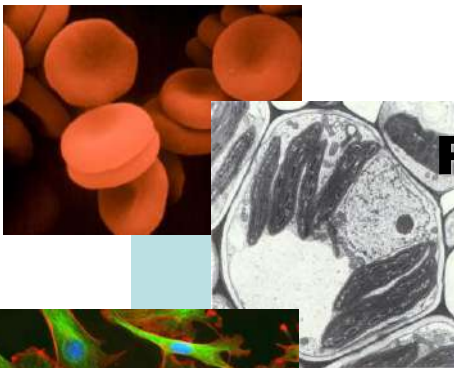


Quantum corral of 48 iron atoms on copper surface
positioned one at a time with an STM tip
Corral diameter 14 nm

The Scale of the Biological World

100 μm
Plant & Animal Cells

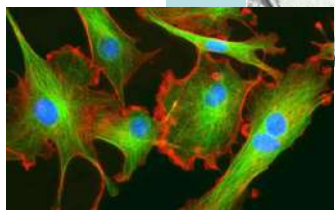
$1 \times 10^4 \text{ m}$



10 μm

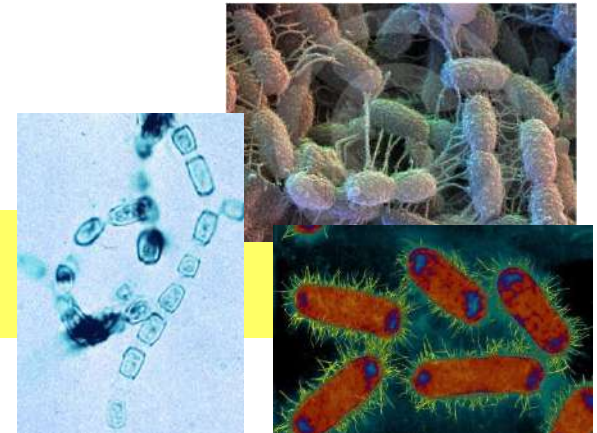
Bacterial Cells

$1 \times 10^5 \text{ m}$



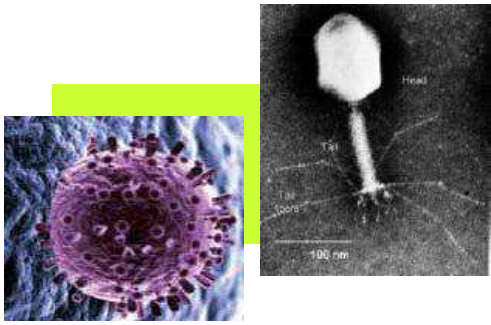
1 μm

$1 \times 10^6 \text{ m}$



100 nm
Viruses

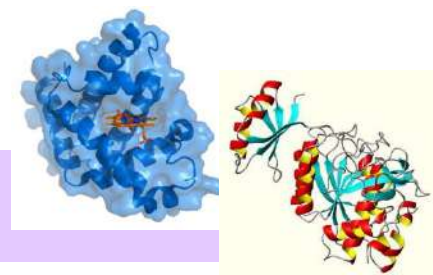
$1 \times 10^7 \text{ m}$



10 nm

Proteins

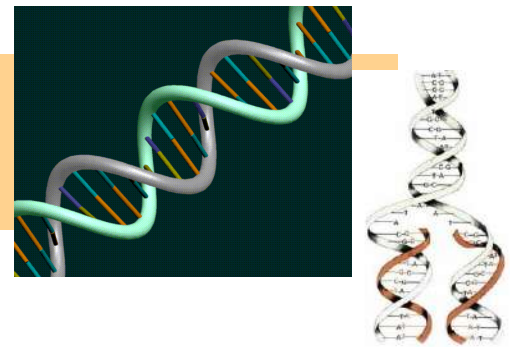
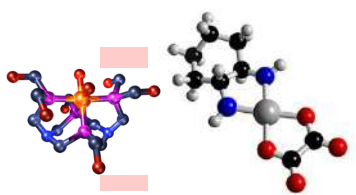
$1 \times 10^8 \text{ m}$



Small Molecules

1 nm

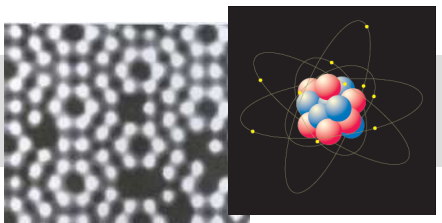
$1 \times 10^9 \text{ m}$



Atoms

1 \AA

$1 \times 10^{10} \text{ m}$



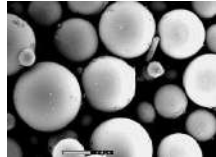
The Scale of Things – Nanometers and More



