Building College-University Partnerships for Nanotechnology Workforce Development

Welcome to the:

INTRODUCTION TO NANOTECHNOLOGY EDUCATORS WORKSHOP

January 22, 2021

PennState

Welcome

Building College-University Partnerships for Nanotechnology Workforce Development

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www.nano4me.org
www.cneu.psu.edu

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Penn State Center for Nanotechnology Education and Utilization (CNEU)

Welcome

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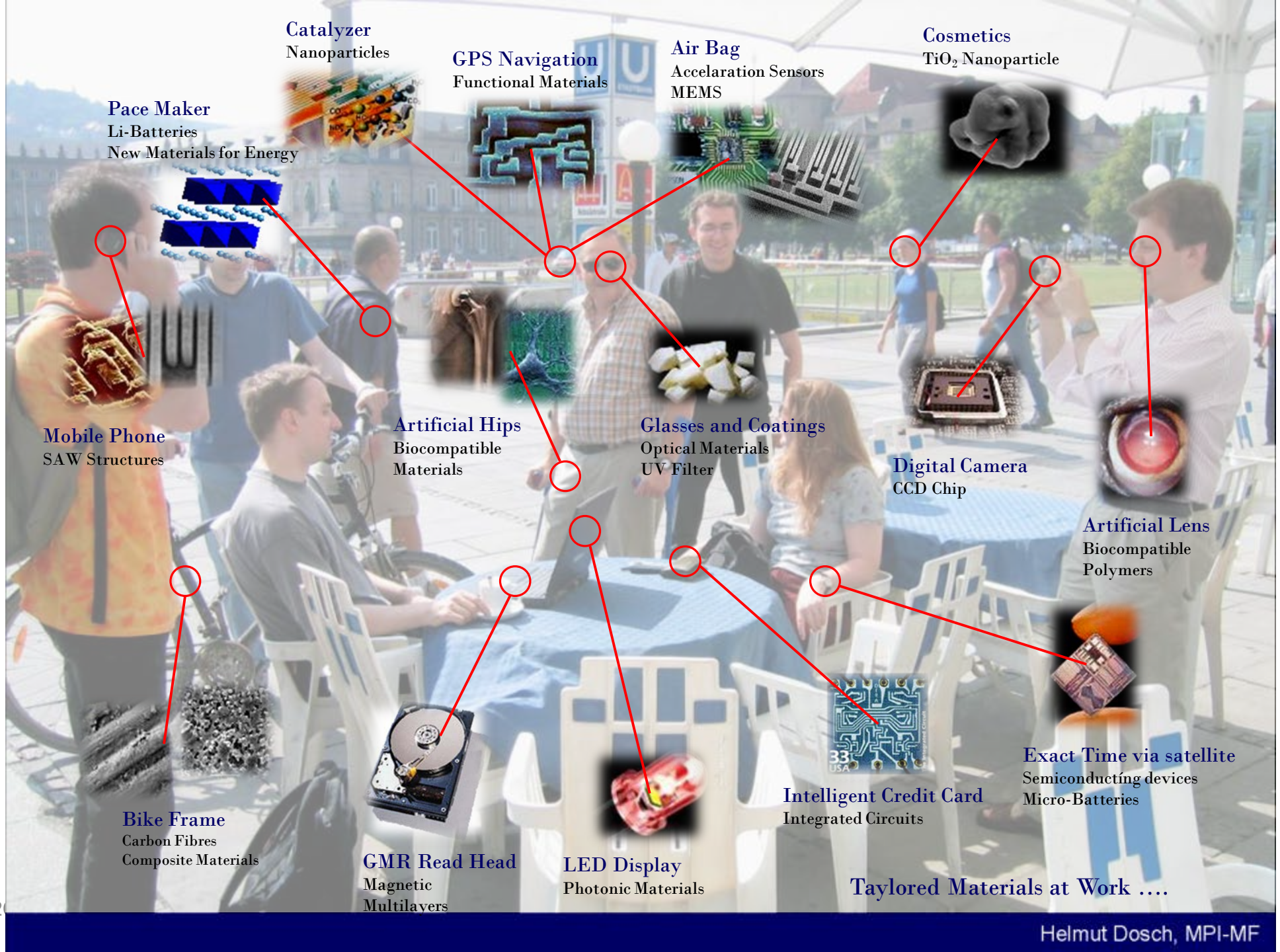
What is nanotechnology?

