Nanobiotechnology

BT603, Even Sem 2025-2026

M01

Introduction to Nanobiotechnology

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NANOBIOTECHNOLOGY [BT603]

Course Highlighys

THEORY

- HISTORY OF NANOBIOTECHNOLOGY
- WHAT ARE NANOPARTICLES
- WHAT IS NANOTECHNOLOGY
- HOW ARE THEY SYNTHESIZED
- HOW ARE THEY CHARACTERIZED
- WHAT ARE THE APPLICATIONS
- ARE THEY TOXIC TO NATURE?
- ETHICAL AND LEGAL ASPECT

PRACTICAL

- CHEMICAL SYNTHESIS
- BIOLOGICAL SYNTHESIS
- GREEN SYNTHESIS
- CHARACTERIZATION
- APPLICATION

COURSE NAME: NANOBIOTECHNOLOGY
COURSE CODE: BT603
COURSE COORDINATOR: AVINASH KADAM, PHD (avinash.kadam@mituniversity.edu.in)
PREETAM BALA, PHD (preetam.bala@mituniversity.edu.in)

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Disclaimer:

The content delivered here should be considered of utmost importance. However, it is to be noted that, this material is not Stand-alone material for the fulfilment of the course syllabus. The content in this presentation should only be used as an aid to learning.

Books and other resources provided are suggested to be referred for exhaustive understanding.

Module 1: Introduction (05 hours)

Introduction and History:

Scientific revolutions –Time and length scale in structures – Definition of a Nano-system – Dimensionality and size dependent phenomena – Surface to volume ratio -Fraction of surface atoms, Classification based on dimensionality

Nanomaterials in Biotechnology:

Quantum Dots, Wells and Wires - Carbon-based Nano materials (buckyballs, nanotubes, graphene) – Metal based nanomaterials (Nano gold, Nano silver and metal oxides) -Nano composites- Nano polymers – Nano glasses –Nano ceramics

Biological nanomaterials – Cells, proteins, lipids, genes, polymers

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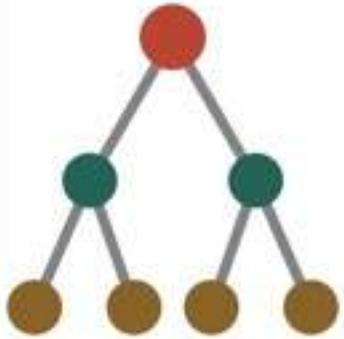
Nature & Nanotechnology

History & Perspective

What is Nano? Back to Basics

Nanoparticles: Classification



Application & Market

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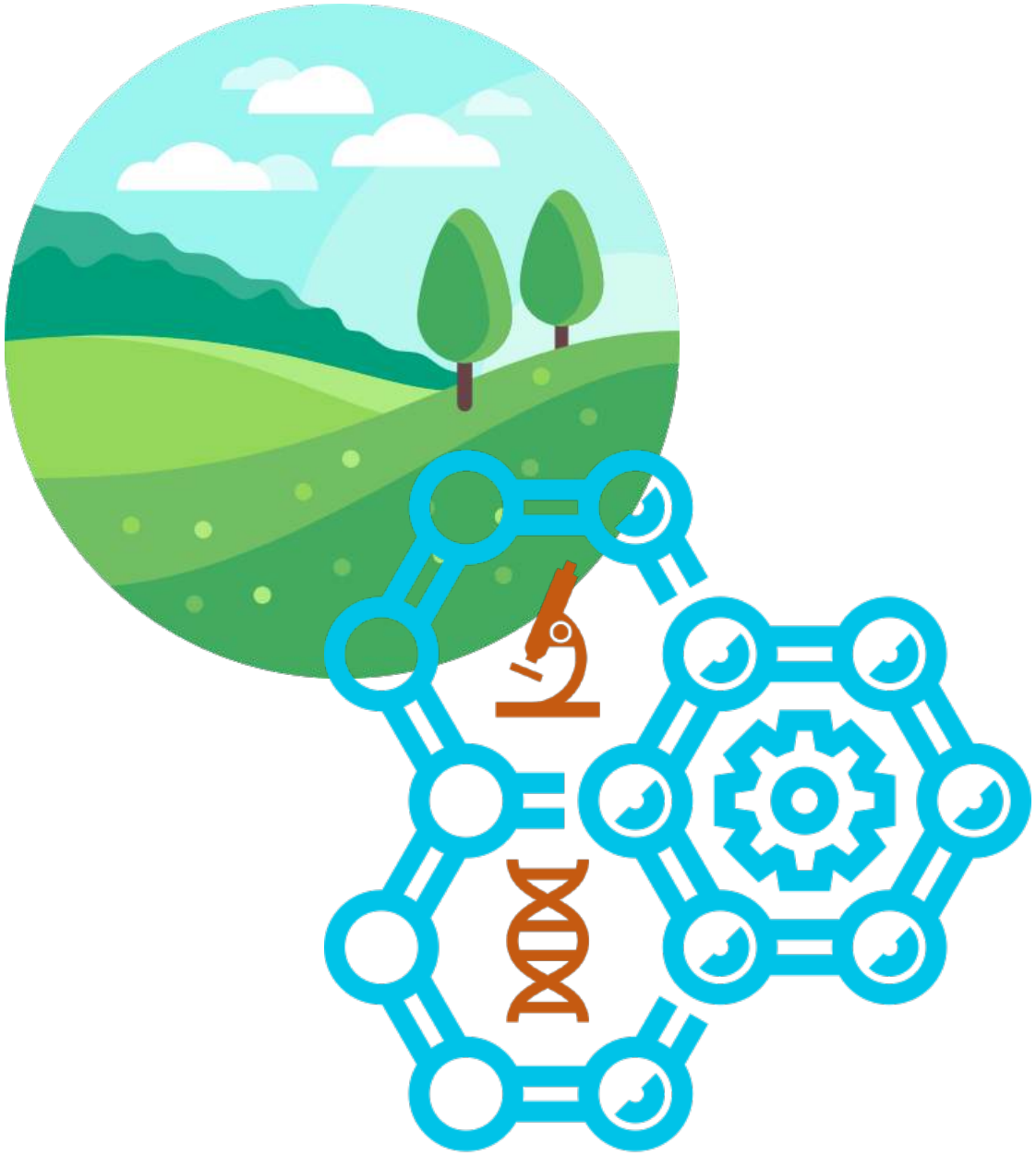
Nature & Nanotechnology



"lotus effect"

- water repellence
- self-cleaning
- free of bacterial colonies, despite living in polluted waters

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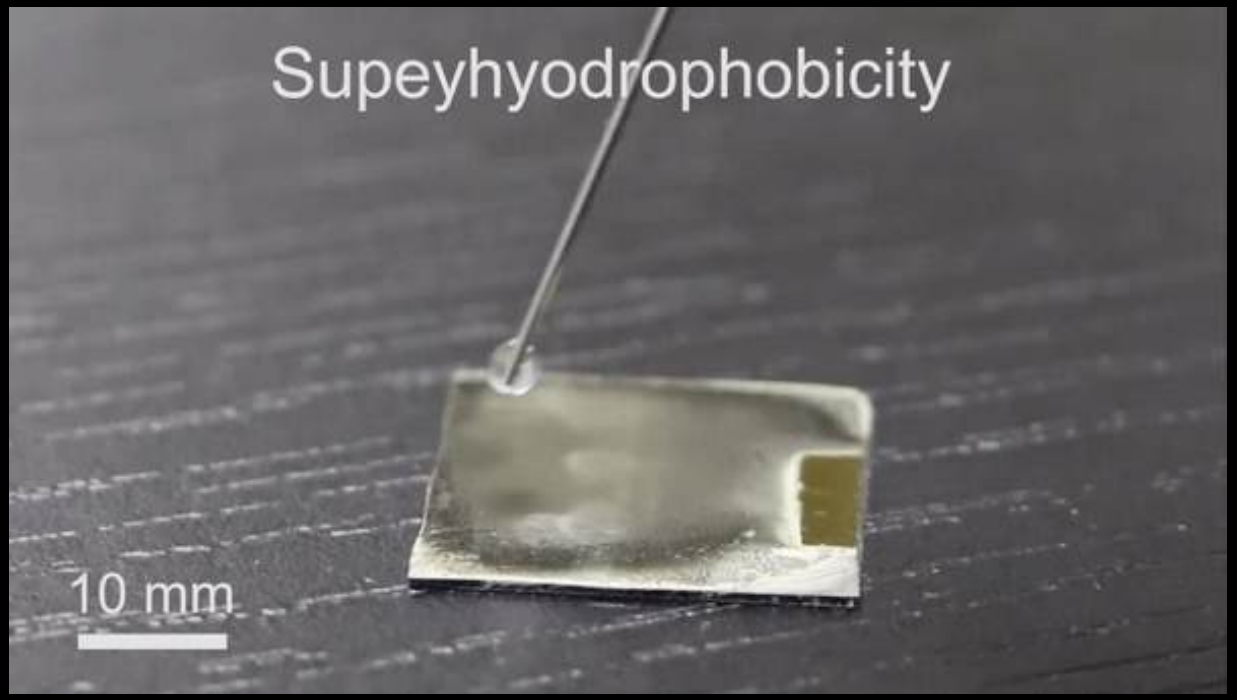

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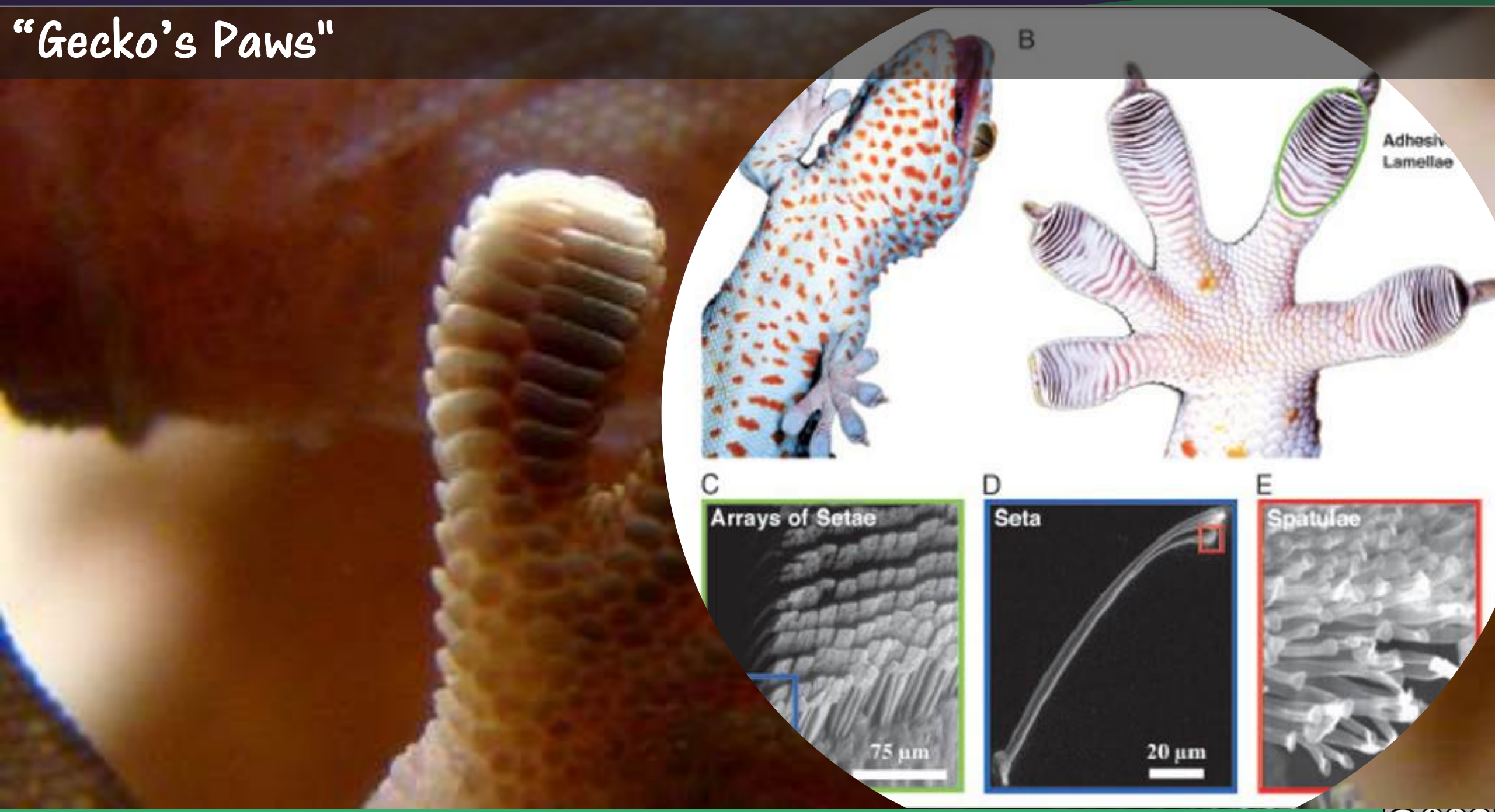
"Gecko's Paws"



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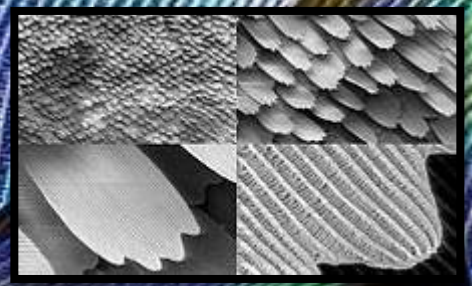
“Butterfly Effect"



differentiating colors under the sun!
This effect is called iridescence.

Contrary to popular belief, it is not pigments that give the wings their bright color. In fact, the wings consist of thousands of transparent structures.
But if the material of the wings is transparent, then where do the colors come from?

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NANOBIOMIMETICS

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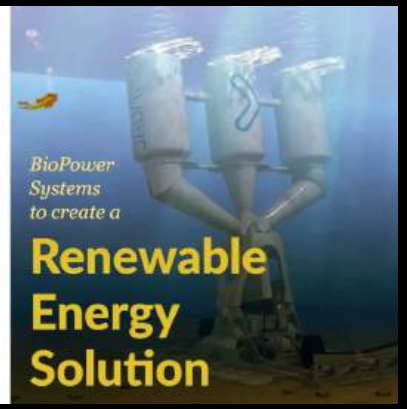

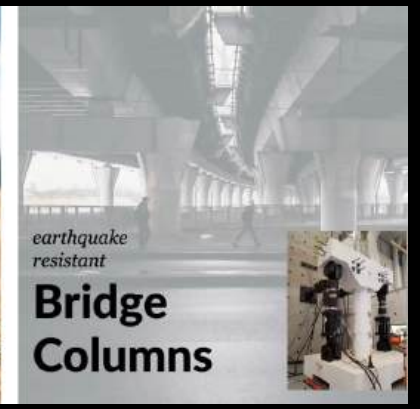

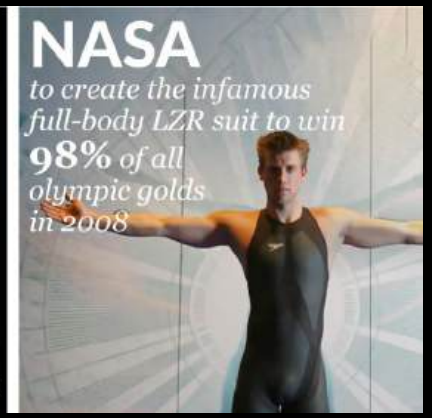

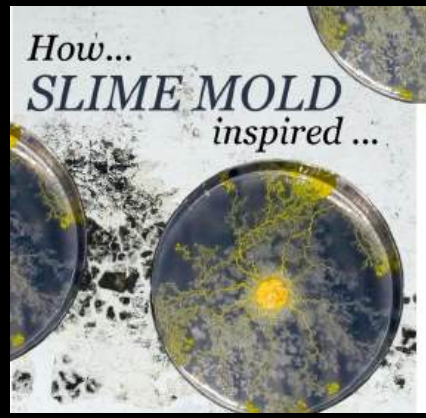

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Biomimicry at the nano level

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Applications

Coatings - self-cleaning windows and stain-proof clothing

The lotus effect has been reproduced on various surfaces, such as wood, plastic, glass, metal and stones including absorbents, textiles, etc., through chemical products of technological innovation.

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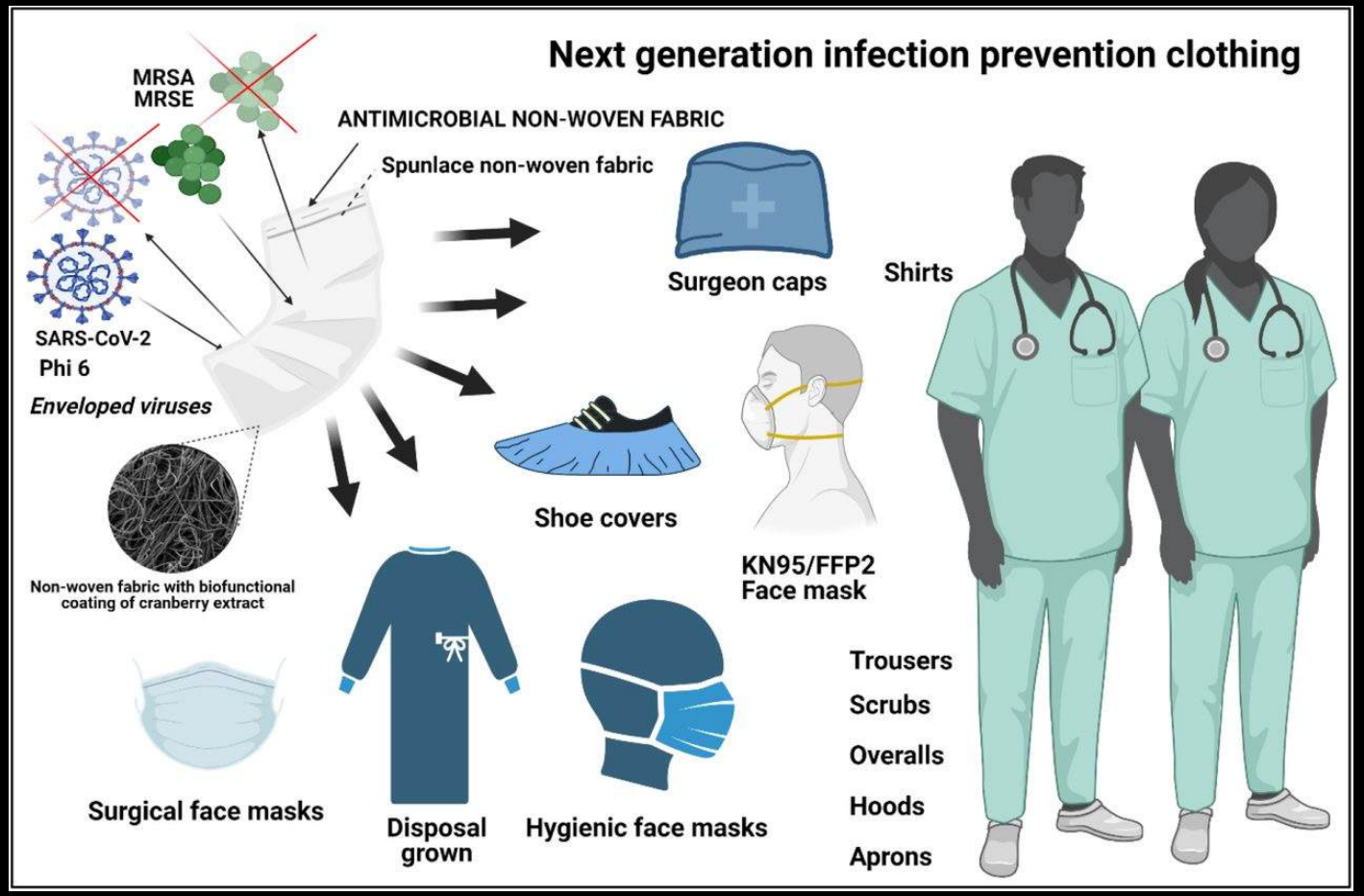
Applications