Dust mite
↔
200 μm



Ant
~ 5 mm

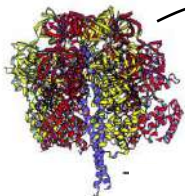


Fly ash
~ 10-20 μm

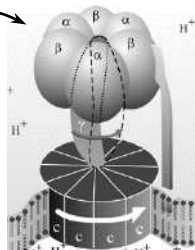


Human hair
~ 60-120 μm wide

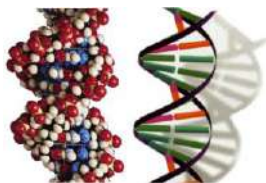
Red blood cells
(~7-8 μm)



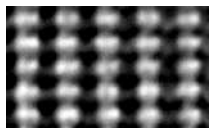
~10 nm diameter



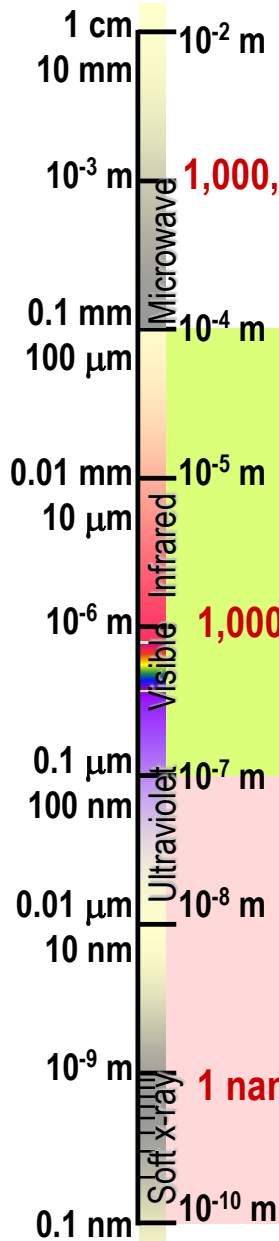
ATP synthase



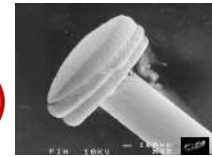
DNA
~2-1/2 nm diameter



Atoms of silicon
spacing 0.078 nm



1,000,000 nanometers = 1 millimeter (mm)



Head of a pin
1-2 mm

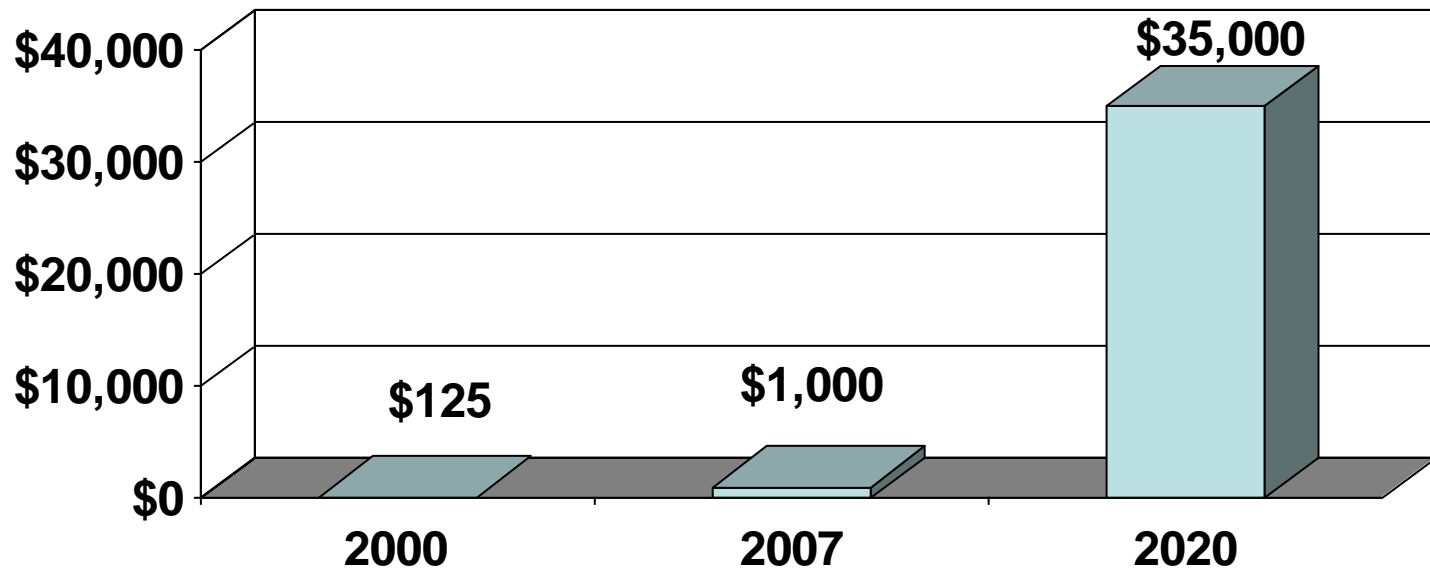
Micro-technology
“The Micro World”