And why should I care about it?


On a typical day...
Anywhere in the world….
Helmut Dosch, MPI-MF


Catalyzer
Nanoparticles
GPS Navigation
Functional Materials
Air Bag
Accelaration Sensors
MEMS
Cosmetics
TiO_2 Nanoparticle
Pace Maker
Li-Batteries
New Materials for Energy
Mobile Phone
SAW Structures
Artificial Hips
Biocompatible
Materials
Glasses and Coatings
Optical Materials
UV Filter
Digital Camera
CCD Chip
Artificial Lens
Biocompatible
Polymers
Bike Frame
Carbon Fibres
Composite Materials
GMR Read Head
Magnetic
Multilayers
LED Display
Photonic Materials
Intelligent Credit Card
Integrated Circuits
Exact Time via satellite
Semiconducting devices
Micro-Batteries
Taylored Materials at Work ....

Nano's contribution to fighting COVID-19

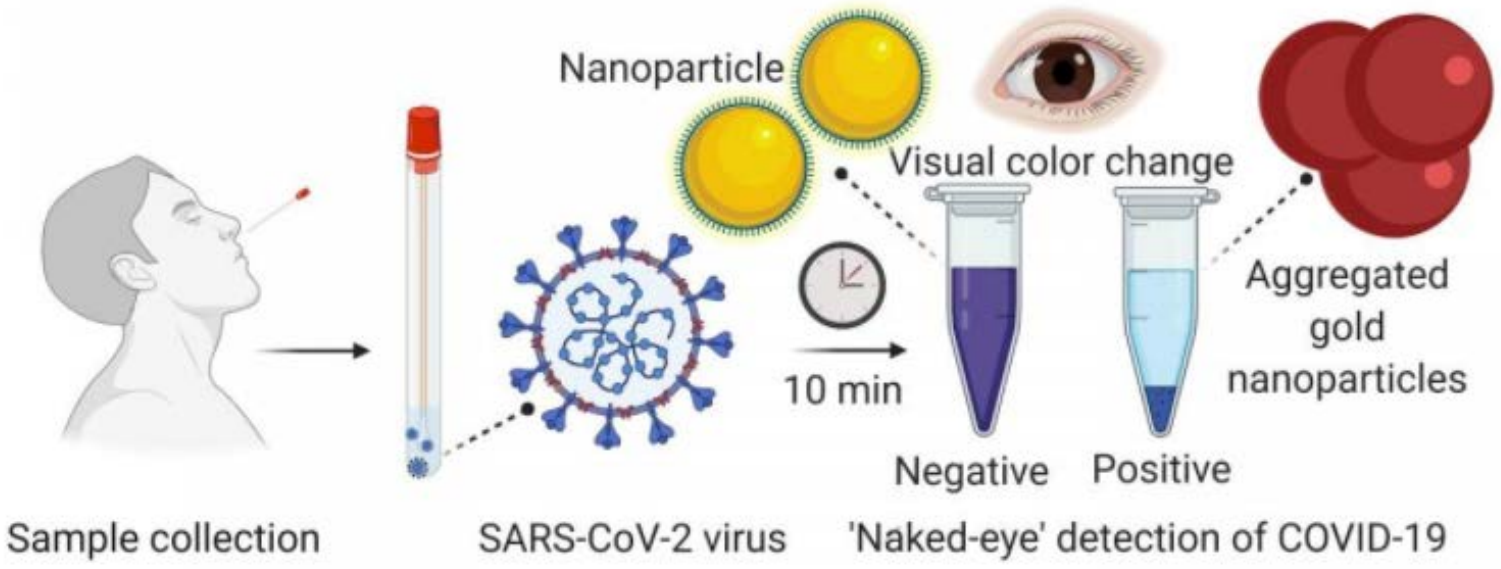
- Point of Care and Laboratory Testing
- At-home tests
- PPE
- Oxygen generators
- Sensors
- Antimicrobial Coatings
- Antibody testing
- Vaccine development
- Vaccine delivery systems
- Medical research (virus understanding)
- EVERYWHERE you can think of