Antibacterial effect of silver



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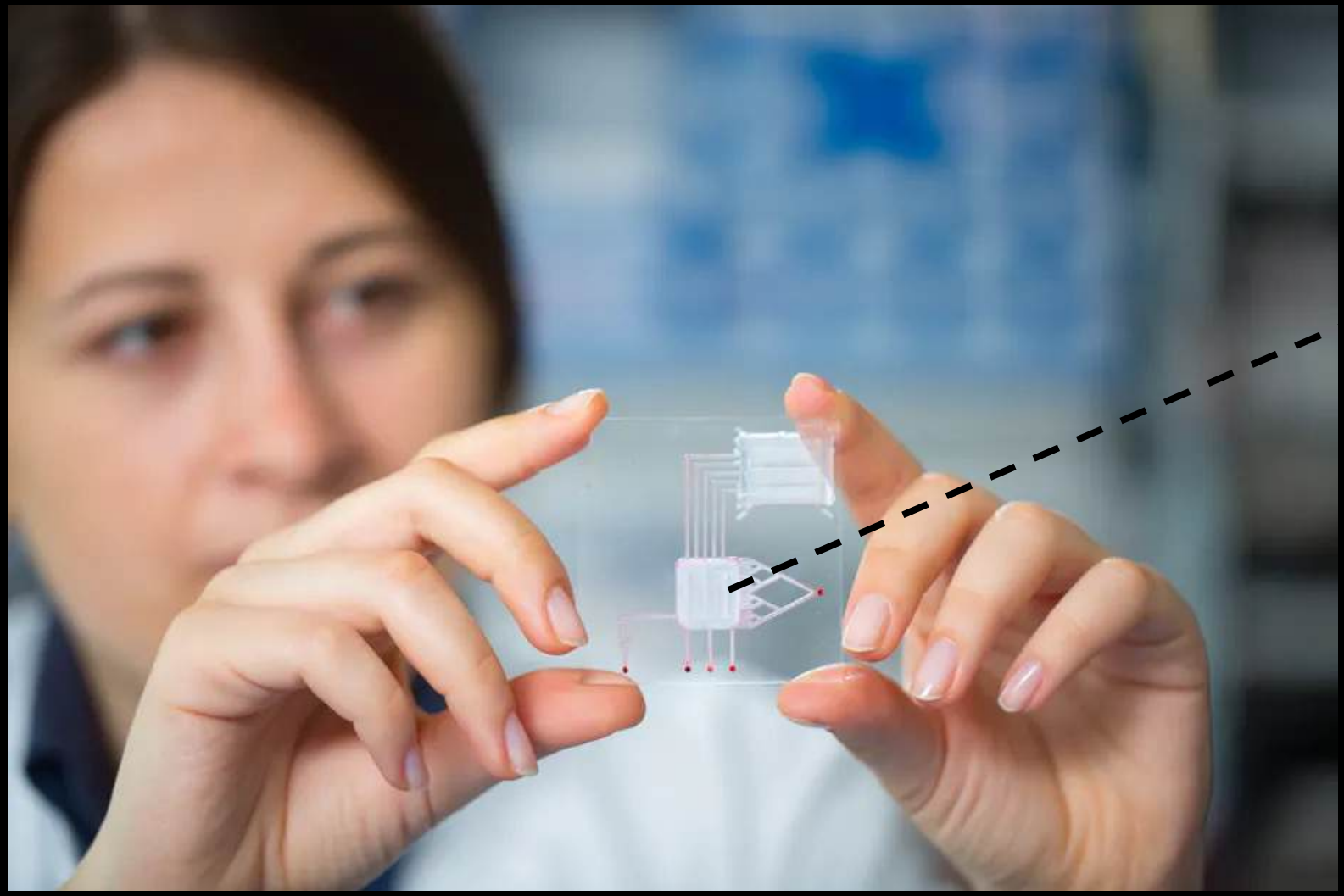
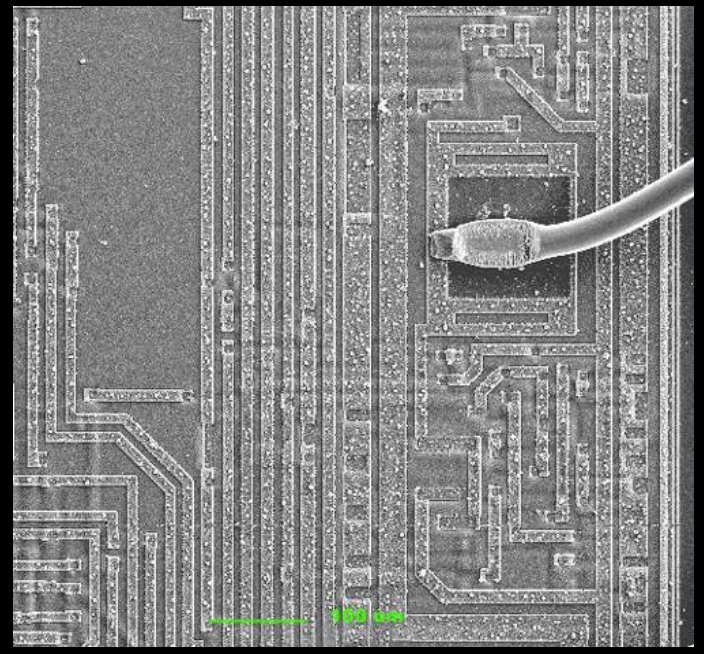
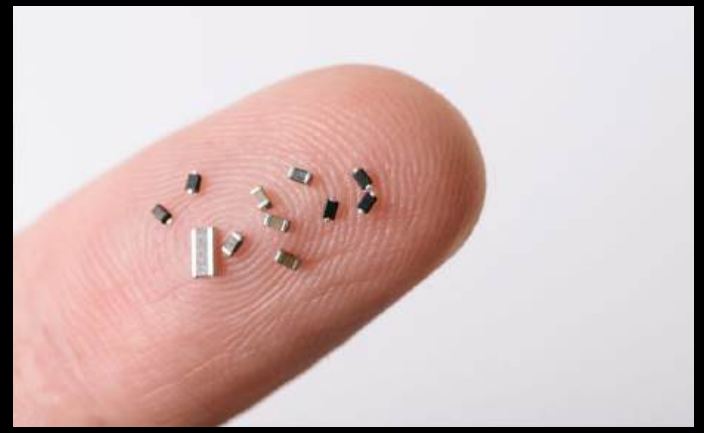
Applications

Microchips







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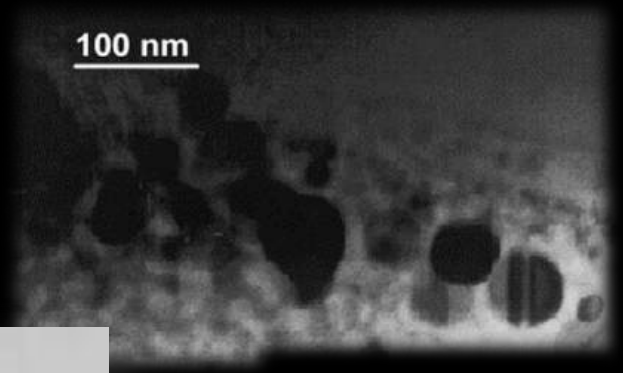
History & Perspective

History



Metal polish

Glazed ceramics,
Mesopotamia, 9th century

Luster ceramics: a 9th century AD nanotechnology

- early Middle Ages, 9th century AD,
- Islamic potters in Iraq succeeded in decorating glazed ceramics with vivid colors showing iridescent effects.

- revealed to be caused by metallic nanoparticles buried below the glaze surface that the ancient potters were able to diffuse through empirical, carefully controlled heat treatments

- particles nano-scaled have optical properties that cause the luster
- presence of separate silver and/or copper nanoparticles dispersed within the outermost layers of the glaze

P. Sciau, in The Delivery of Nanoparticles, InTech, 2012.

History

Mihrab with 9th century lusterware tiles, **Mosque of Uqba** (or Great Mosque of Kairouan), Tunisia

11th century bowl fragment, with mounted rider, Egypt, Fatimid dynasty

Bowl, Kashan, Iran, c. 1260-1280

Bowl, Raqqa, Syria, around 1200

Star tile, Kashan, Iran, 13th-14th century

Hispano-Moresque dish, Manises, 1400-60

Hispano-Moresque bowl, Andalusia, 1500-1550

Safavid wine jug, Iran, 2nd half 17th century, probably originally with a set of matching cups

- To achieve the red and gold luster effects, particles of copper and silver metal between 5 and 100 billionths of a meter were used.
- Instead of scattering light, the particles cause light to bounce off their surface at different wavelengths, giving metallic or iridescent effects.

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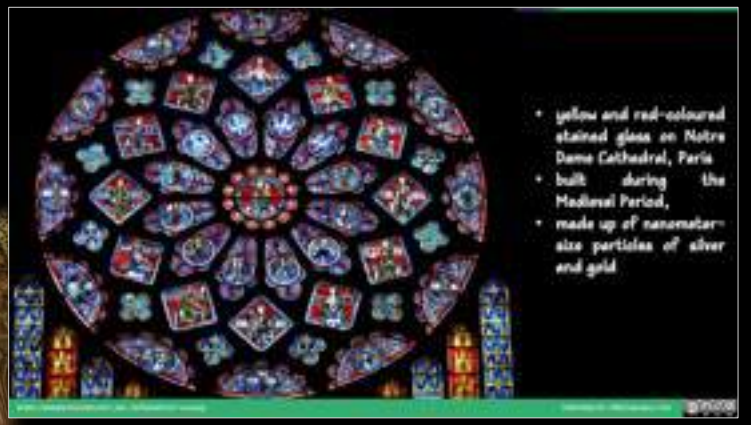
History

Luster and glass technology



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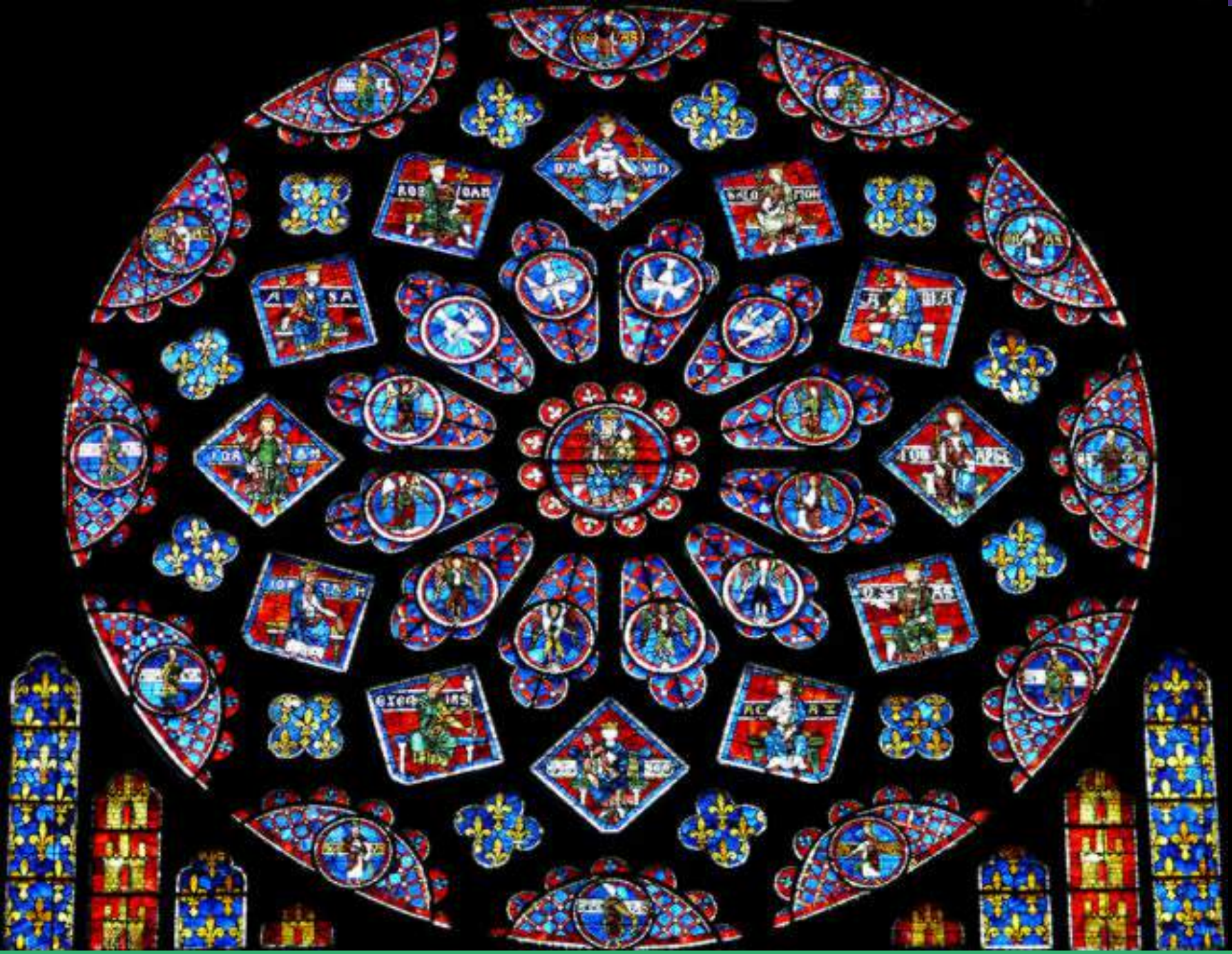

- yellow and red-coloured stained glass on Notre Dame Cathedral, Paris
- built during the Medieval Period,
- made up of nanometer-size particles of silver and gold

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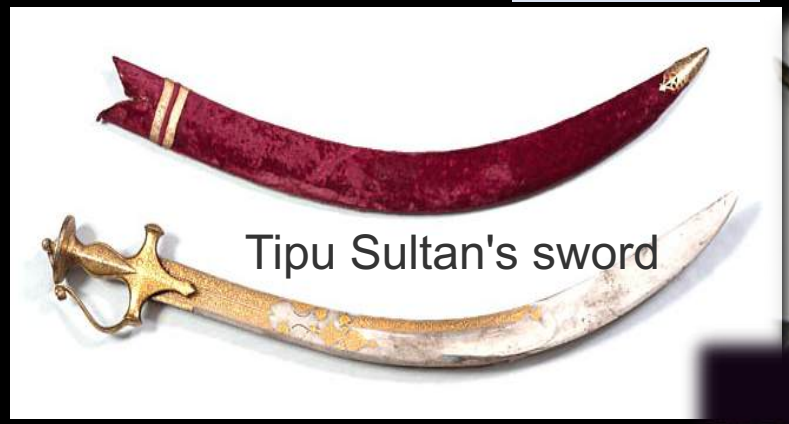
Nanotechnology in India – 2000 yr. old

Art & Religion

Carbon nanotechnology In Paintings of Ajanta Caves

Warfare



Wootz / Damascus Steel
Wootz is the westernized version of Kannada ukku and Sangam Tamil ekku, meaning crucible steel

Architecture

Iron pillar in the Qutub Minar area: Forge-welding, reduction of iron ore to iron using carbon

Healthcare

Ayurvedic bhasmas (Charak Samhita 1500 BC) : Mixture of precious metals and coal powder and other minerals

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History/Lycurgus Cup

4th-century Roman glass cage cup made of dichroic glass

made in Alexandria" or Rome 290–325 AD

King Lycurgus of Thrace

- 2400-year-old jade green Roman chalice that changes colour depending on the direction of the light upon it
- acquired by the British Museum in the 1950s. They could not work out why the cup **appeared jade green when lit from the front, but blood red when lit from behind.**
- ***They had impregnated the glass with particles of silver and gold, ground down until they were as small as 50 nanometres in diameter, less than one-thousandth the size of a grain of table salt.***

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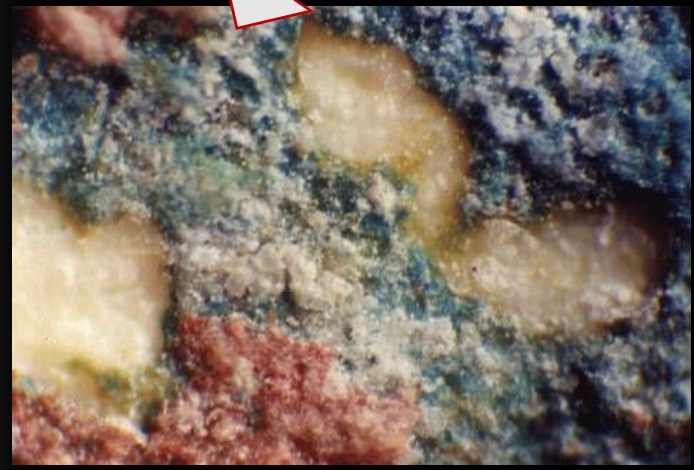
History/Maya Blue

- first produced in AD800, was discovered in the pre-columbian Mayan city of Chichen Itza.
- It is complex material containing clay with nanopores into which indigo dye was combined chemically to create an environmentally-stable pigment.



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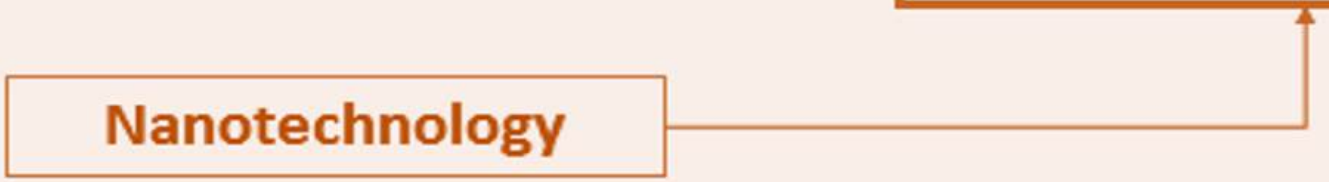
Types of nanomaterials

Naturally Occurring	Human Origin (Incidental)	Human Origin (Engineered)
Forest fires	Cooking smoke	Metals
Sea spray	Diesel exhaust	Quantum dots
Mineral composites	Welding fumes	Buckyballs/Nanotubes
Volcanic ash	Industrial effluents	Sunscreen pigments
Viruses	Sandblasting	Nanocapsules



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1850's .. first examples of metallic gold colloids.