Nanotechnology
“The Nano World”

1 nanometer (nm)

U.S Market Nanomaterials Projections

(In Billions)

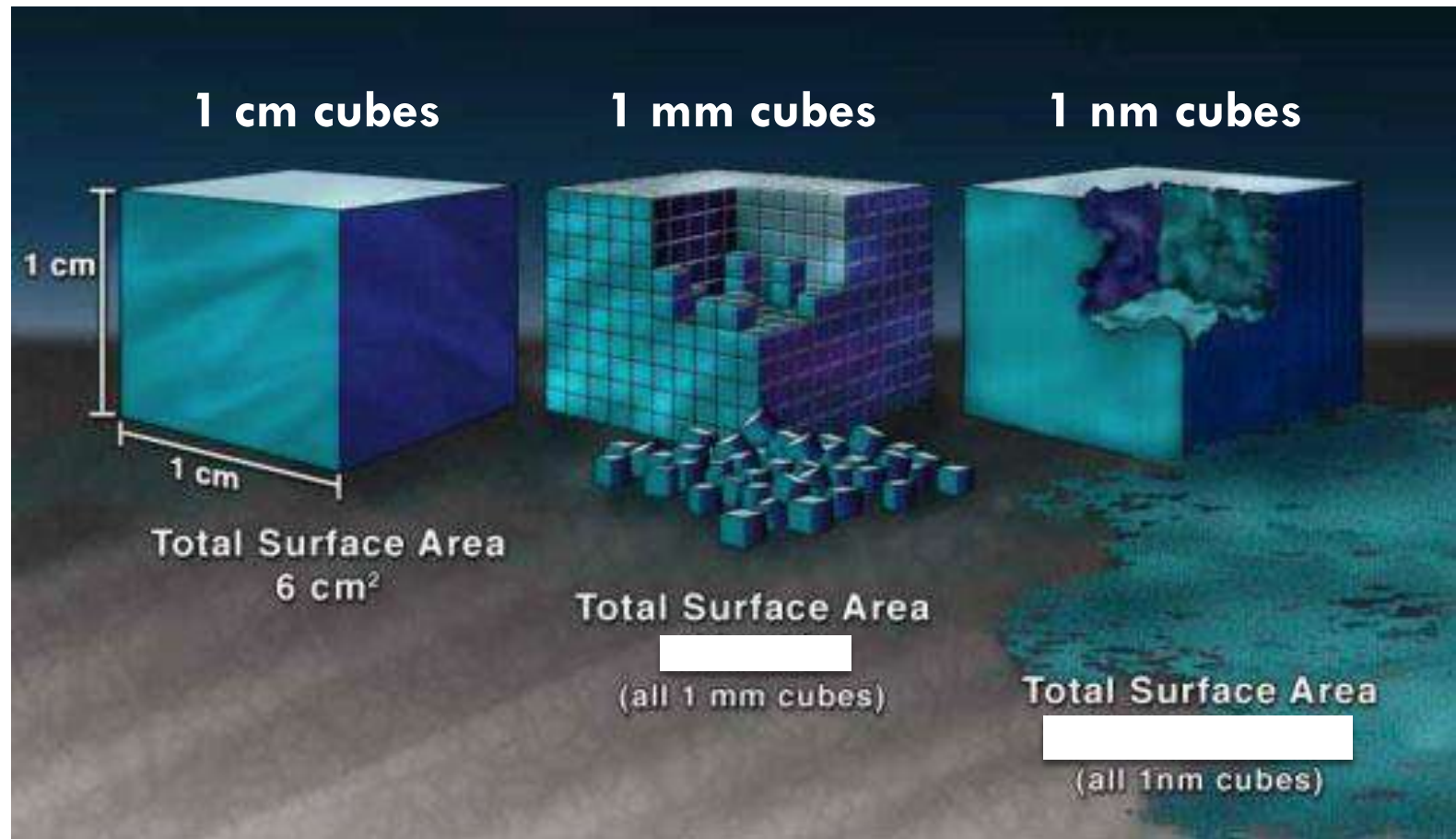


Source: The Fredonia Group

Why is the nanometer scale different?