Gold np's enabling rapid COVID testing

UMSOM

5-29-20

Rapid COVID-19 Test



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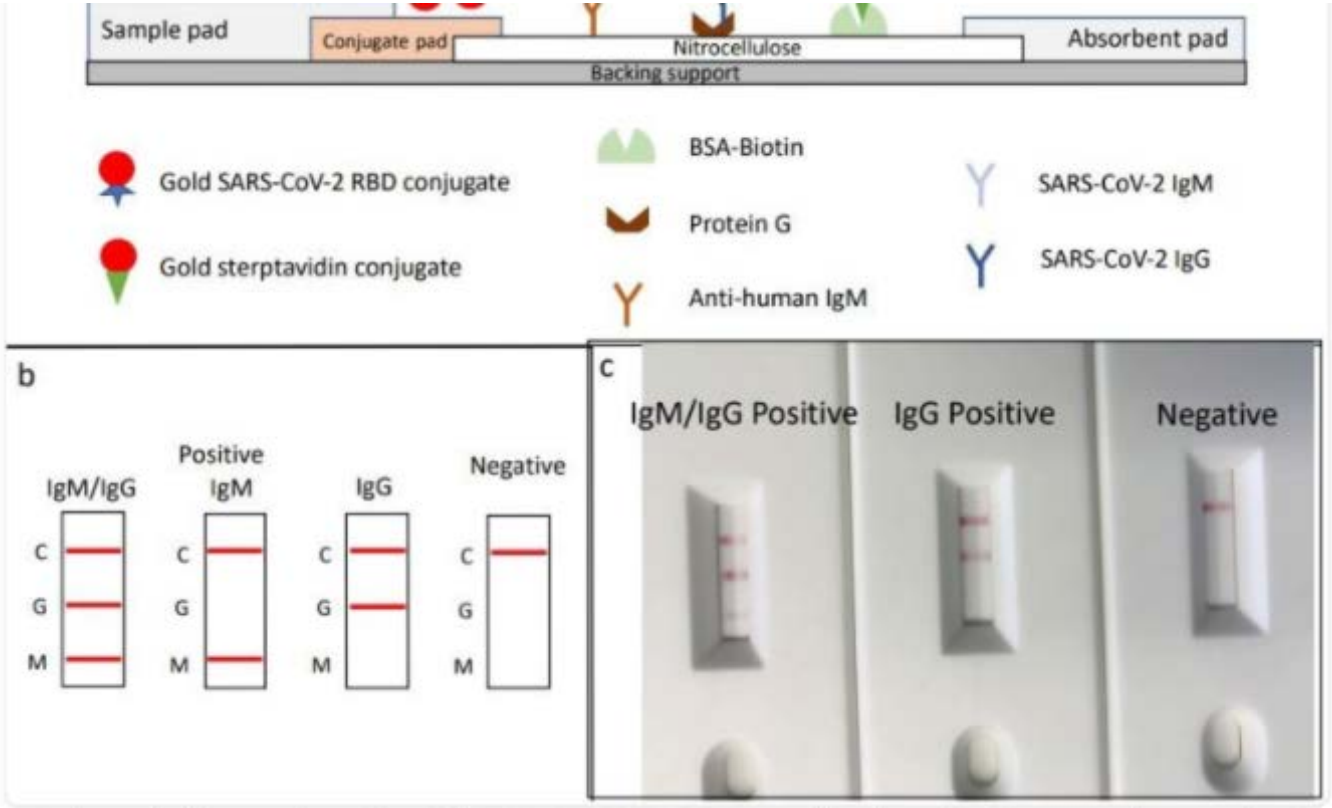
Gold np-enabled COVID antibody test

Rapid SARS-CoV-2 IgM-IgG combined antibody test

CEO & co-founder of GaDia SA



Schematic illustration of rapid SARS-CoV-2 IgM-IgG combined antibody test and example of typical results. a, Schematic diagram of the detection device; b, illustration of different testing results; c, example of typical results obtained with the RDT.

Vaccines: WHAT IS MESSENGER RNA (mRNA) AND WHY IS IT SO IMPORTANT

mRNA can be thought of as a set of instructions that tell your body's cells how to make proteins. While COVID-19 may seem new to many of us, **researchers have been studying coronaviruses for over 50 years**. During this time, they've also been learning how mRNA technology can help develop effective vaccines.