They were made, accidentally, by Michael Faraday whilst he was mounting thin sheets of gold leaf onto microscope slides.

one of the first researchers into nanoscience and nanotechnology

Michael Faraday

colloidal solutions of gold

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Faraday-Tyndall effect

Faraday-Tyndall effect

light scattering by particles in a colloid or in a very fine suspension

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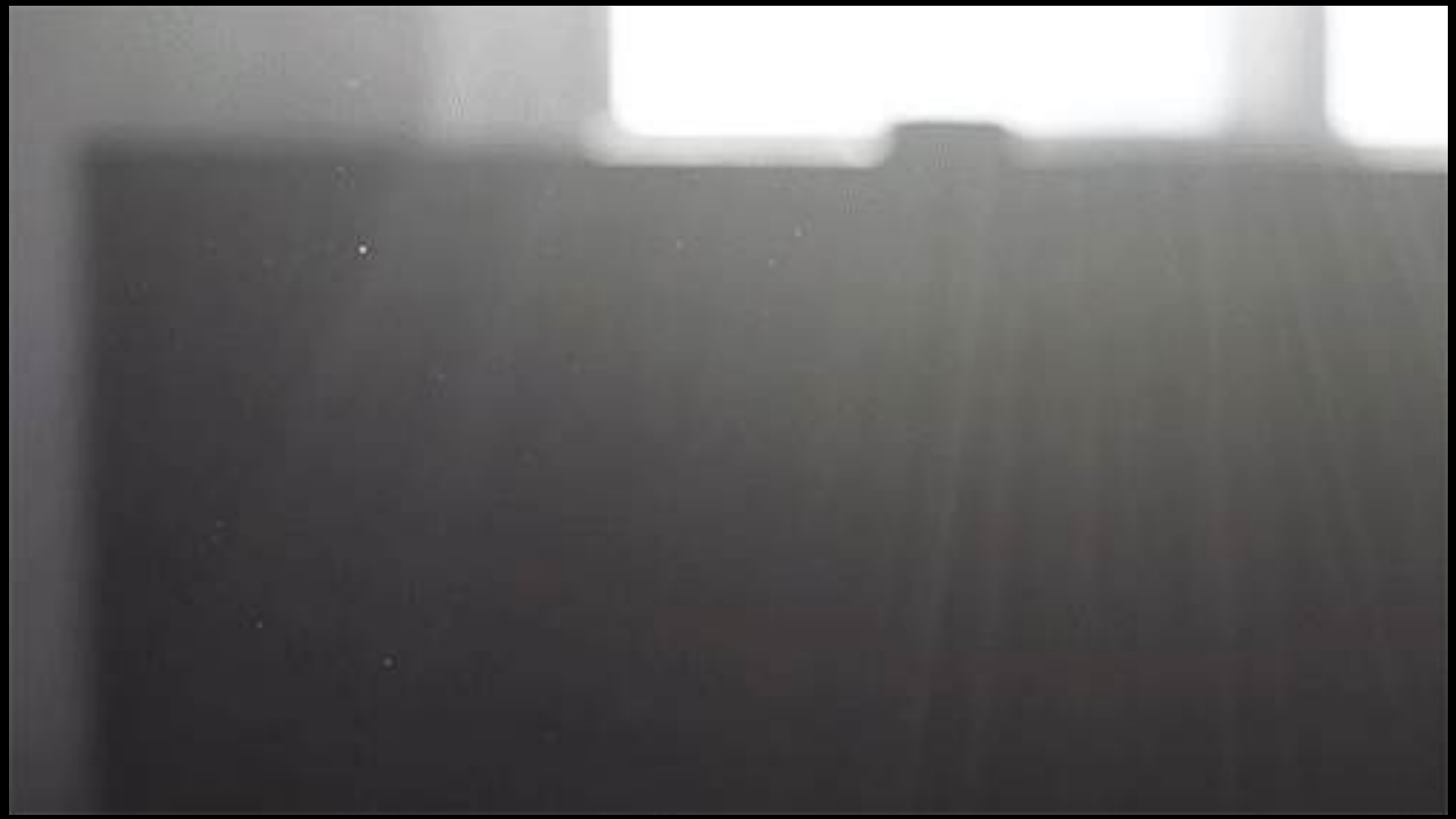
Tyndall effect



19th-century physicist John Tyndall.

light scattering by particles in a colloid or in a very fine suspension

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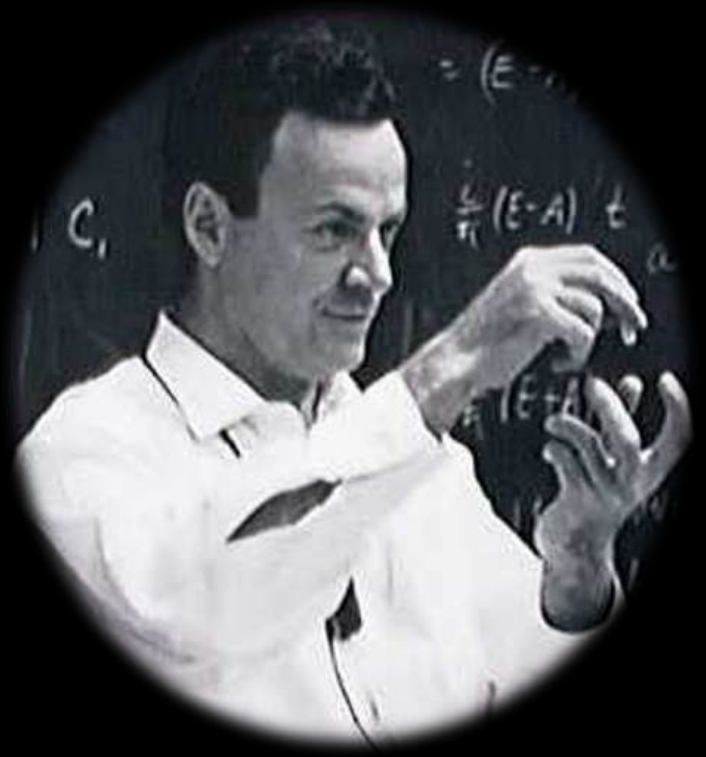
The Idea!



'Father of Nanotechnology'

- possibility of direct manipulation of individual atoms as a more powerful form of synthetic chemistry
- The idea of **Nanotechnology** was born
- The talk is referred as "Origin of the nanotechnological paradigm"

RICHARD FEYNMAN

during his lecture "***There's Plenty of Room at the Bottom***: An Invitation to Enter a New Field of Physics"

Annual American Physical Society meeting, Caltech, December 29, 1959

NORIO TANIGUCHI

coined term NANOTECHNOLOGY In 1974

E. DREXLER

"Vehicles of creation: the arrival of the nanotechnology era" Book,1986

N. K. Tolochko, Nanosci. Technol, 2009

R. P. Feynman, 'There is plenty of room at the bottom for innovation': a report on 'Nano2004', the 7th International Conference on Nanostructured Materials., 1960.

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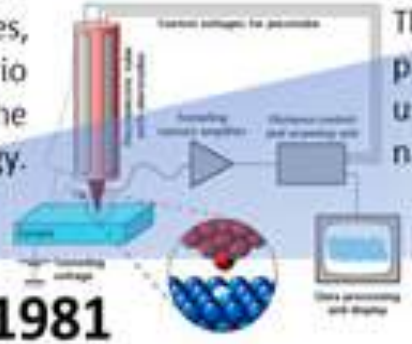
Nanotechnology – Research Milestones

1959

The ideas that define nanoscience and nanotechnology were mentioned long before the terms were coined, in a lecture by American physicist Richard Feynman "There's Plenty of Room at the Bottom" in 29, 1959. Feynman described processes that would allow scientists to manipulate and control individual atoms and molecules.

1974

While working on the development of ultra-precision machines, that Professor Norio Taniguchi coined the term nanotechnology.



1981

Gerd Binnig and Heinrich Rohrer developed the scanning tunnelling microscope (STM), that modern nanotechnology began. The STM allowed researchers to view atoms on the surface of materials for the first time ever, and since then nanotechnology began its gradual growth. However, recently the nanotechnology market has exploded and become a hotbed of innovation.

1989

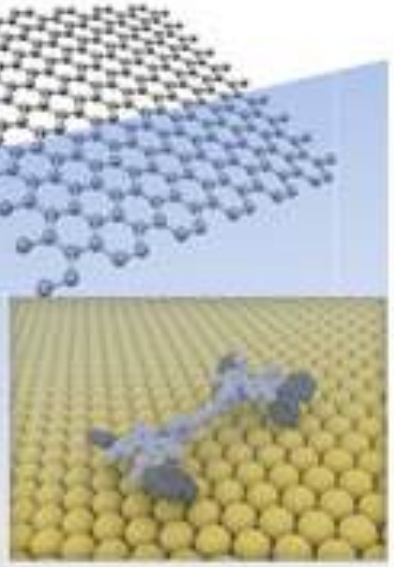
Don Eigler and Erhard Schweizer at IBM's Almaden Research Center manipulated 35 individual xenon atoms to spell out the IBM logo. This demonstration of the ability to precisely manipulate atoms ushered in the applied use of nanotechnology

1990's–2000's

Research groups and commitees formed to drive nano-related research. Consumer products making use of nanotechnology began appearing in the marketplace.

2004

The material was later rediscovered, isolated and characterized in 2004 by Andre Geim and Konstantin Novoselov at the University of Manchester. This work won the Nobel Prize in Physics in 2010



2016

Jean-Pierre Sauvage, J. Fraser Stoddart, and Bernard Feringa win the Nobel Prize in Chemistry for their research in developing Nano-scale machines including a 'nanocar'

adopted as an official SI prefix, 10^{-9} of an SI base unit, at the 11th Conférence Générale des Poids et Mesures (CGPM) in 1960

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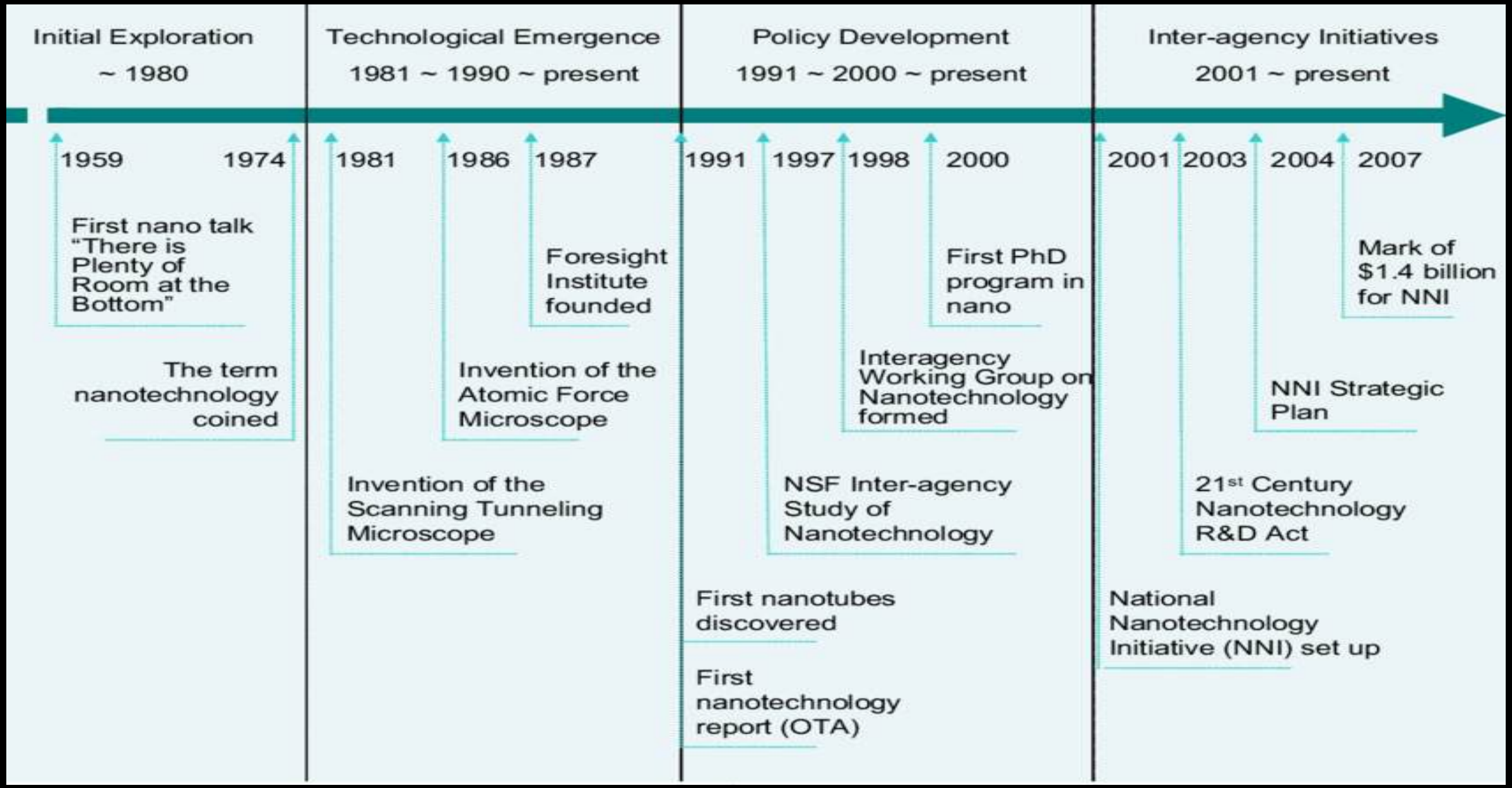
Nanotechnology – Research Milestones



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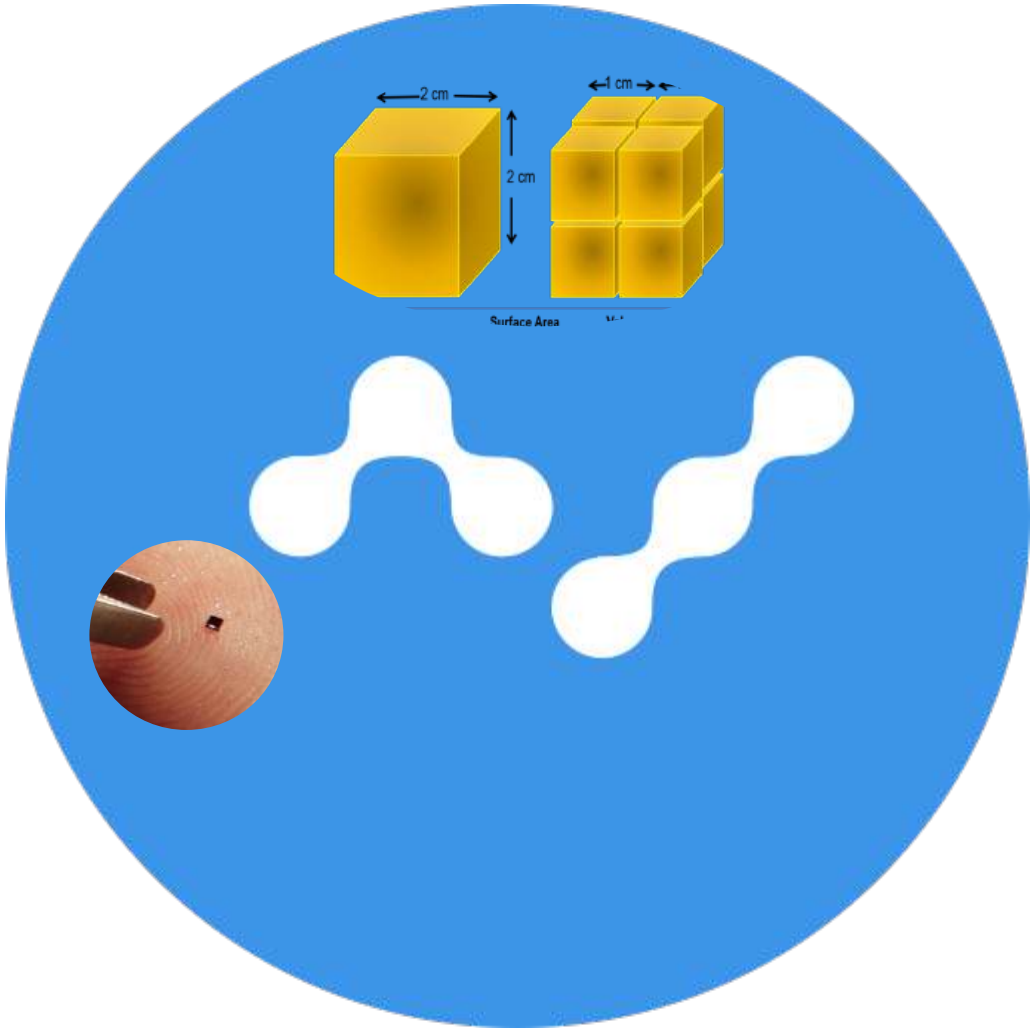
What is Nano?
Back to Basics



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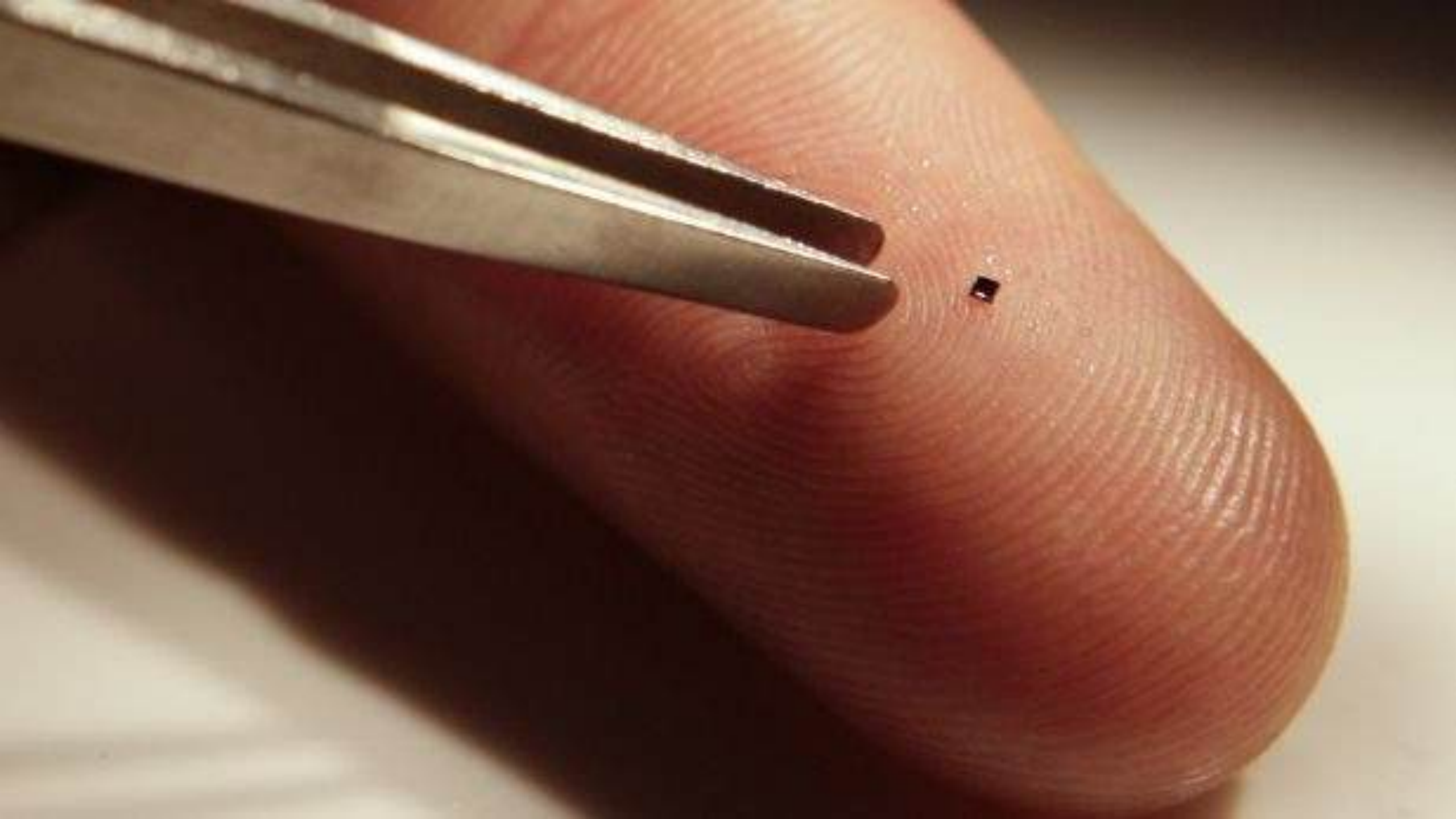

NANOTECHNOLOGY

NANOMETRE (nm)

Unit of length
one billionth of a metre (10^{-9})

Nano
Greek, nanos, "dwarf")

Metre
Greek, ***metron***, "unit of measurement"

'Study of manipulation of matter on an atomic, molecular, and supramolecular scale'