1. The wavelike properties of electrons inside matter are influenced by variations on the nanometer scale.
2. The systematic organization of matter on the nanometer length scale is a key feature of biological systems.
3. Nanoscale components have very high surface areas.
4. The finite size of material entities, determine an increase of the relative importance of surface tension and local electromagnetic effects.
5. The interaction wavelength scales of various external wave phenomena become comparable to the material entity size.

Surface Areas at the Nanoscale



What is so special about the Nanoscale?

- Scale at which quantum effects dominate properties of material
- Scale at which much biology occurs
- Scale at which surfaces and interfaces play a larger role in material properties and interactions

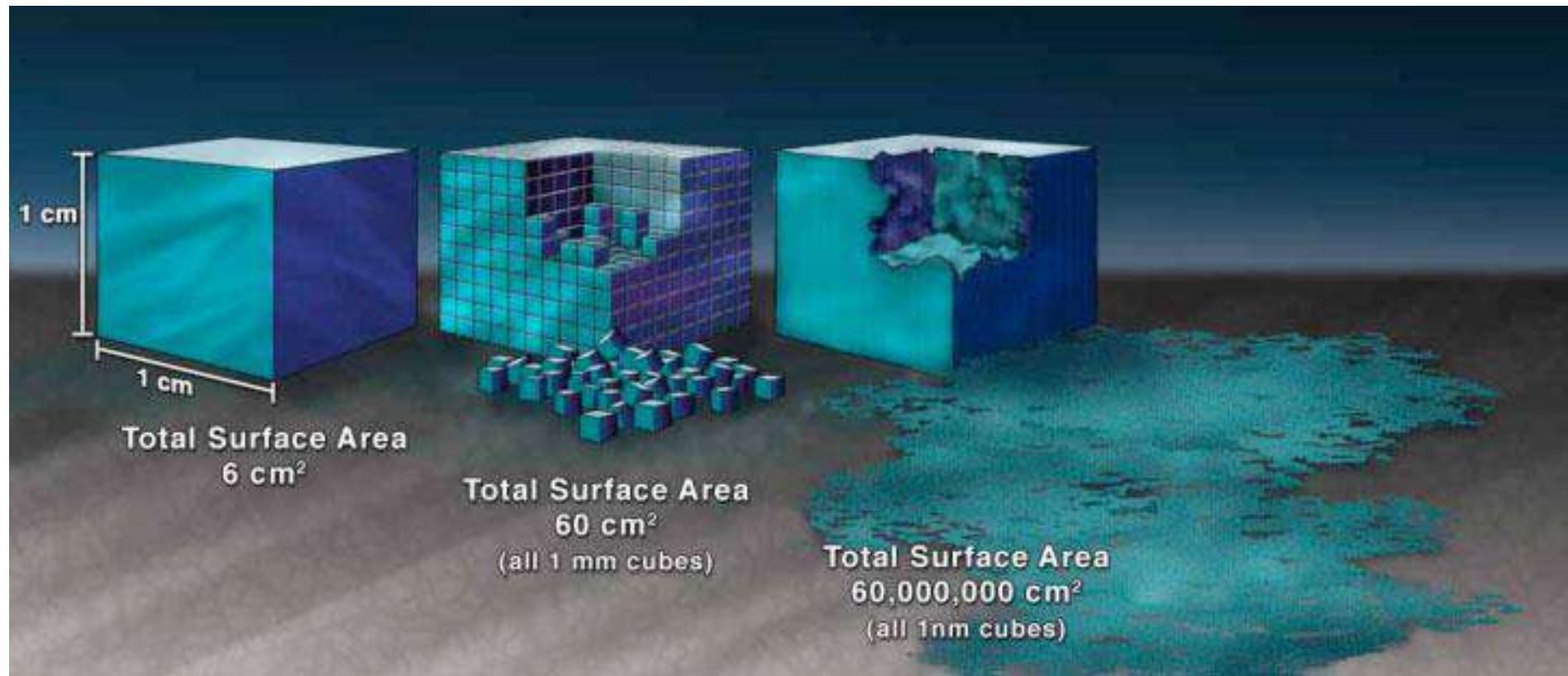
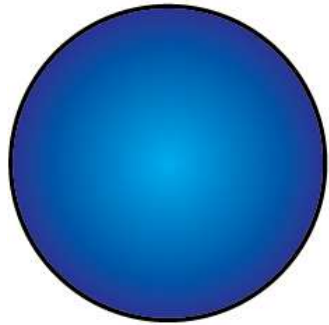