Here's how mRNA technology used in COVID-19 vaccines works:

The mRNA vaccine tells your body to make a small, non-infective portion of the outer part of the COVID-19 virus particle called a "spike protein".

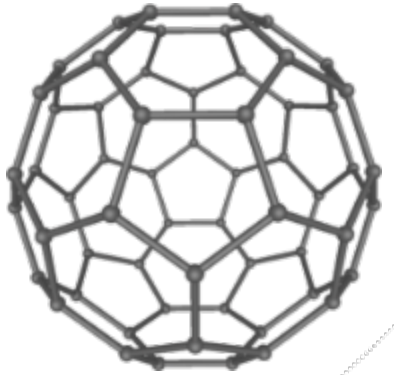
This trains your immune system into recognizing the virus and your body responds by building antibodies.

Later, if you are exposed to the real virus, these antibodies are then able to attack it and prevent you from getting sick. The antibodies' ability to prevent sickness is what is meant when people say a vaccine provides immunity.

A key benefit of mRNA vaccines is that the process to develop them can be standardized and scaled up more efficiently than other methods, which has been especially important in our response to COVID-19.

What is nanotechnology?

The creation of functional materials, devices, and systems through control of matter at the scale of *1 to 100 nanometers* , and the exploitation of *novel properties* and phenomena at the same scale.



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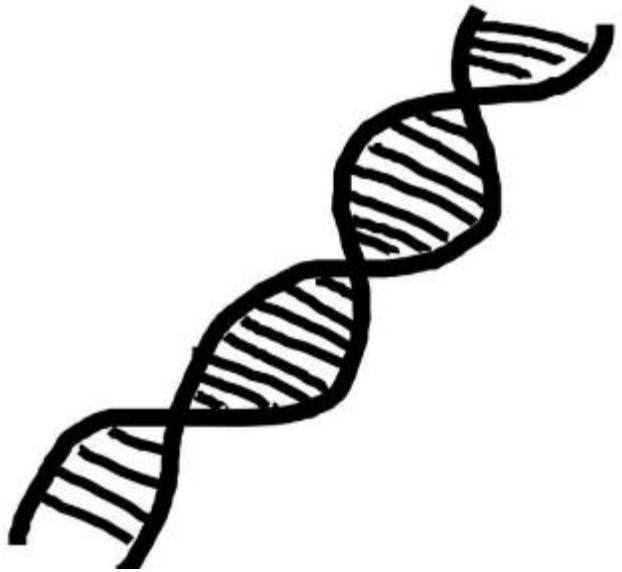
How Small is a Nanometer?

Size & scale

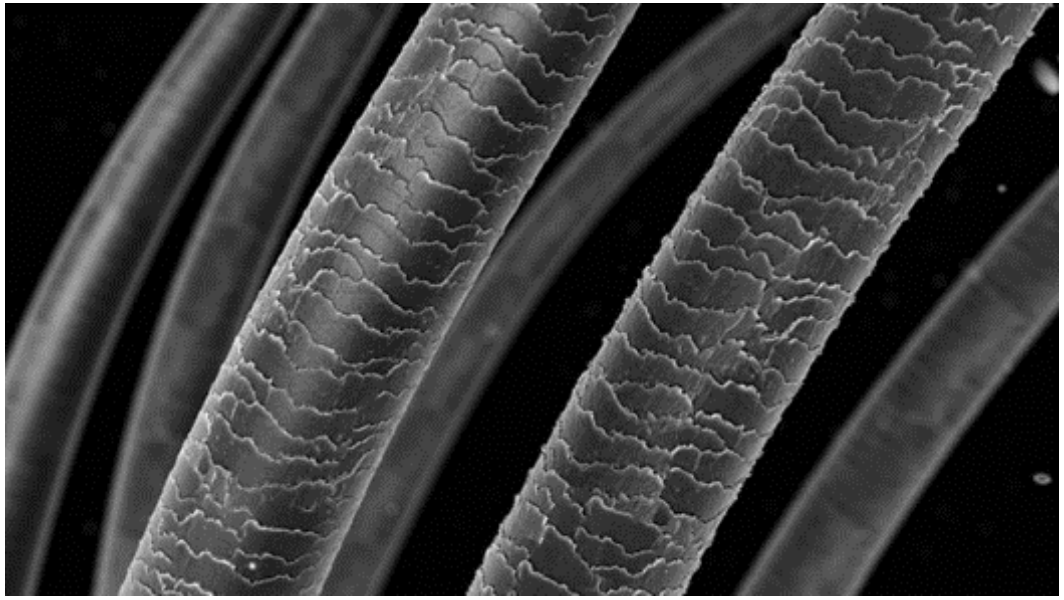
How small is a nanometer?