TECHNOLOGY

"science of craft", collection of techniques, skills, methods, and processes used in the production of goods or services or in the accomplishment of objectives, such as scientific investigation

the application of scientific knowledge for practical purposes

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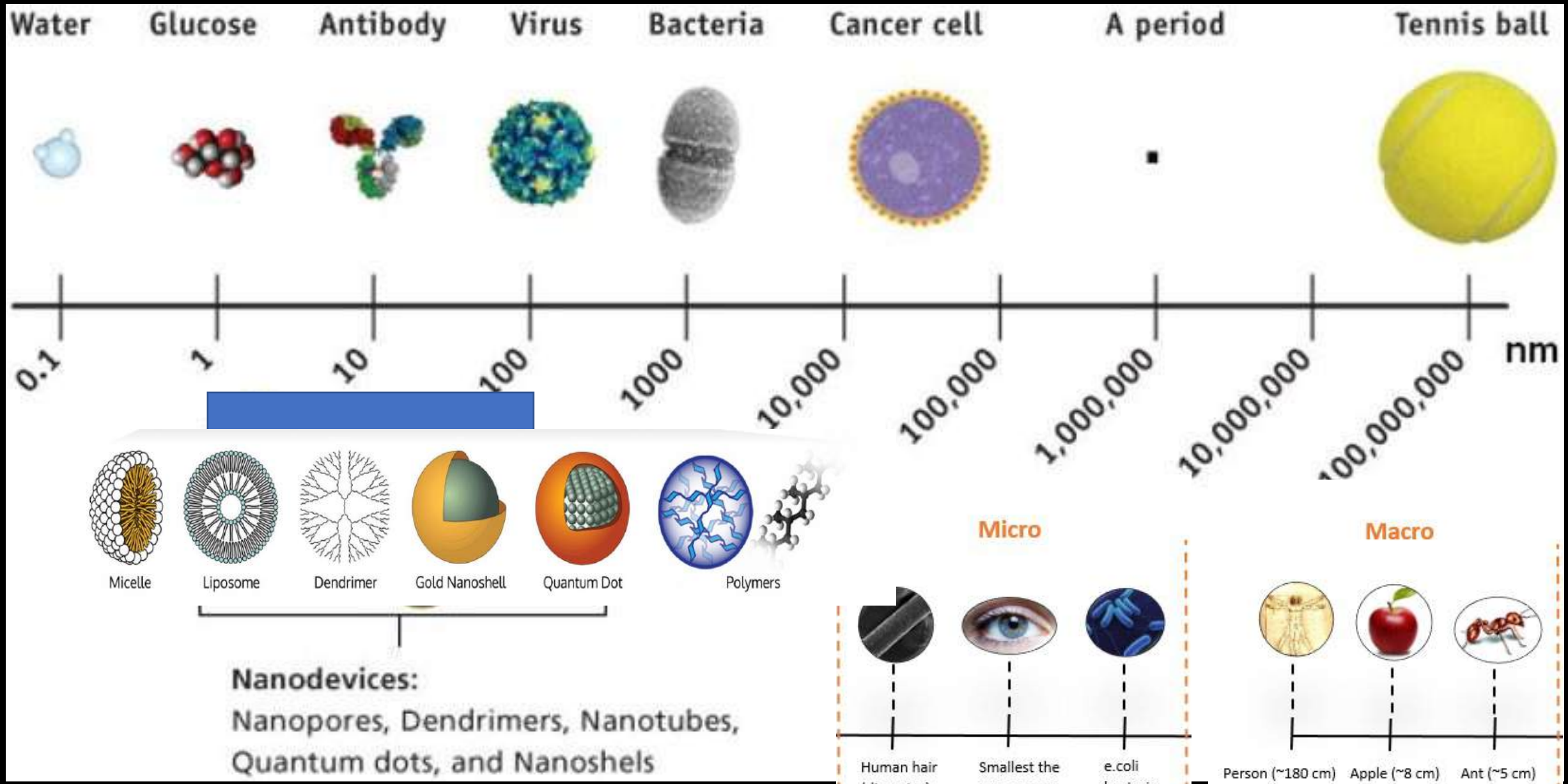

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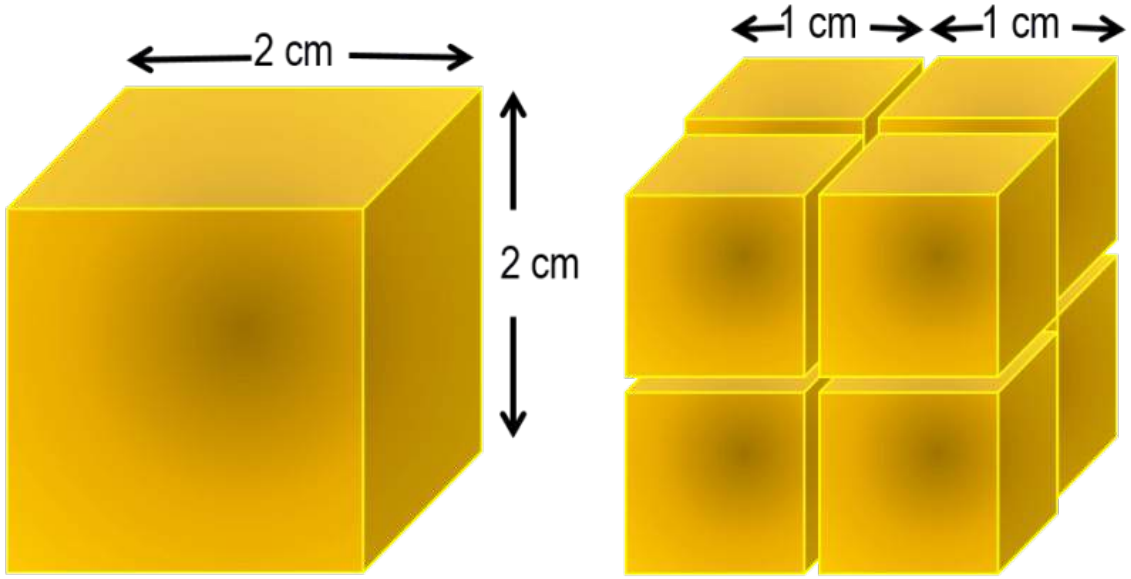
Surface-to-Volume Ratio



# of Cube (s)	Dimensions (cm)	Surface Area (l x l x 6 cm^2)	Volume (l x l x l cm^3)	Surface Area/Volume ratio
1	2 x 2	(2 x 2 x 6) = 24	(2 x 2 x 2) = 8	3
8	1 x 1	8 (1 x 1 x 6) = 48	8 (1 x 1 x 1) = 8	6

Representation of increasing area as the particle size decreases

Increase in surface area

↓

Higher surface-to-volume ratio

↓

Increase in the amount of exposed surface area

↓

Increase the rate of reaction

Responsible for the development of unique properties of a substance at the Nano-scale level

Gold:
macro scale:
melting point = 1064 °C / Conducts electricity

2 nm scale:
melting point ~ 532 °C / Non Conductive

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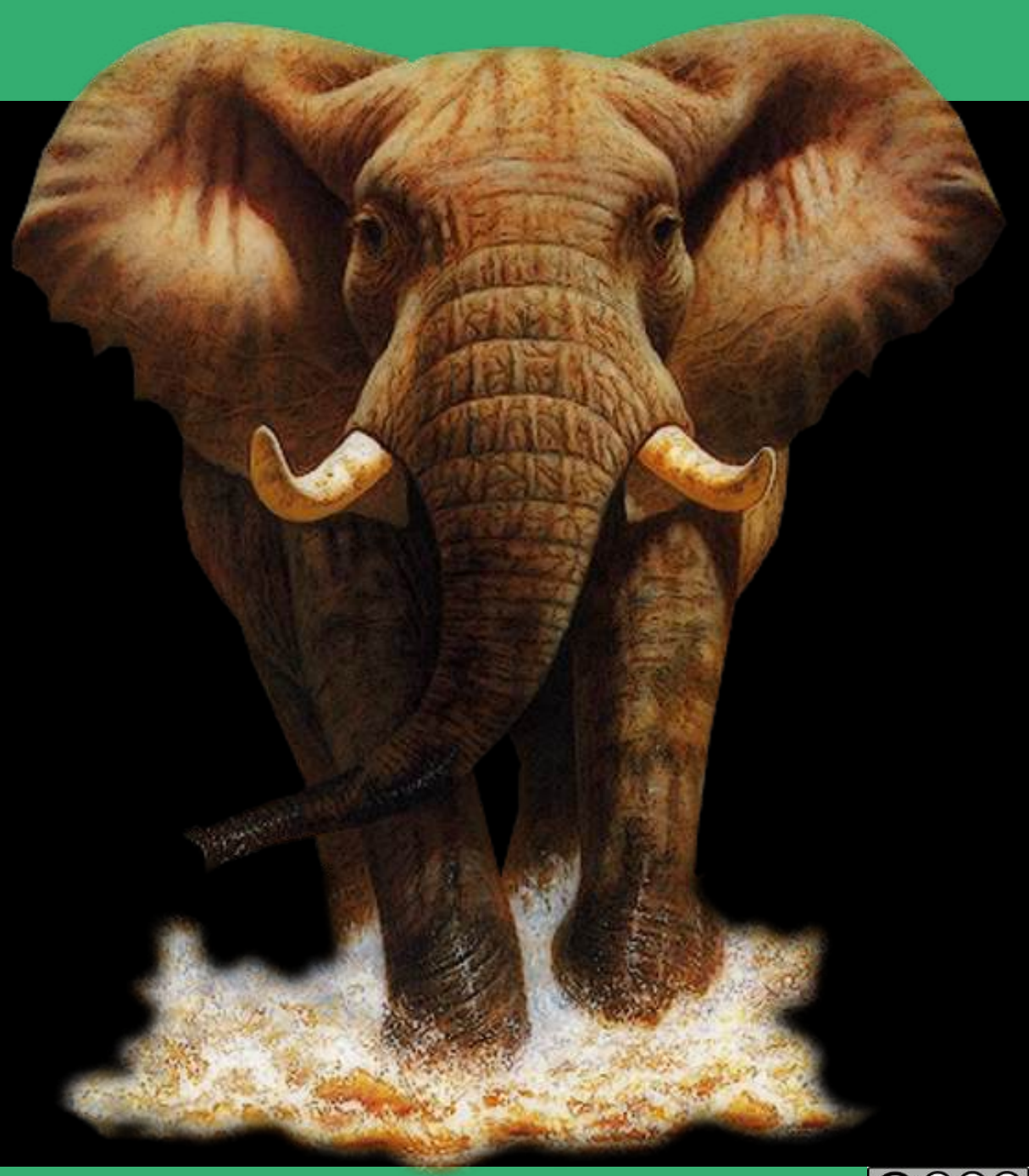
Surface area matters!

- maintain body temperature,
- Because they are so large, they generate a lot of heat.
- unlike humans, do not have the ability to sweat to regulate their body temperature.
- large floppy ears - easy way out.
- In the ear of the animal, there are a colossal number of blood vessels. Despite their size, these veins are very close to the skin. They let the elephant's body temperature be regulated by allowing the elephant's surplus heat to be expelled from their body.
- Their ears have the ability to reduce body temperature by up to 5 degrees Celsius (9 degrees Fahrenheit).



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Size matters! why are cells so small

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Size matters! why are cells so small

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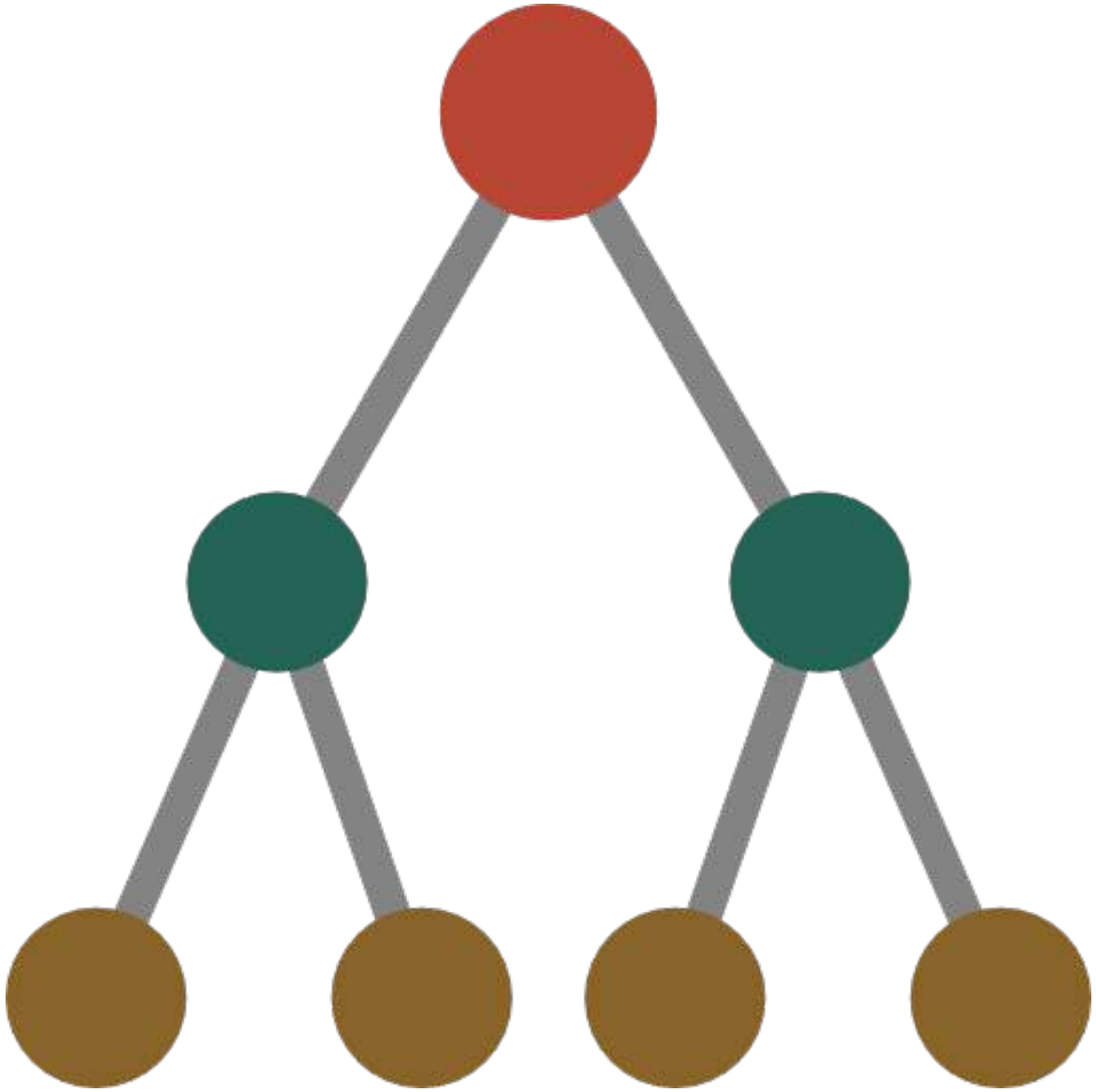
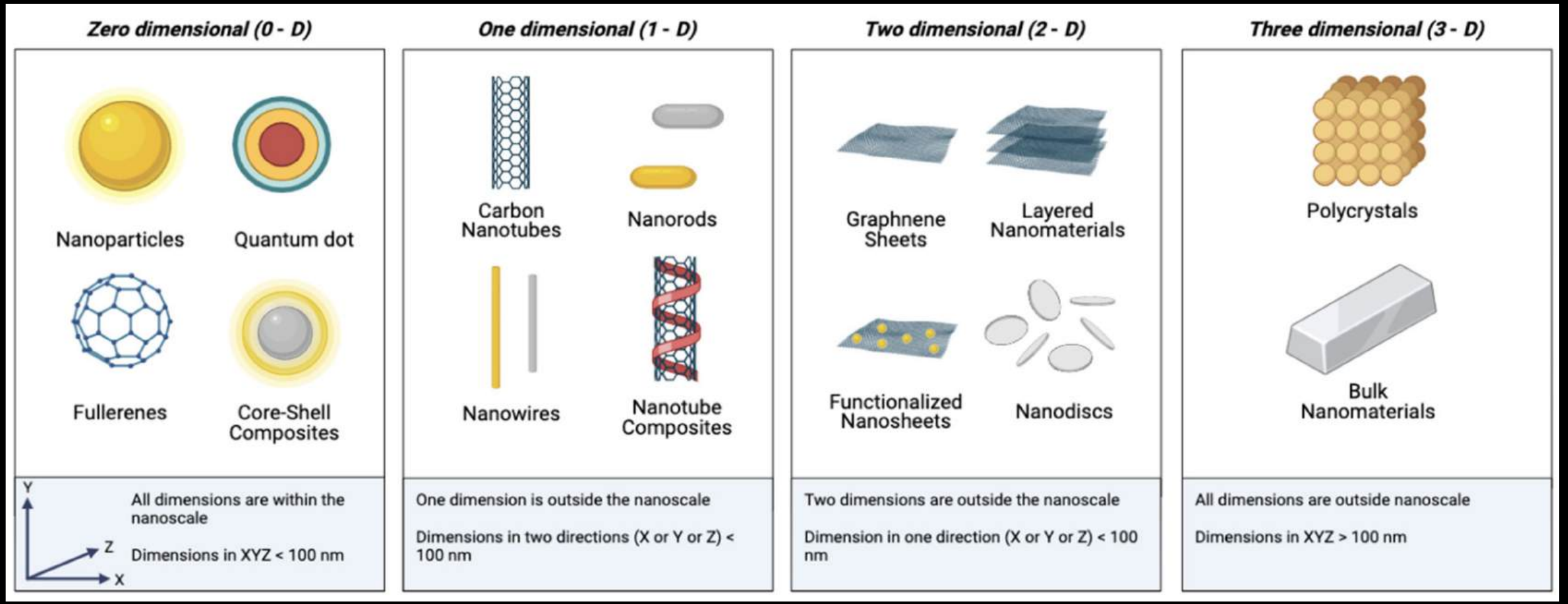
Nanoparticles: Classification