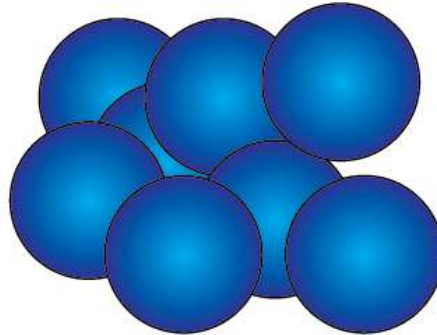
Illustration demonstrating the effect of the increased surface area provided by nanostructured materials

How Surface Area Scales (Changes)

Single particle
(radius = 1 cm)



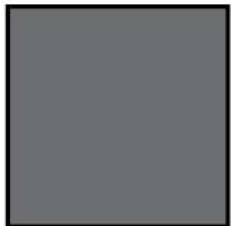
8 particles
(radius = 0.5 cm)



Same total
volume
(4.2 cm³)



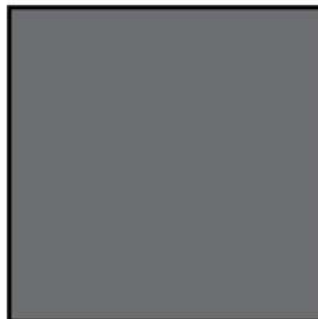
Surface area =
12.6 cm²



Surface
area
doubles



Surface area =
25.1 cm²

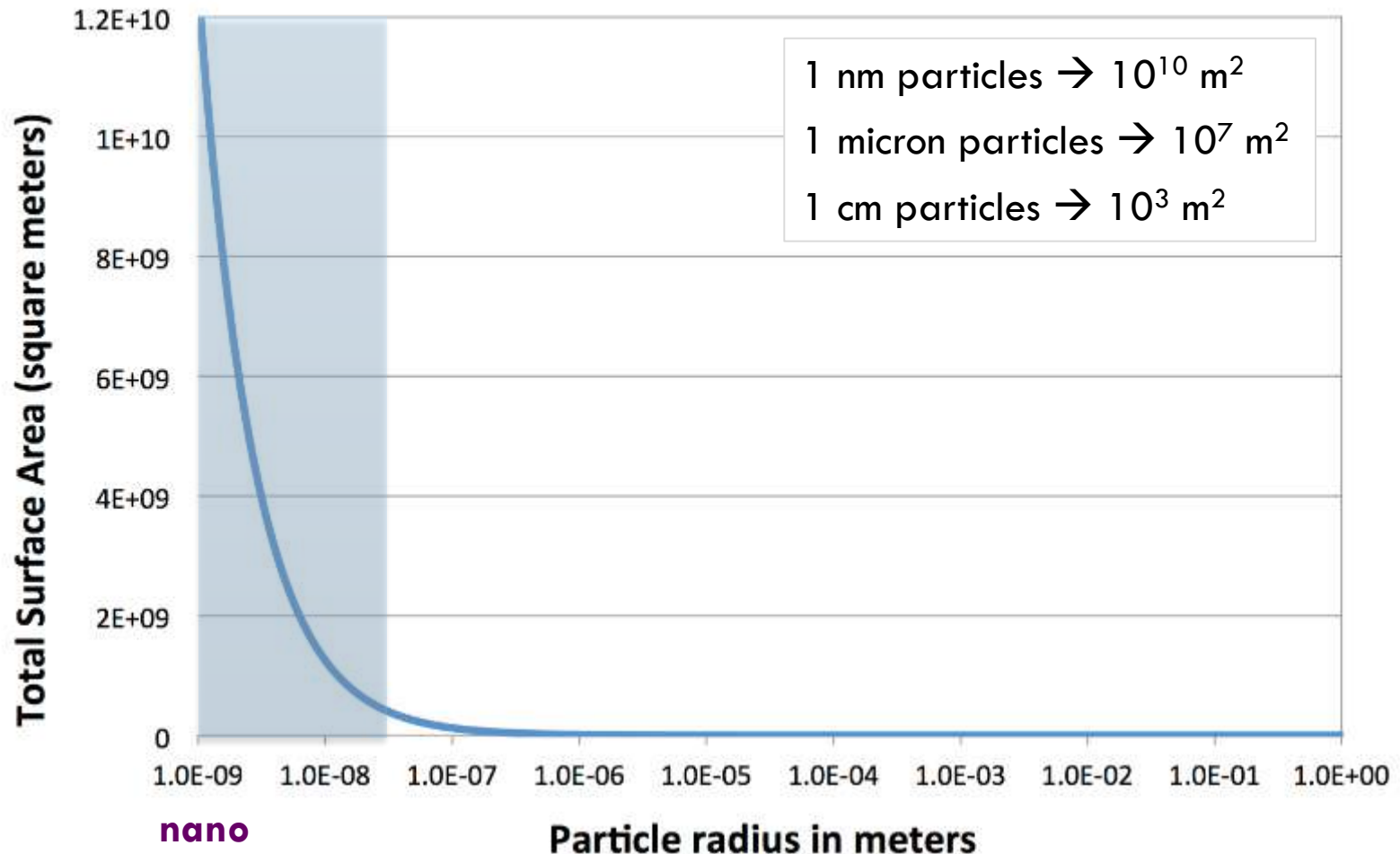


For a fixed total volume, decreasing the radius by a factor of two doubles the surface

Crushing a 1 cm particle into nano particles increases the surface area thousands of times!

How Surface Area Scales (Changes)

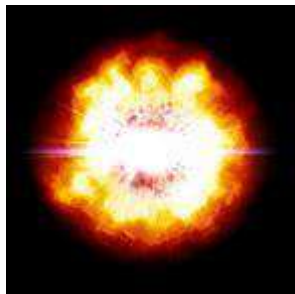
How Particle Size Affects the Surface Area



Smallness Leads to New Properties



Bulk Aluminum



Nano Aluminum

Reactivity
Melting point
Strength
Conductivity
Color



Bulk Gold



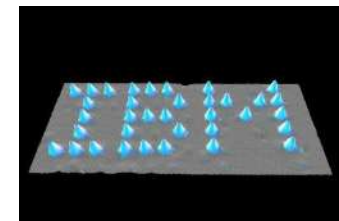
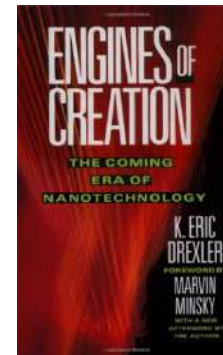
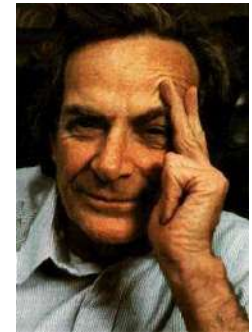
Nano Gold

Nanoscale Size Effect

- Realization of miniaturized devices and systems while providing more functionality
- Attainment of high surface area to volume ratio
- Manifestation of novel phenomena and properties, including changes in:
 - Physical Properties (e.g. melting point)
 - Chemical Properties (e.g. reactivity)