One nanometer is a billionth of a meter.



If we measured in nanometers...

Source: https://www.ngccoin.com/



Source: https://www.labmanager.com/

How small is a nanometer?

And if the Earth were **one meter** in diameter, a nanometer would be…

One billionth…

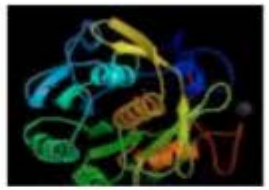
How long ago was 1 million seconds?	Jan 11th	2021
How long ago was 1 billion seconds?	May 16th	1989

Source: https://imgur.com/gallery/iMrJ7dF

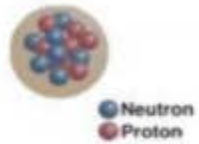
Size and Scale Challenge

Order the items from smallest to largest.

5. width of a proteinase enzyme



2. nucleus of an oxygen atom

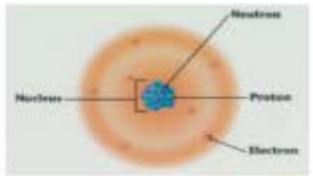


3. diameter of a red blood cell

19. diameter of a carbon nanotube

4. height of a typical 5-year-old child

22. diameter of a nitrogen atom



12. width of a water molecule

10. diameter of a ribosome

13. width of a bacterium

15. diameter of a virus

1. thickness of a penny

24. wavelength of visible light

Visible Light Spectrum

18. length of a human muscle cell

6. length of a dust mite

14. length of an apple seed

8. length of an amoeba

11. thickness of sewing thread

23. thickness of a staple

How small is small?

Largest

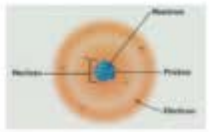
Smallest

14. length of an apple seed

19. diameter of a carbon nanotube

2. nucleus of an oxygen atom

22. diameter of a nitrogen atom



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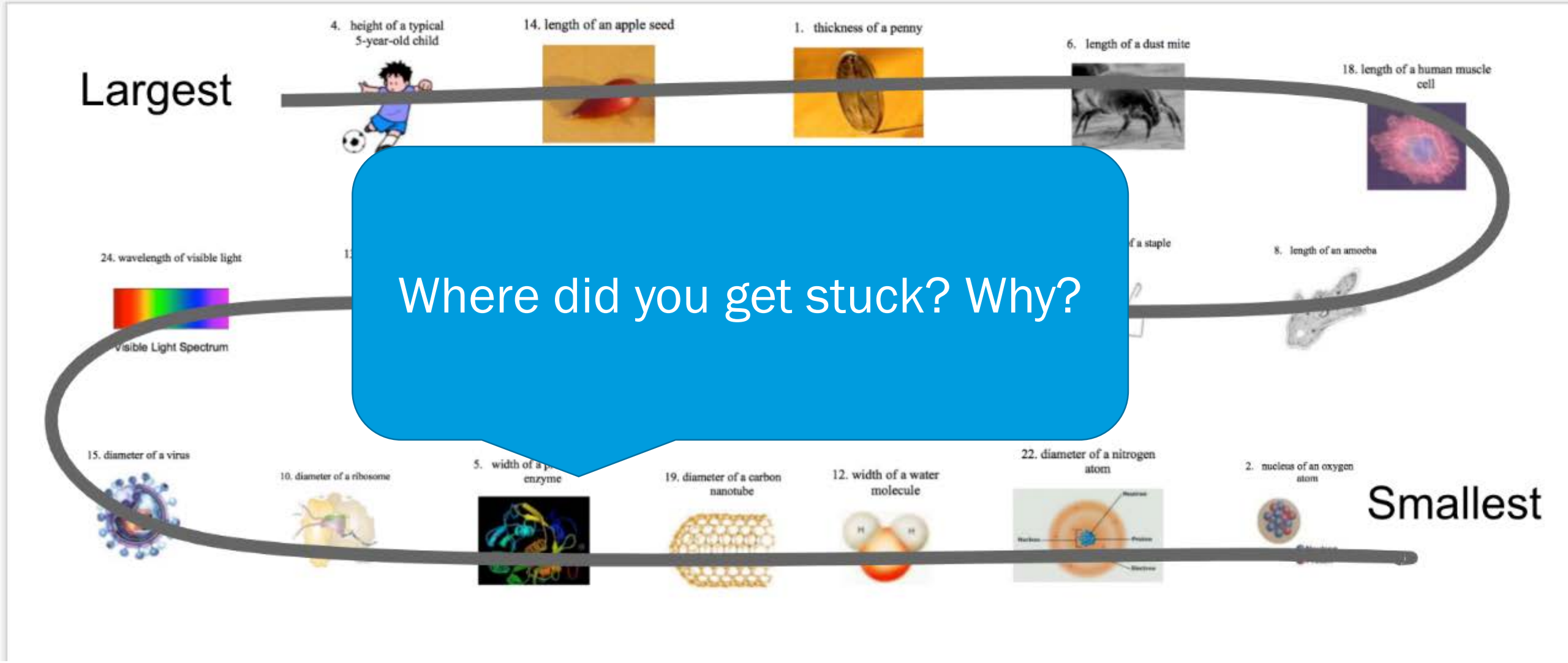
How small is small?