Classification based on Dimensionality



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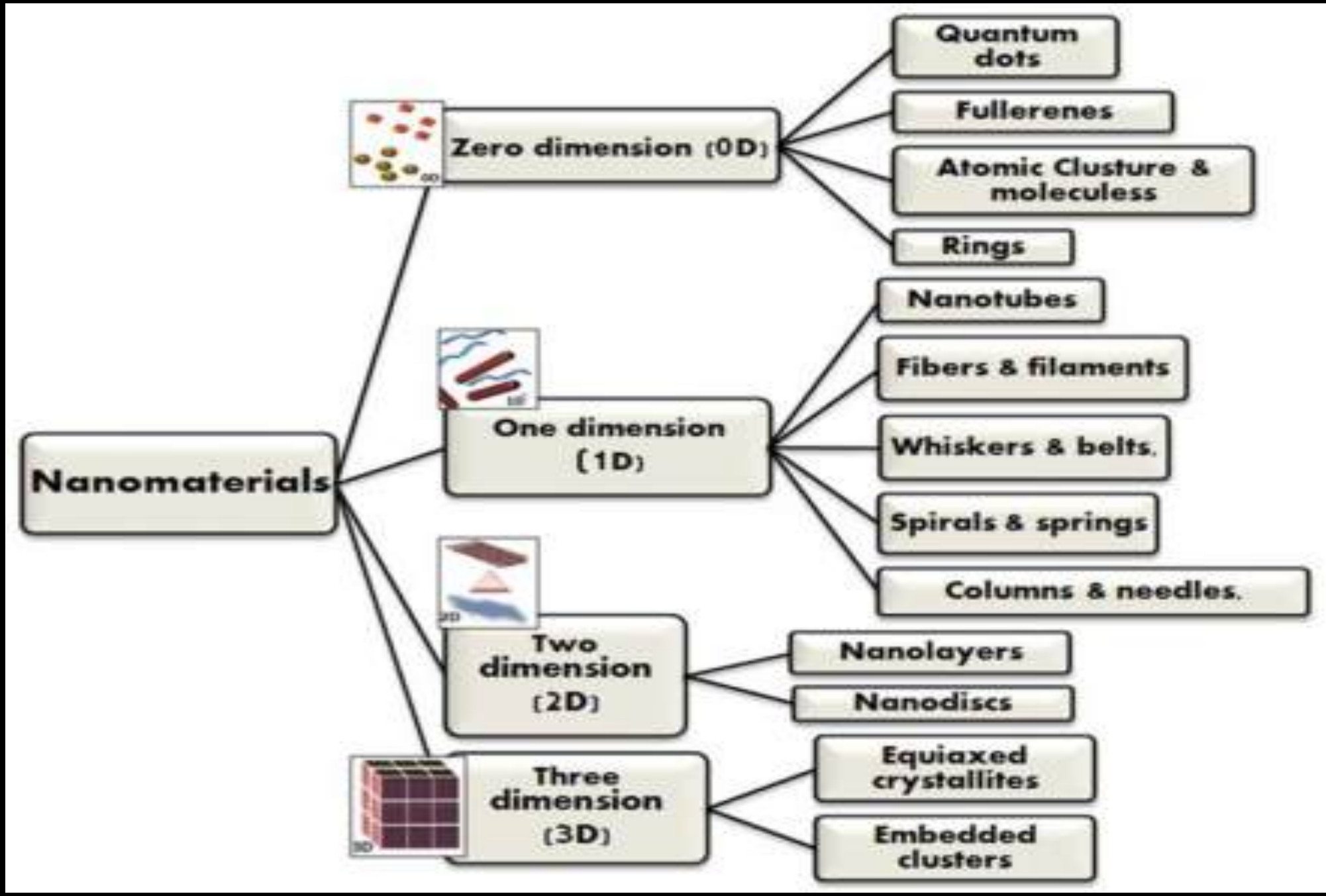
Classification based on Dimensionality



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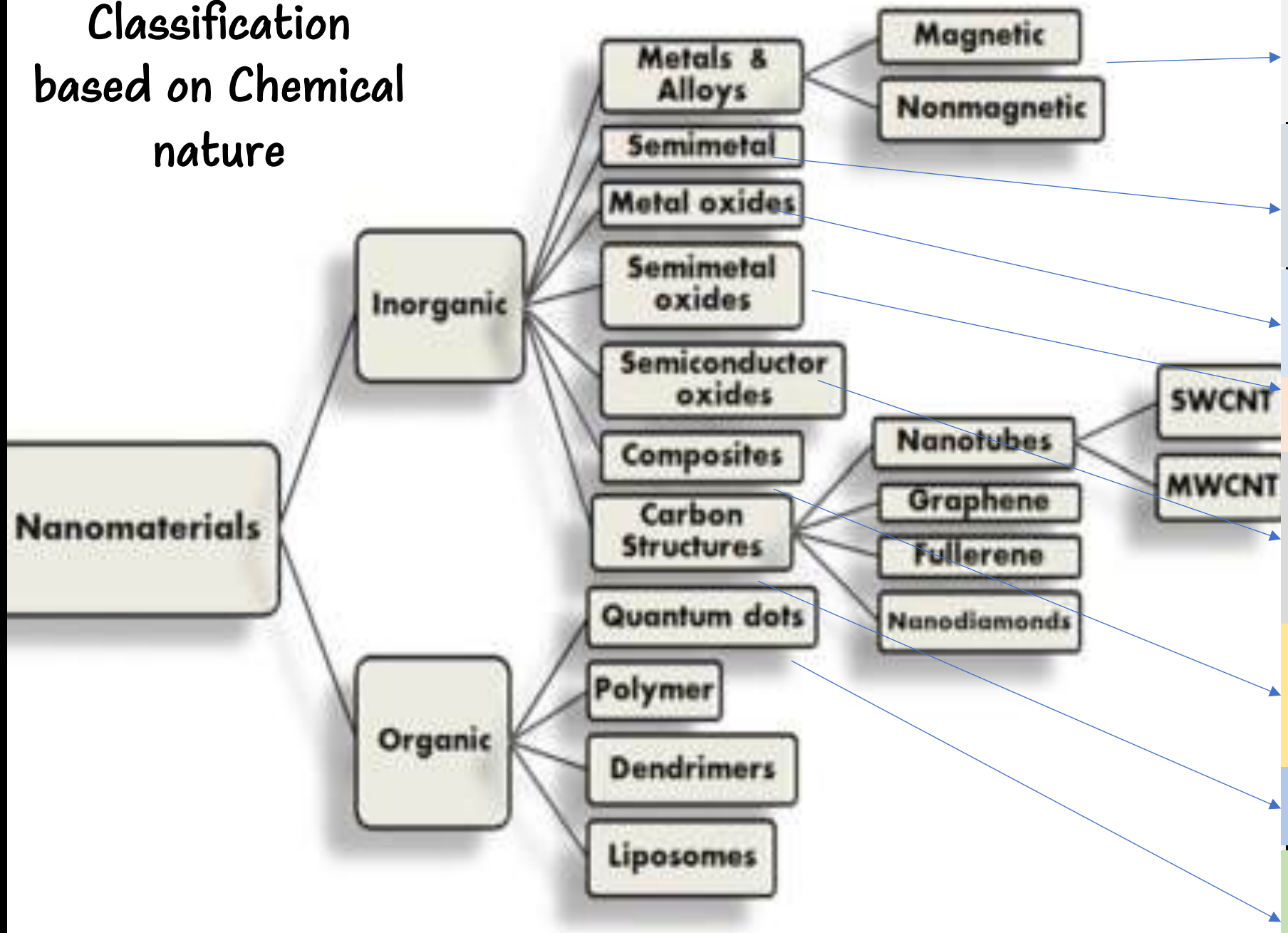
Classification based on Chemical nature



Hard, good electrical and thermal conductivity. **Alloys** are made by *melting two or more elements* together, at least one of them a **metal**

an element (e.g. arsenic, antimony, or tin) whose properties are *intermediate between those of metals and solid non-metals or semiconductors*.

reaction of a **metal** and oxygen e.g. magnesium reacts with oxygen to form magnesium **oxide**

Oxide of mixture of, those of metals and non-metals. i.g. boron, silicon

it can be doped with impurities that alter its electronic properties in a controllable way,
gallium arsenide (GaAs) has six times higher electron mobility than silicon

made from two or more constituent materials with significantly different physical or chemical properties
Reinforced concrete, Reinforced plastics

three-dimensional array of carbon atoms

a semiconductor crystal of nanometre dimensions with distinctive conductive properties determined by its size.

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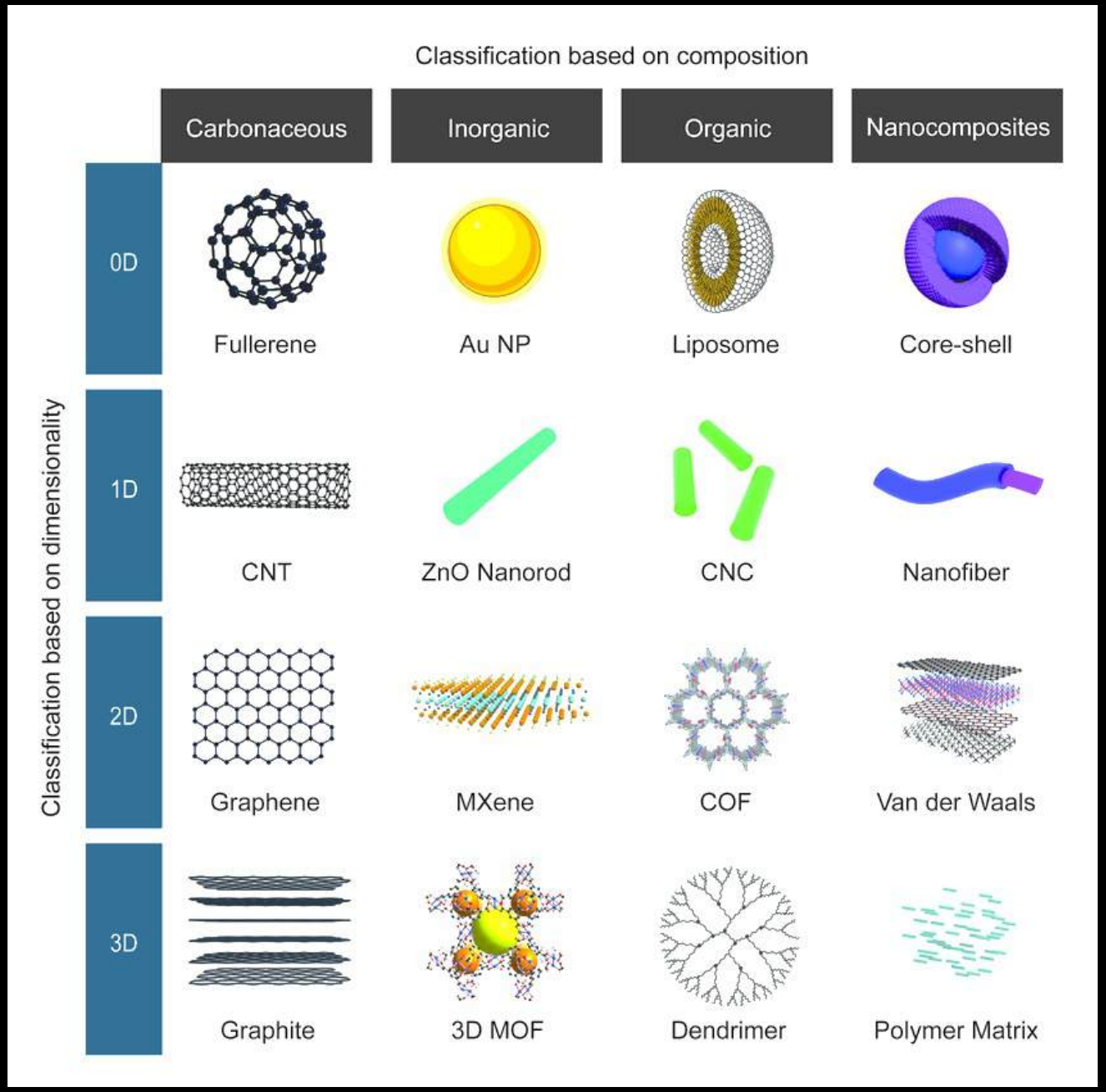

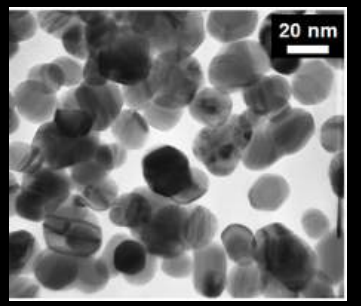

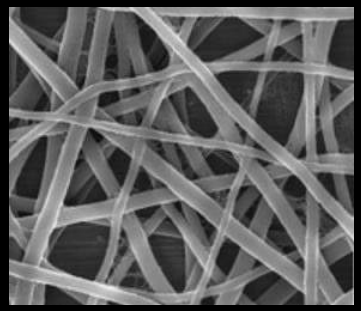

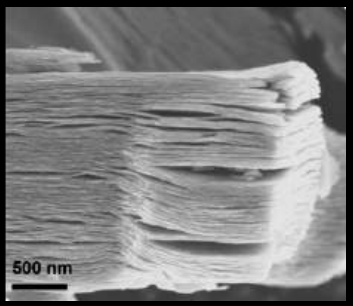

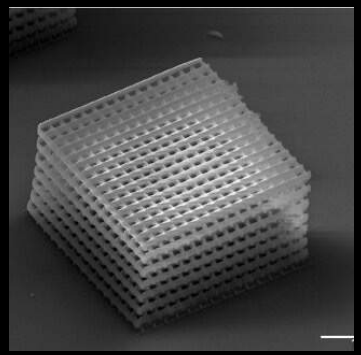

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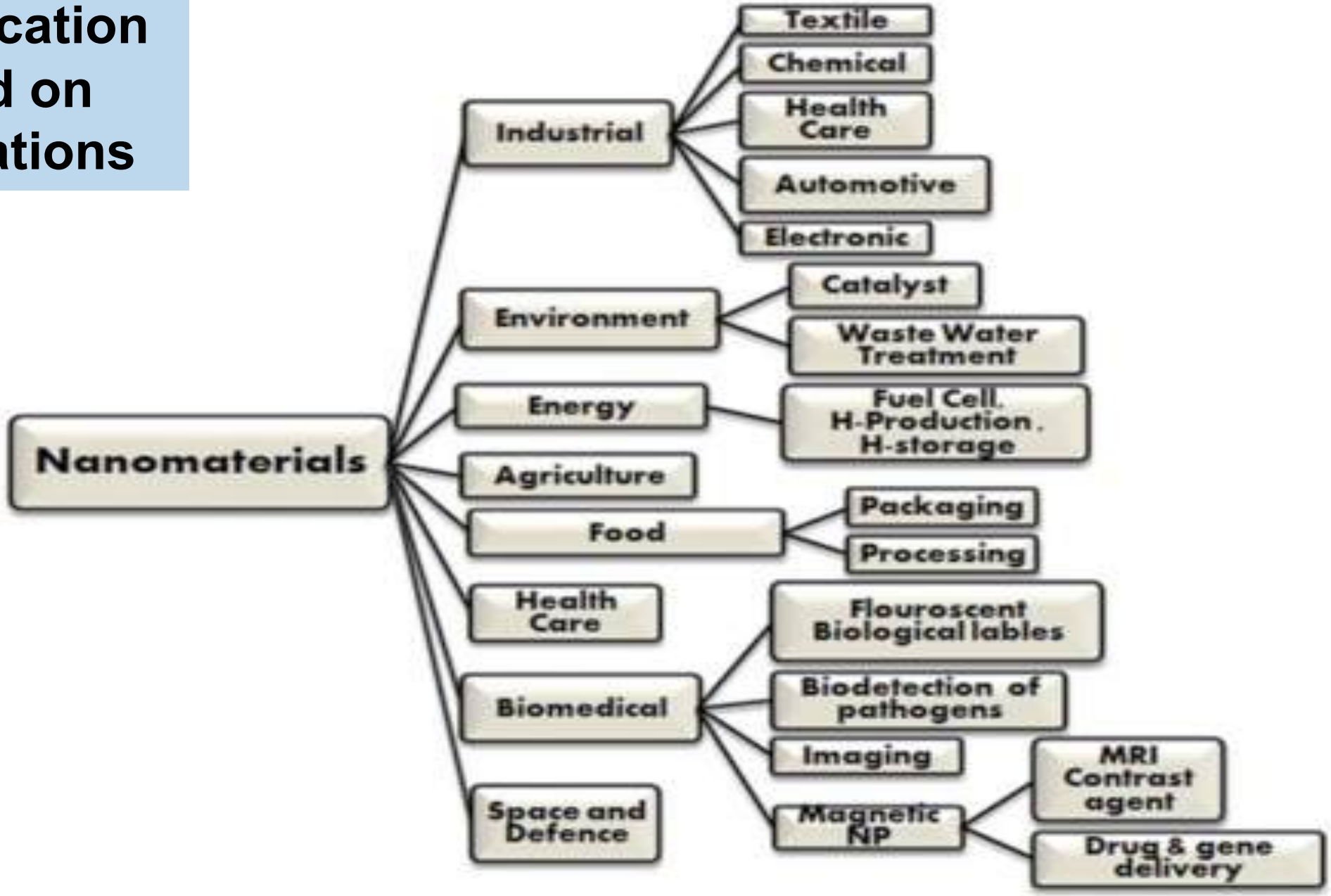
Classification based on Applications



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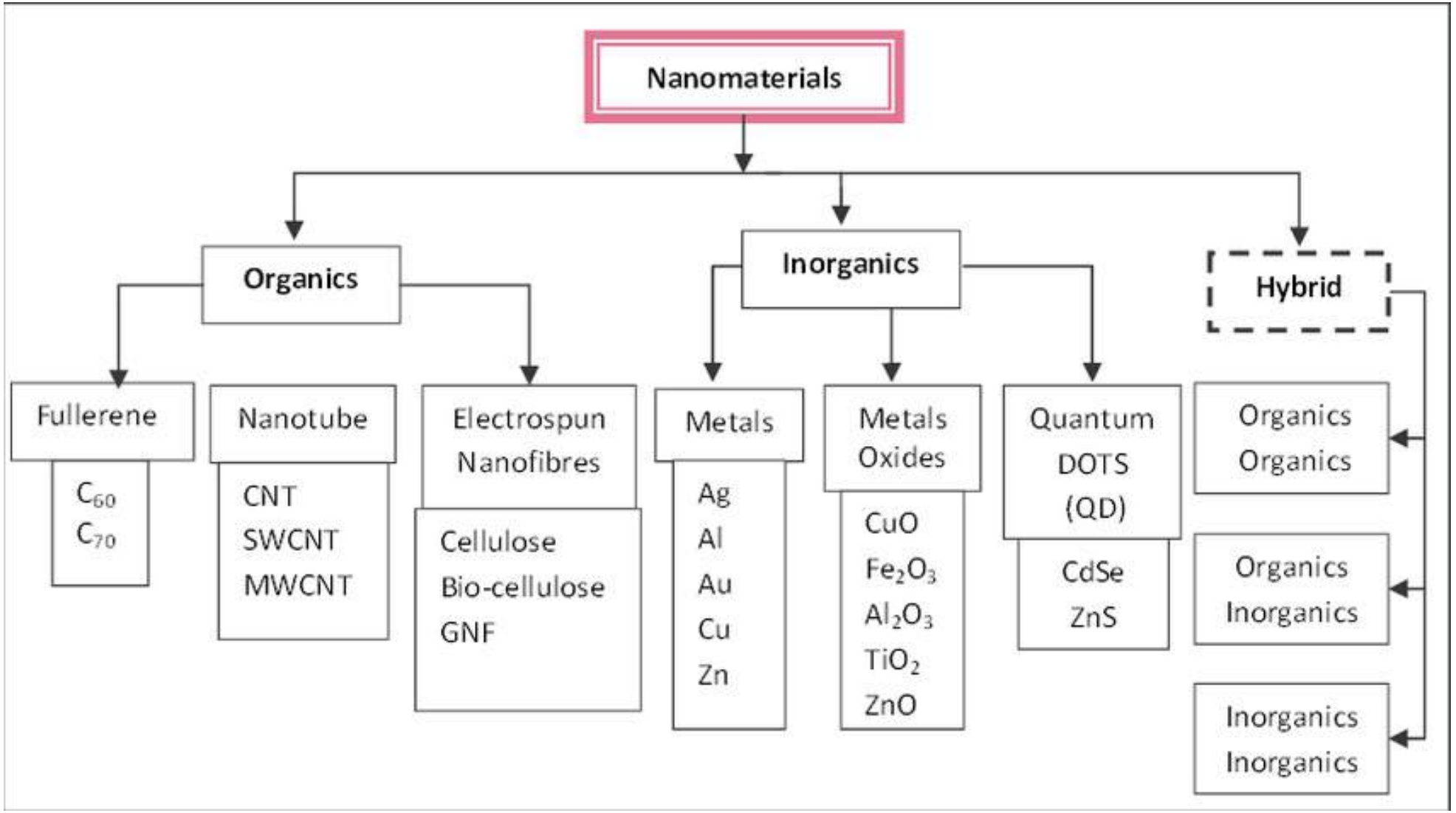
Classification based on Origin