 - Electrical Properties (e.g. conductivity)
 - Mechanical Properties (e.g. strength)
 - Optical Properties (e.g. light emission)

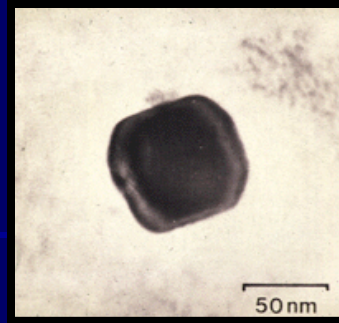
History of Nanotechnology

- ~ **2000 Years Ago** – Sulfide nanocrystals used by Greeks and Romans to dye hair
- ~ **1000 Years Ago (Middle Ages)** – Gold nanoparticles of different sizes used to produce different colors in stained glass windows
- **1959** – “There is plenty of room at the bottom” by R. Feynman
- **1974** – “Nanotechnology” - Taniguchi uses the term nanotechnology for the first time
- **1981** – IBM develops Scanning Tunneling Microscope
- **1985** – “Buckyball” - Scientists at Rice University and University of Sussex discover C_{60}
- **1986** – “Engines of Creation” - First book on nanotechnology by K. Eric Drexler. Atomic Force Microscope invented by Binnig, Quate and Gerber
- **1989** – IBM logo made with individual atoms
- **1991** – Carbon nanotube discovered by S. Iijima
- **1999** – “Nanomedicine” – 1st nanomedicine book by R. Freitas
- **2000** – “National Nanotechnology Initiative” launched



Nanocomposites

- Resulting nanocomposite may exhibit drastically different (often *enhanced*) properties than the individual components
 - Electrical, magnetic, electrochemical, catalytic, optical, structural, and mechanical properties



Lycurgus Cup



Lycurgus Cup is made of glass.