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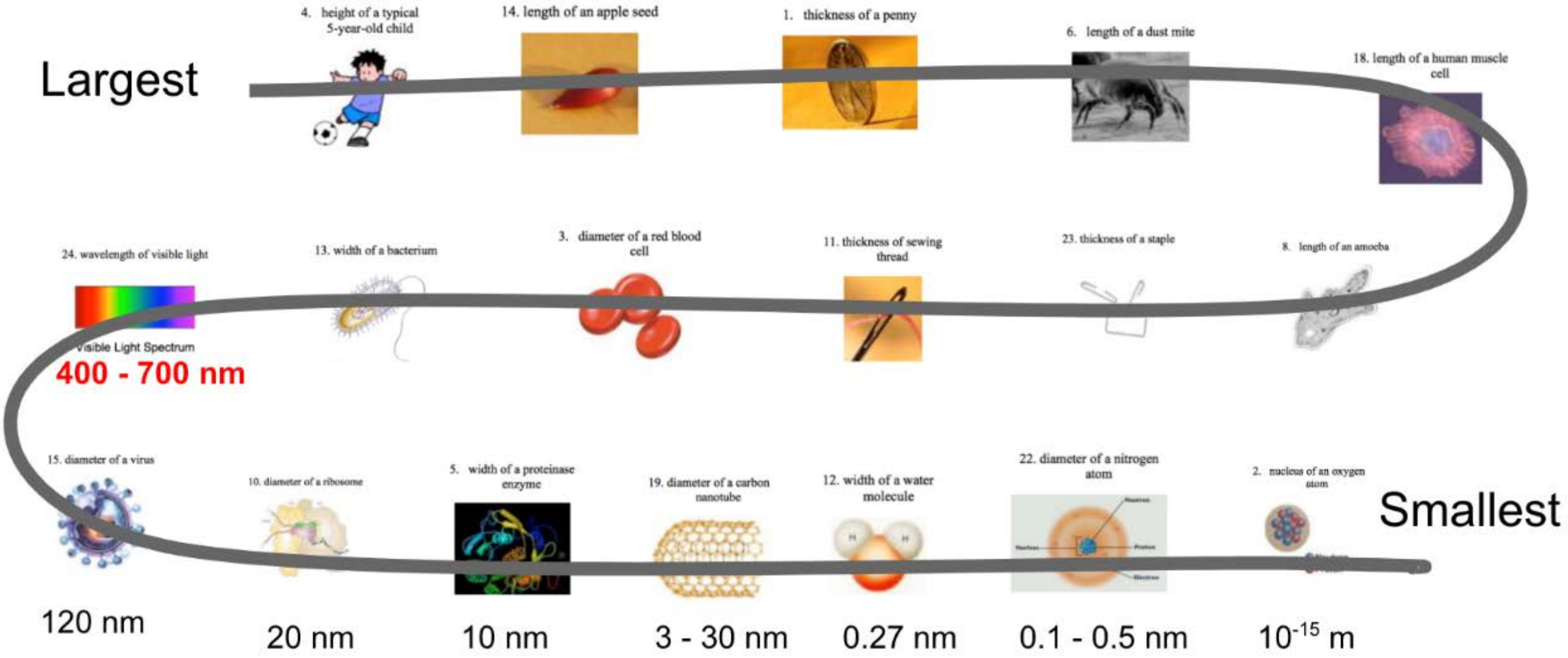