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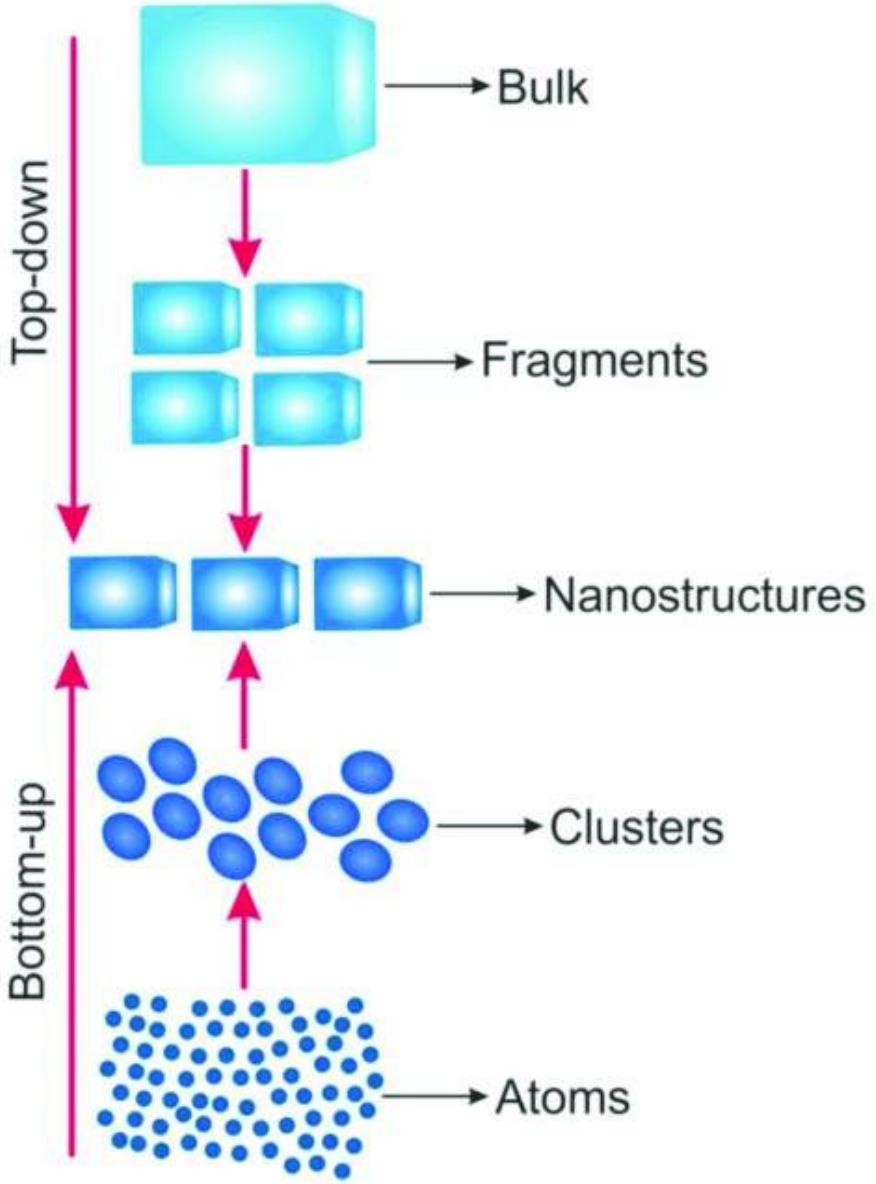
Top-down and Bottom-up



synthesized by etching out crystals planes (removing crystal planes) which are already present on the substrate

- By nature, aren't cheap and quick to manufacture
- Slow and not suitable for large scale production

e.g. Photolithography: manufacturing computer chips

synthesized onto the substrate by stacking atoms onto each other

- gives rise to crystal planes, crystal planes further stack onto each other
- Fabrication is much less expensive

synthesis of the nanostructures

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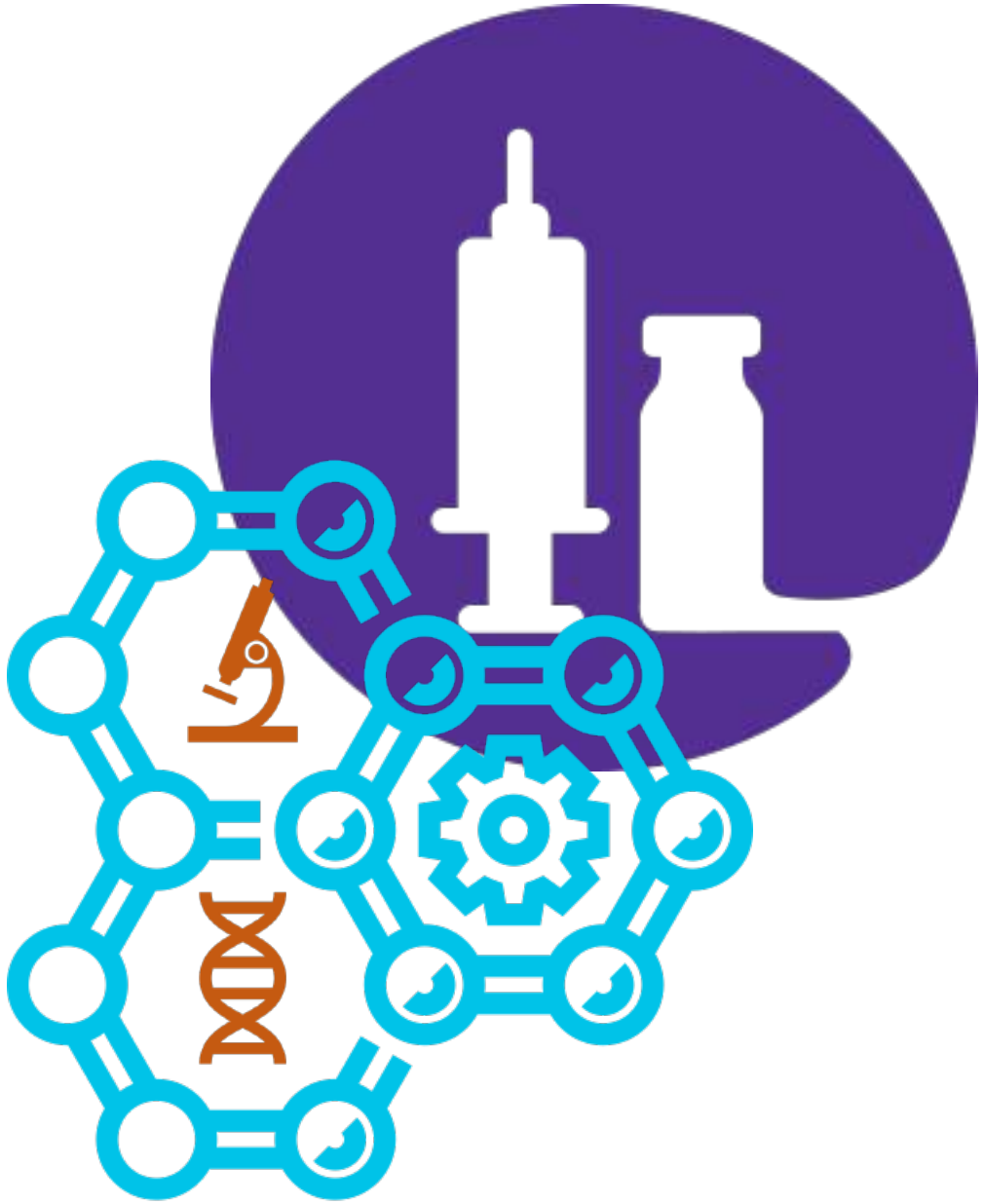
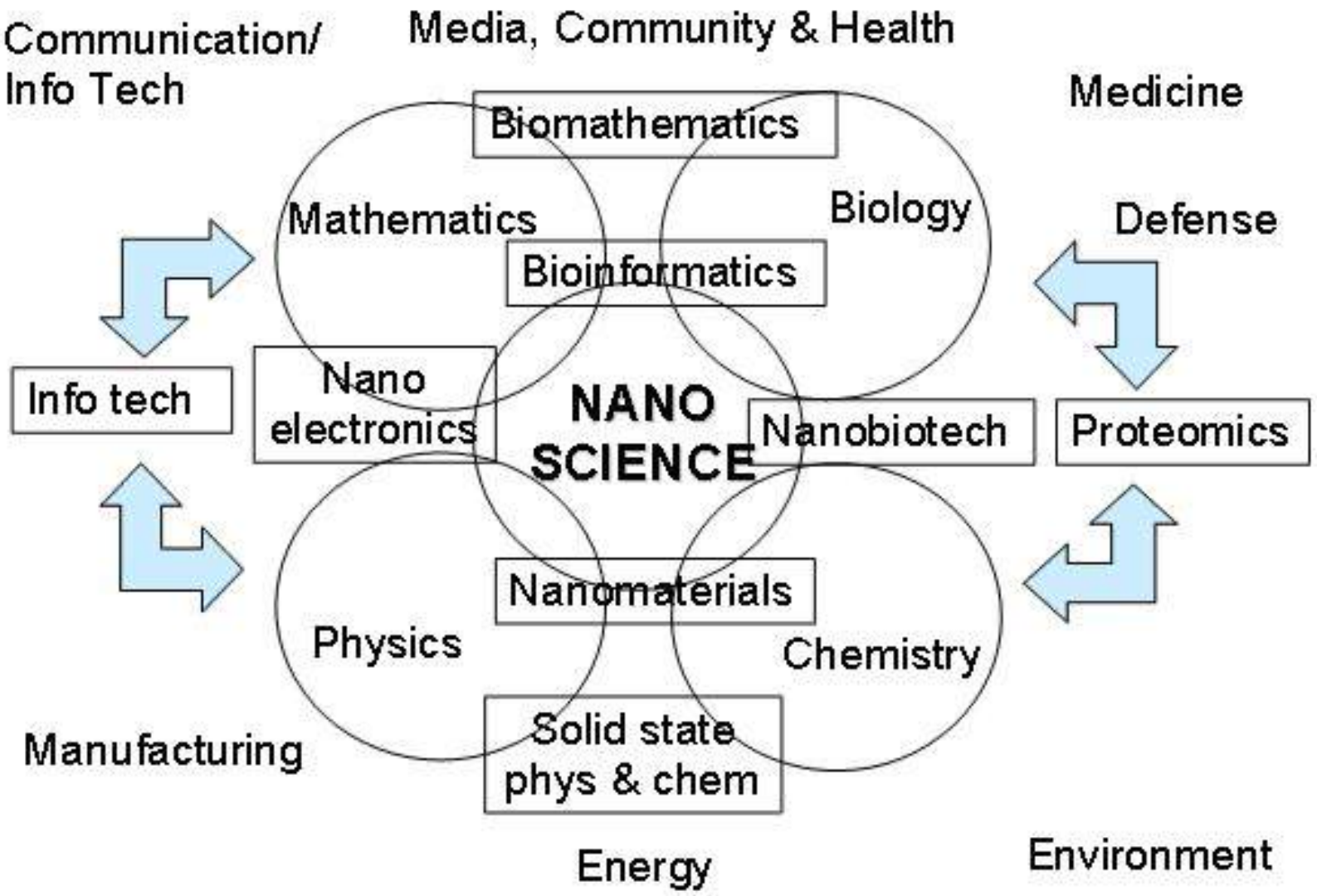
Application & Market



Nanotechnology - Application



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Nanotechnology – Application Sectors

Health industry research and consulting- pharmaceutical, medical, agriculture, food and beverage, environment industries

Research and development in government, universities and private research institutes

Education and academics

Biotechnology industry

Communication and media, interfacing of new technologies

Many new industries emerging as a result of advances in nanotechnology

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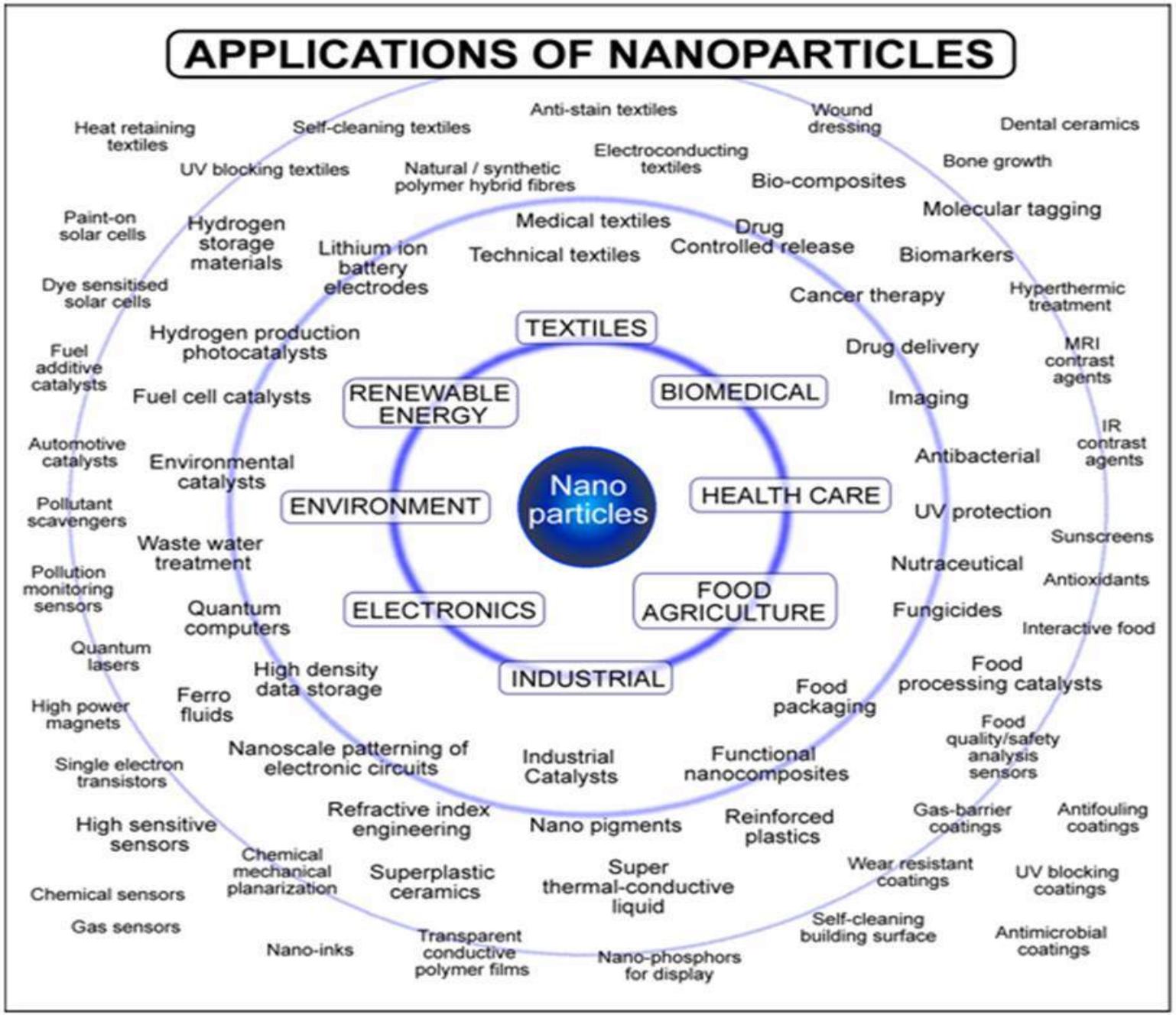

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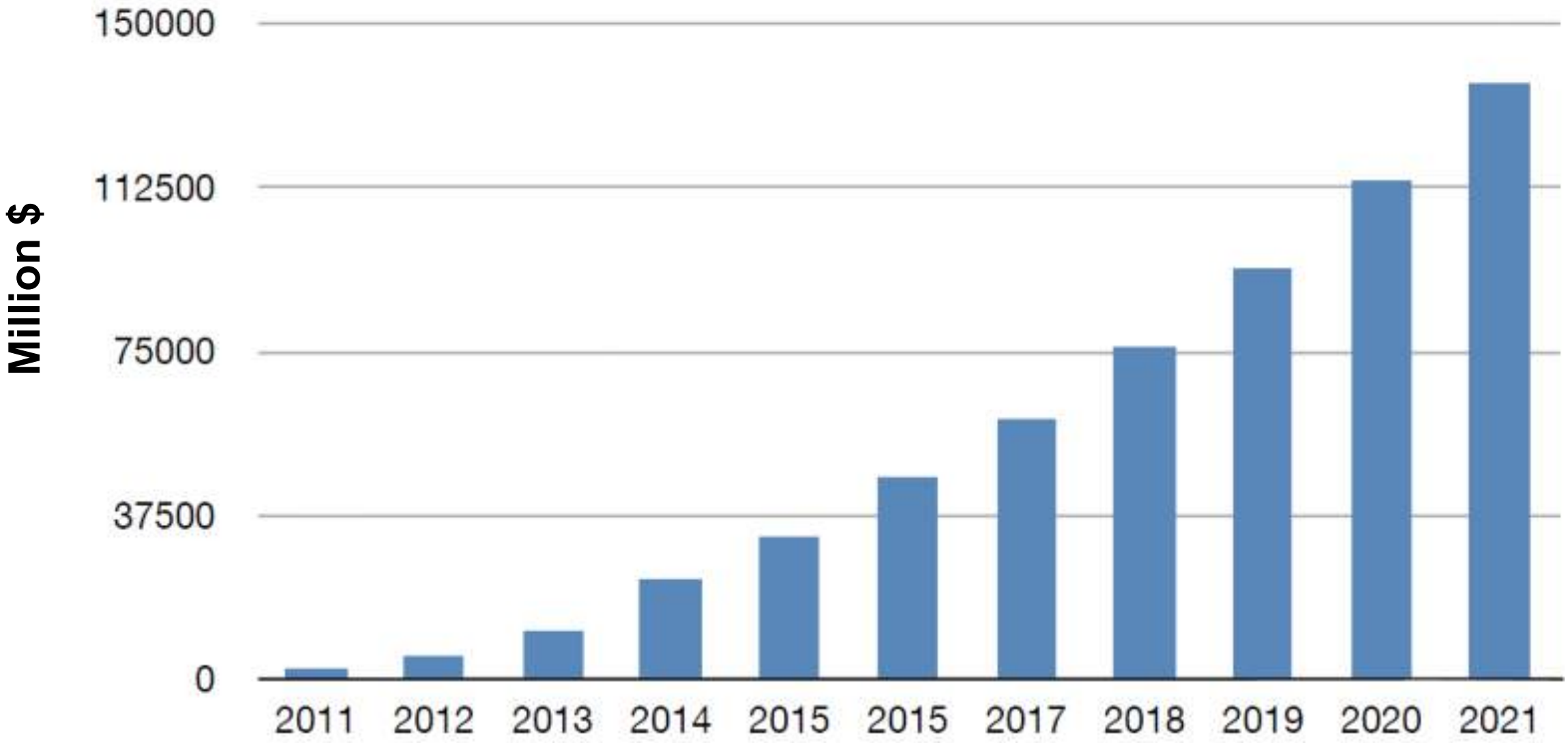
Nanotechnology World Market



Martins, Pedro & Rosa, Daniela & Fernandes, Alexandra & Baptista, Pedro. (2013). Nanoparticle Drug Delivery Systems: Recent Patents and Applications in Nanomedicine. Recent Patents on Nanomedicine. 3. 10.2174/1877912304666140304000133.