Roman ~400 AD,
Myth of King Lycurgus

Appears green in reflected light and red in transmitted light

http://www.britishmuseum.org/explore/highlights/highlight_objects/pe_mla/t/the_lycurgus_cup.aspx

Nanocomposites

The Institute of Nanotechnology <http://www.nano.org.uk/>

The First Nanotechnologists

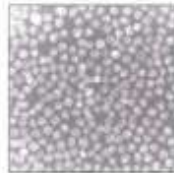
Ancient stained-glass makers knew that by putting varying, tiny amounts of gold and silver in the glass, they could produce the red and yellow found in stained-glass windows. Similarly, today's scientists and engineers have found that it takes only small amounts of a nanoparticle, precisely placed, to change a material's physical properties.

Gold particles in glass

Size: 25 nm
Shape: sphere
Color reflected:

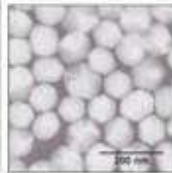


100 nanometers =
0.0001 millimeter



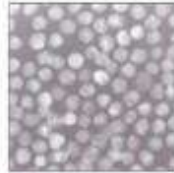
Silver particles in glass

Size: 100 nm
Shape: sphere
Color reflected:

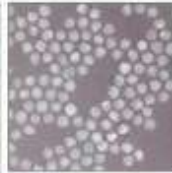


Had medieval artists been able to control the size and shape of the nanoparticles, they would have been able to use the two metals to produce other colors. Examples:

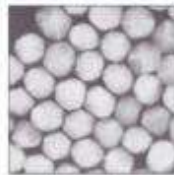
Size: 50 nm
Shape: sphere
Color reflected:



Size: 40 nm
Shape: sphere
Color reflected:



Size: 100 nm
Shape: sphere
Color reflected:



Size: 100 nm
Shape: prism
Color reflected:



Source: Dr. David A. Hristov, Institute of Nanotechnology, Nottingham University

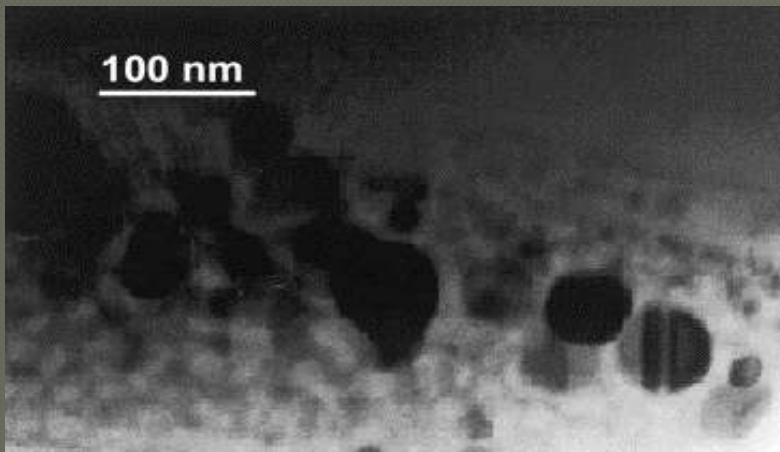
*Approximate

**Technology re-
discovered in the
1600s and used
for colored
stained glass
windows**



History

- Have been documented to in use since the use 9th century in Mesopotamia for ancient pottery



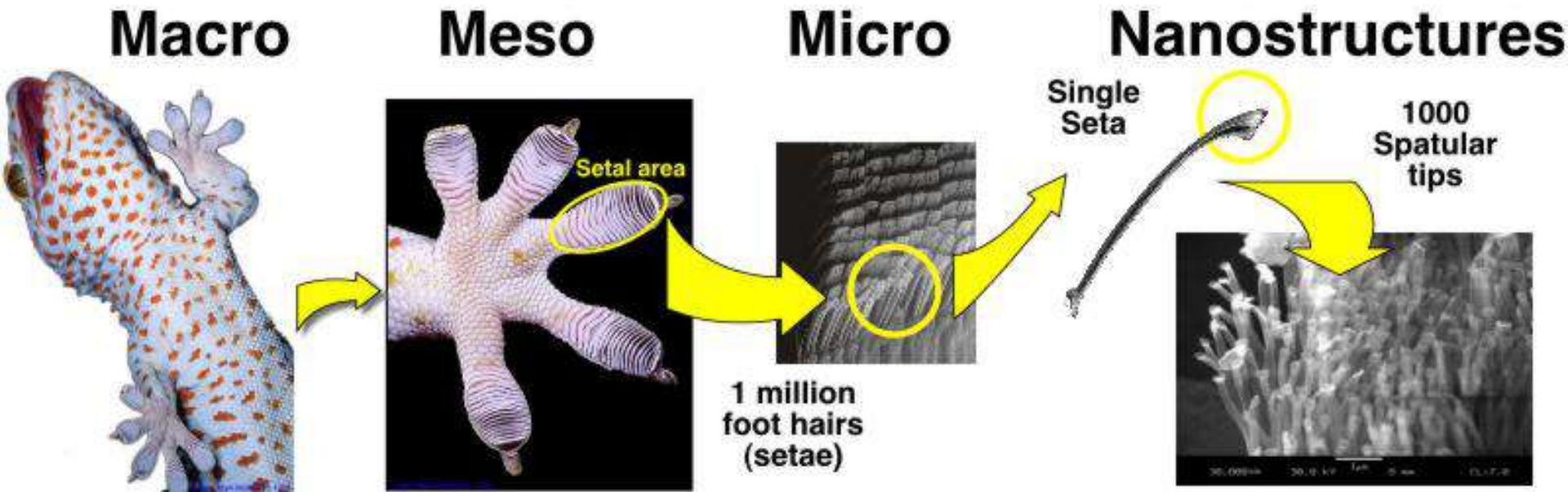
- Gold particles nanoscaled have optical properties that cause the luster