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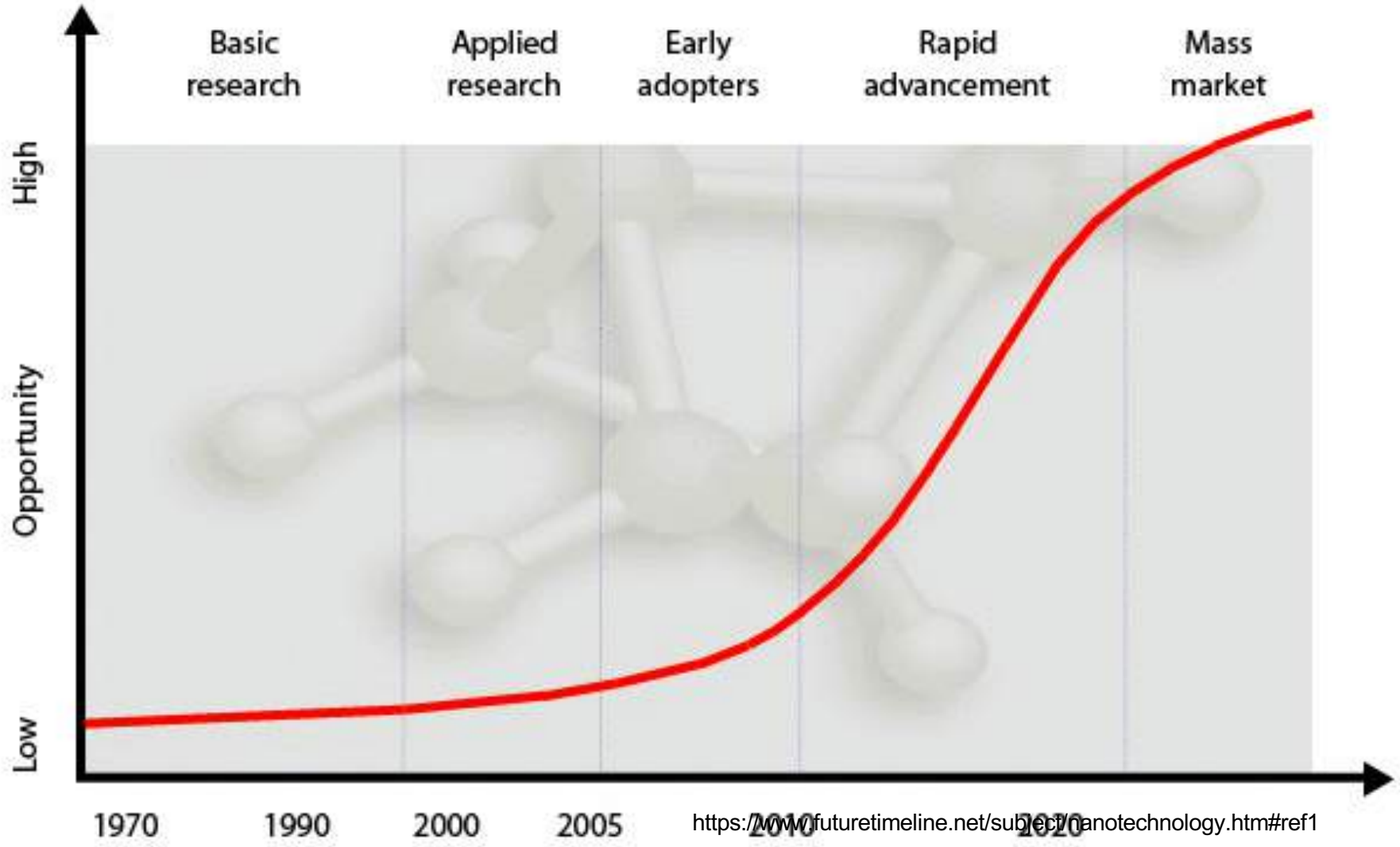
Growth of Nanotechnology



https://www.futuretimeline.net/subject/nanotechnology.htm#ref1

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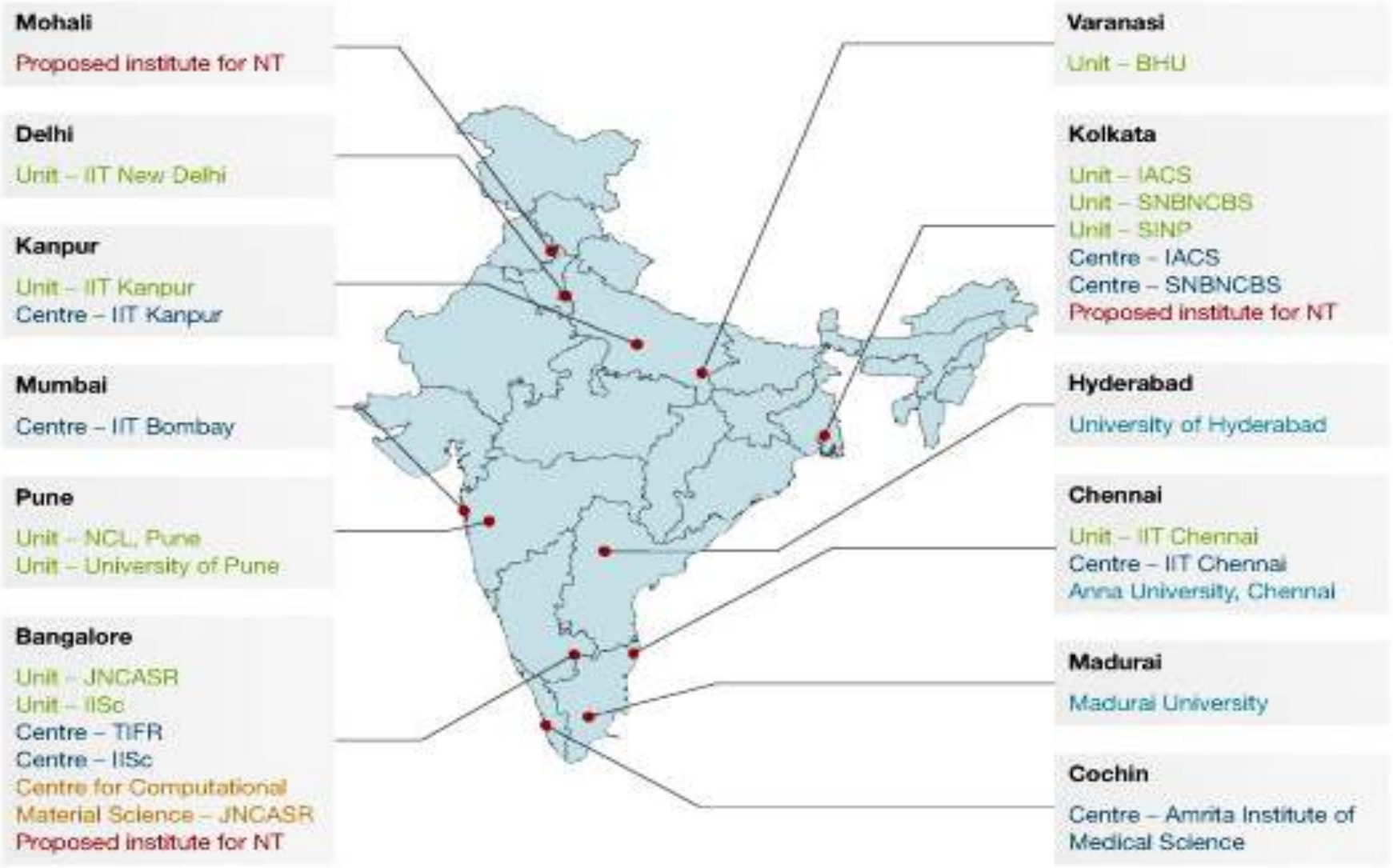
Nanotechnology – Indian Scenario



http://www.indempan.org/image/india-map.jpg

Unit (CoE) | Centre (CoE) | Centre for Computational Material Science (CoE) | Proposed institute for Nanotechnology | Other Centres established at various Institution

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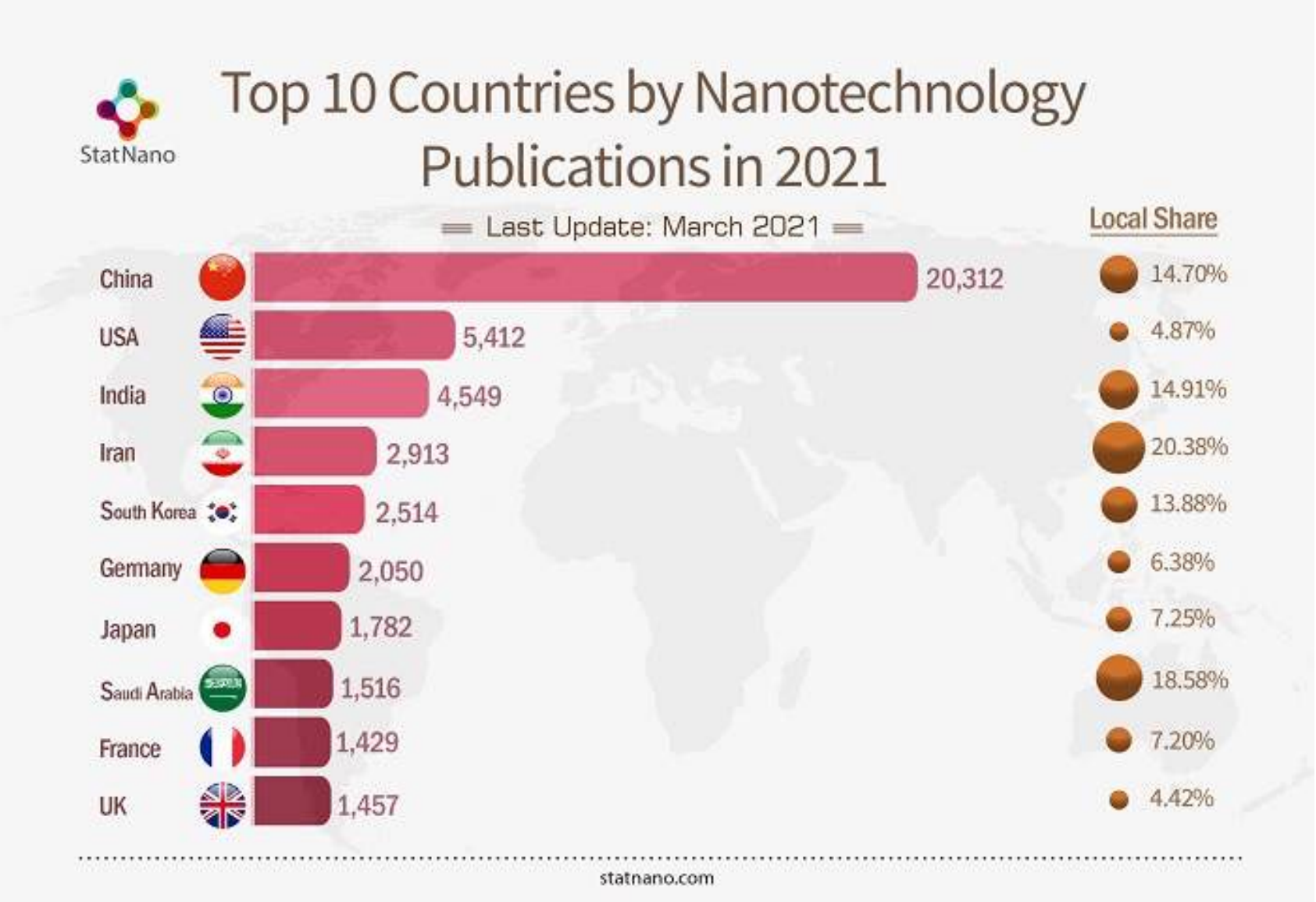
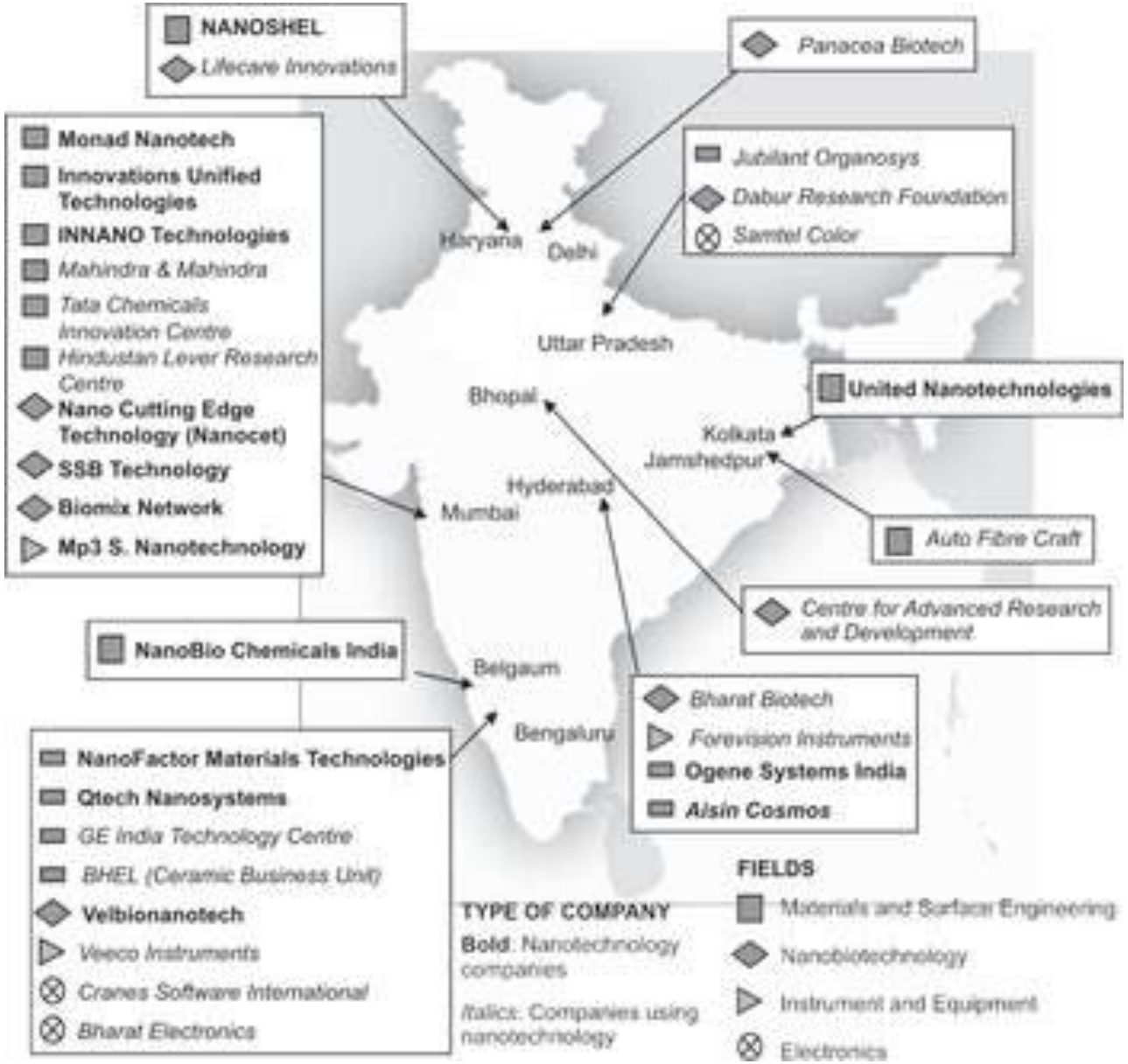


https://statnano.com/

Nanotechnology – Indian Scenario



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Applications

Catalysts
- Envirox™ cerium oxide

Nanoremediation
- SAMMS technology to remove mercury

Paper
- photographic paper

Filters
- nanofibres

Toothpaste
- to remineralise teeth

Food
- packaging

Paint
- improved adhesion and anti-fungal qualities/anti-graffiti

Clothes
- non-staining and anti-radiation

Batteries
- (Black & Decker) phosphate nanocrystal technology

Cleaning products

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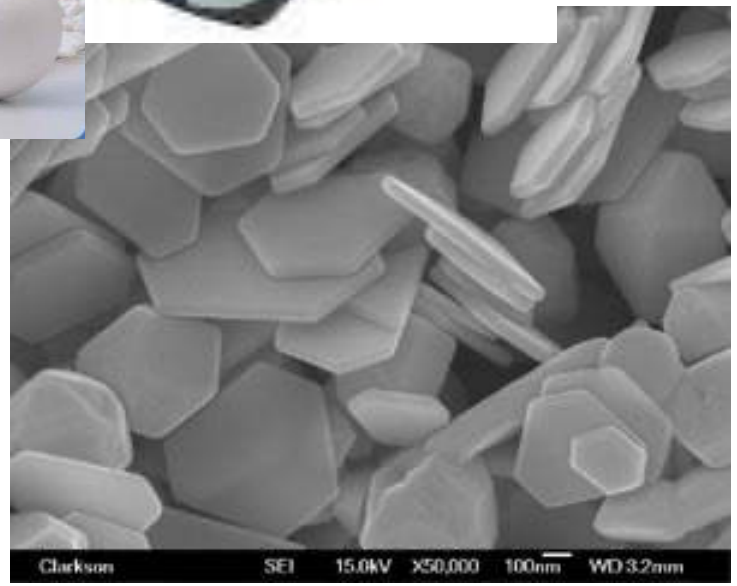
Applications

- Antibacterial effect of silver



- Sunscreens and cosmetics

www.nanotech-now.com

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Applications

- Coatings - self-cleaning windows and stain proof clothing

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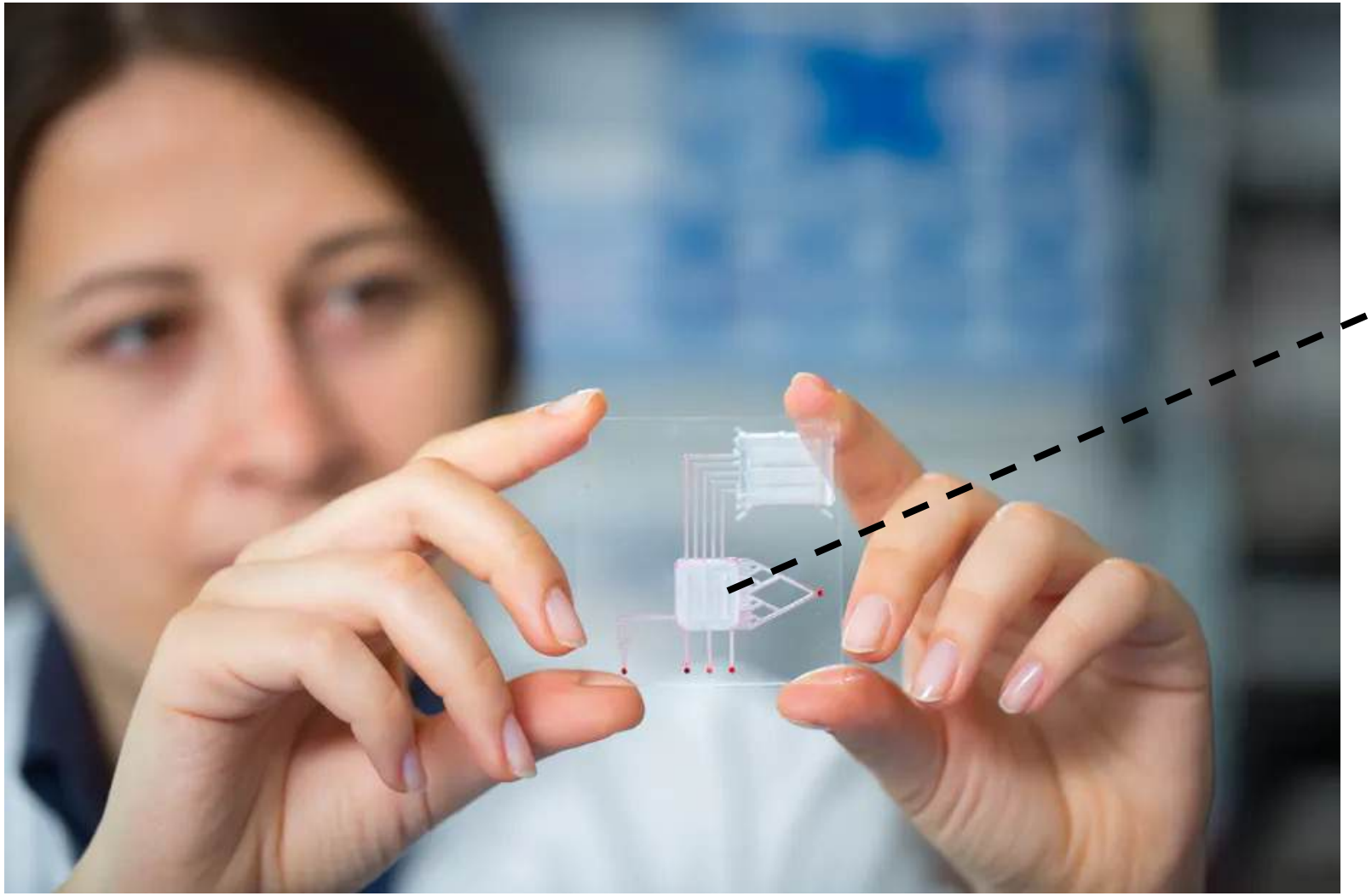
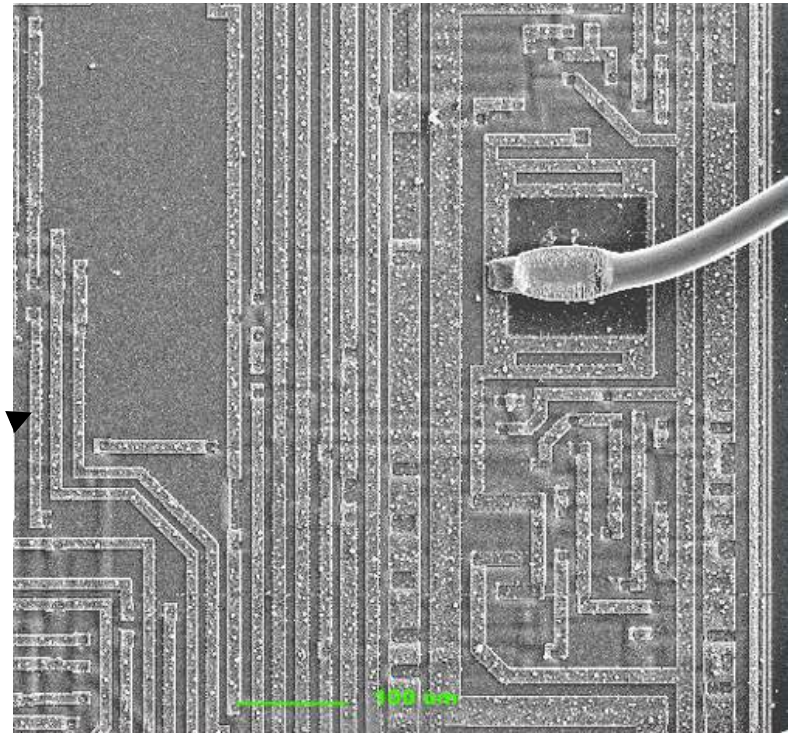
Applications

- Microchips





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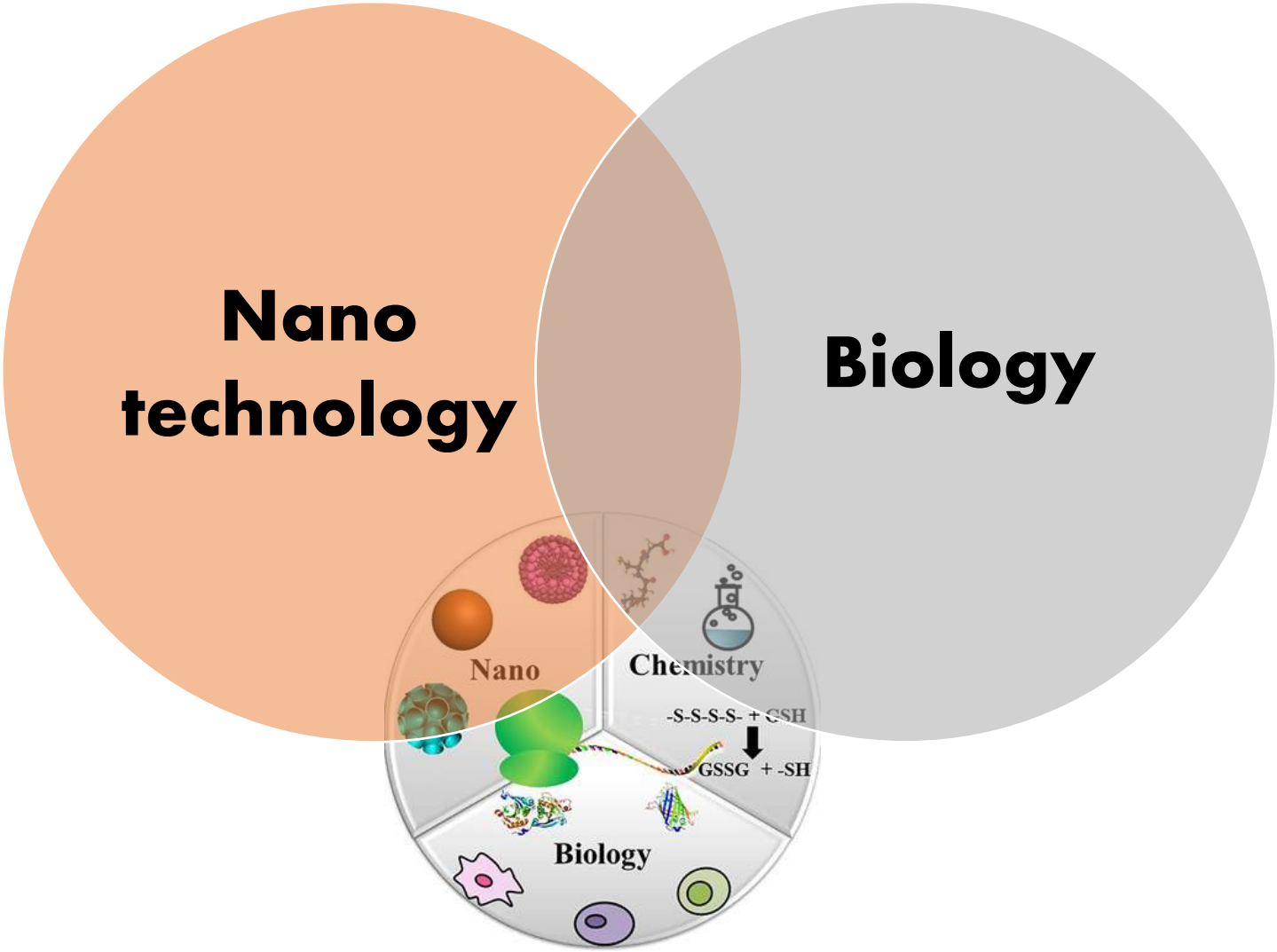
Nanobiotechnology



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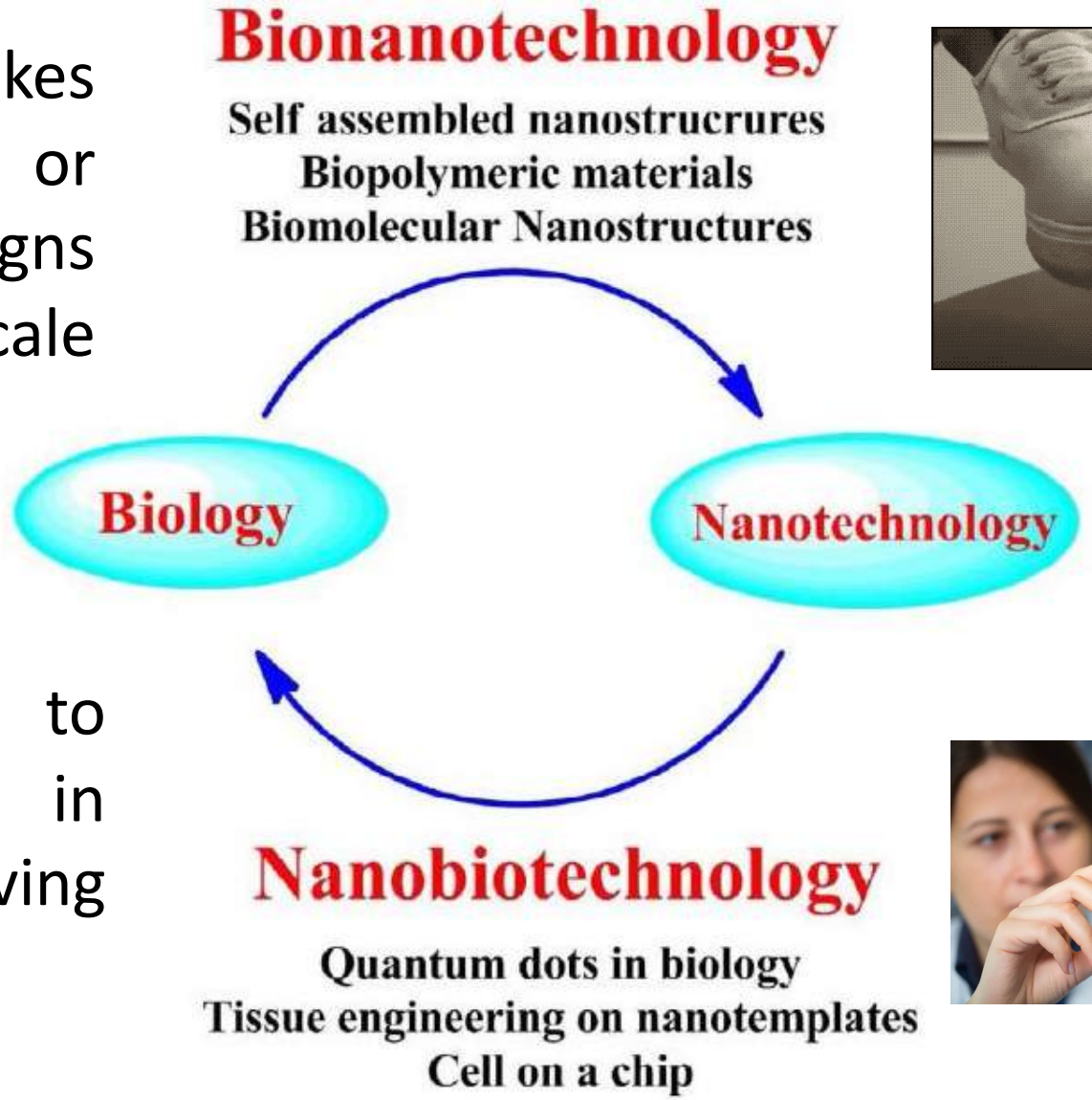
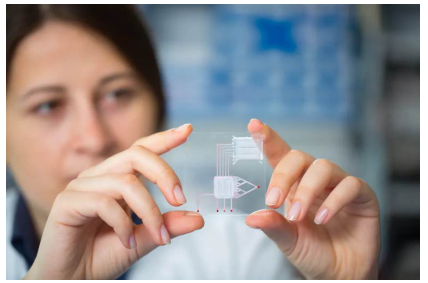
Nanobiotechnology & Bionanotechnology

Bio-nanotechnology takes advantage of natural or biomimetic systems and designs to produce unique nanoscale structures.



Nano-biotechnology aims to exploit advances in nanotechnology for improving biotechnology.



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Applications

Nanoresearch Area	Potential Application in Nanobiotechnology
Nanofibre	• DNA analysis • DNA sequencing • Nanofilteration to obtain ultra-dense fermentation broth for cell cultures • Post-harvest technology, e.g., nanofilteration for production of oiligosaccharide rich syrups
Nanoprobe	• DNA sequencing
Graphene nanoribbon	• DNA sequencing
Nanosphere	• Transfection with expression vectors • Gene therapy
Nanoprojectile	• Direct gene transfer
Nanobeads	• Nanovaccines • DNA vaccines
Dendrimers	• Diagnoses, treatment and eradication of malignant tumours in small animal populations
Quantum dots	• Genetic analysis • Drug discovery • Disease diagnostics
Buckyballs	• Drug delivery
Carbon nanoparticles	• Enzyme based biofuel production

Source: Authors' survey.

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Why is there so much interest/concern about nanotechnology?

Nanobiotechnology

- Enormous potential
- Huge gaps in knowledge and application
- Difficulty in synthesis
- Absence of regulation

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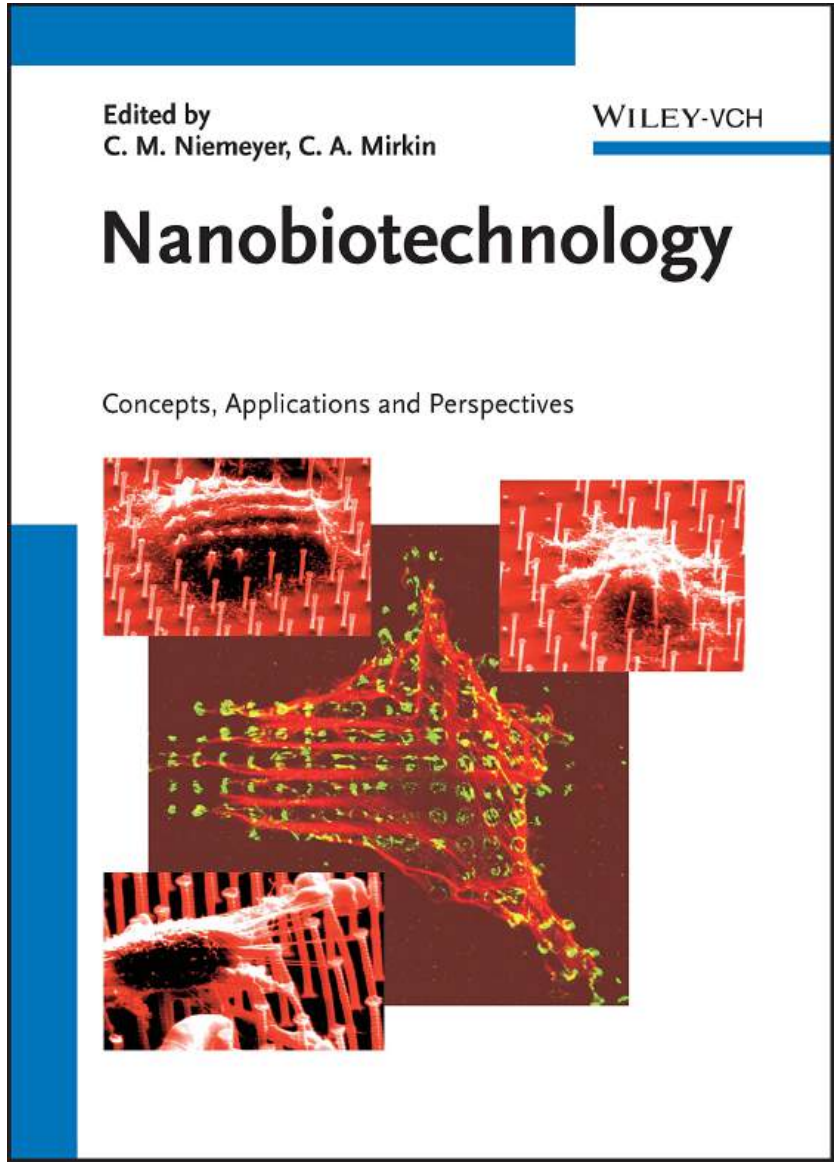
Reference book



Nanobiotechnology: Concepts, Applications and Perspectives
by
Christof M. Niemeyer and Chad A. Mirkin
Wiley-VCH, 2004
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https://www.sciencedaily.com/news/matter_energy/nanotechnology/

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https://nano-magazine.com/

https://news.mit.edu/topic/nanotech

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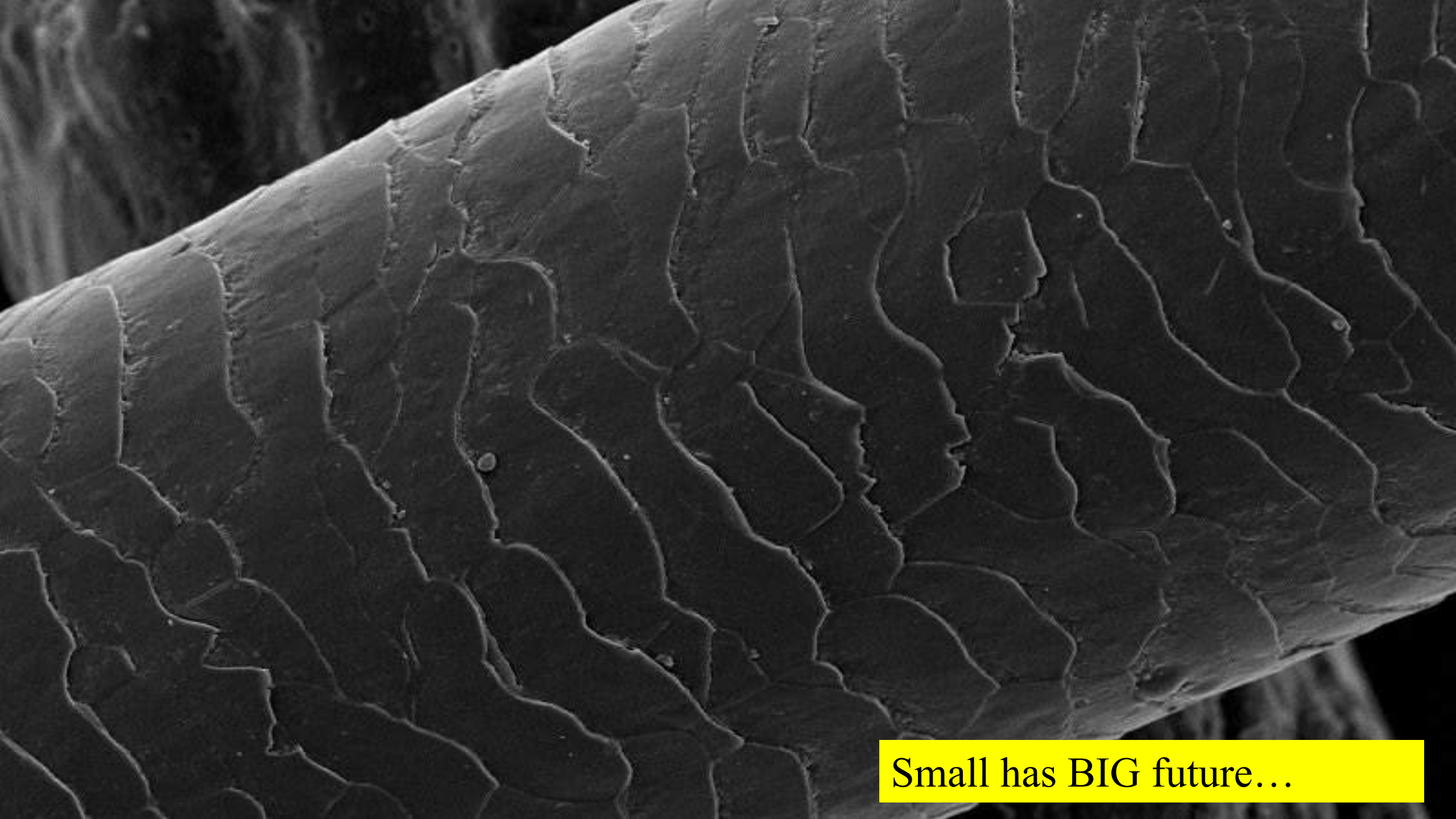
Small has BIG future…

MIT School of Bioengineering Sciences and Research

(A Constituent unit of MIT ADT University)

Rajbaug Campus, Next to Hadapsar, Loni Kalbhor, Maharashtra 412201

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