Geckos Walk on Walls



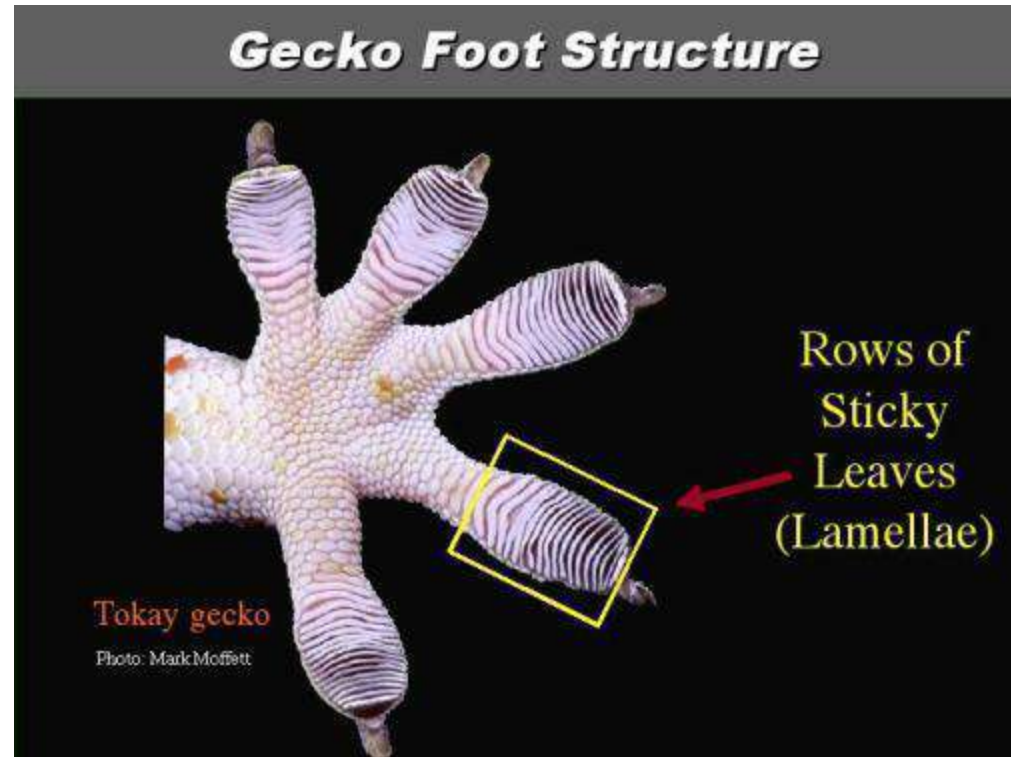
Nano-Finger Tips Allow Geckos to Stick

Gecko adhesive system



Nano-adhesion mechanism of Gecko

- * Many hypotheses
 - Suction: Gadow, 1901
 - Electrostatics: Schmidt, 1904
 - Friction: Madhendra, 1941
 - Micro-interlocking:
Madhendra, 1941
 - Capillary wet adhesion



Ref):<http://www.lclark.edu/~autumn/climbing/climb.html>

Nanoscale Processes and Fabrication

<u>Top-down Approaches</u>	<u>Bottom-up Approaches</u>
Optical and x-ray lithography	Layer-by-layer self assembly
E-beam and ion-beam lithography	Molecular self assembly
Scanning probe lithography	Direct assembly
Atomic force microscopic lithography	Coating and growth
Material removal and deposition (Chemical, mechanical, or ultrasonic)	Colloidal aggregation
Printing and imprinting	

END
LECTURE 1