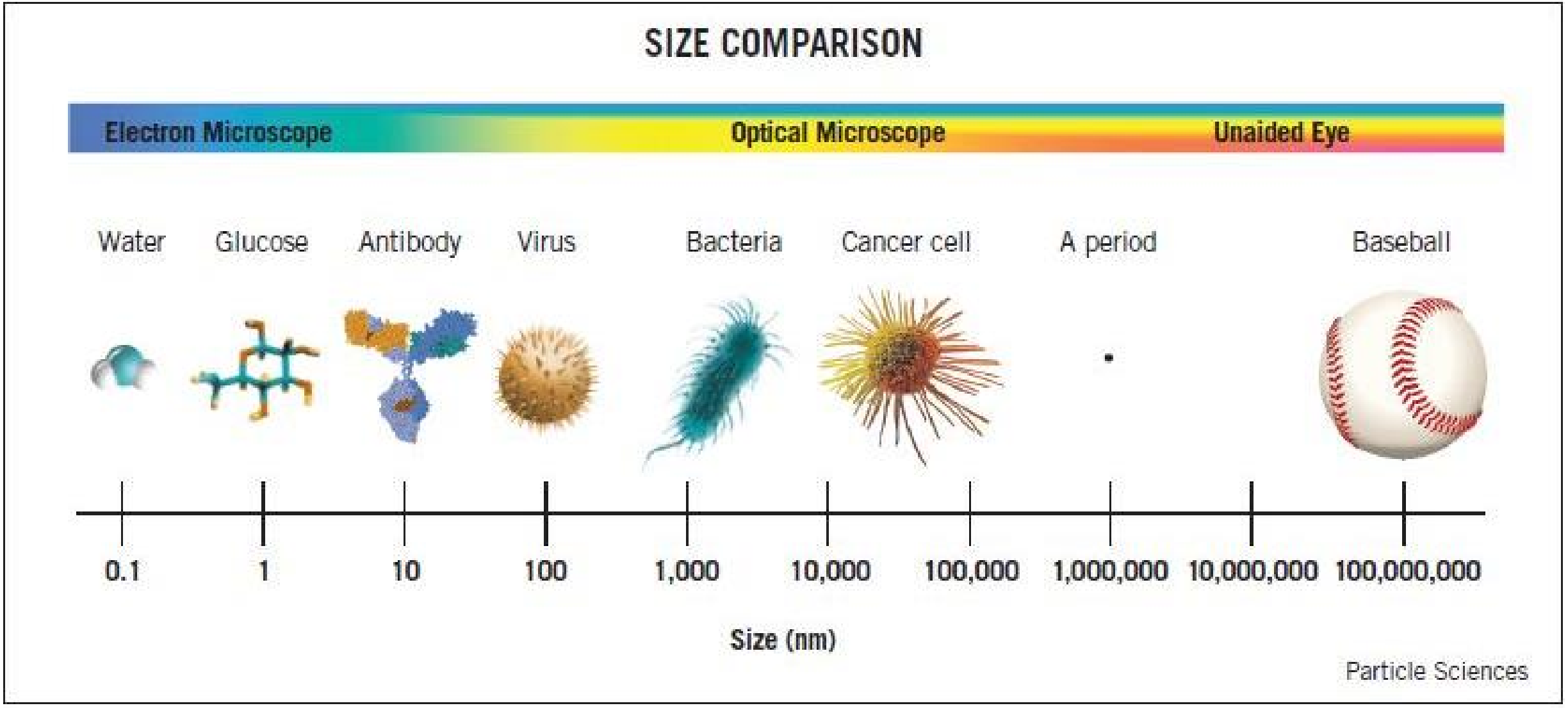


How small is small?



What’s so special about the nanoscale?

Properties

What's so special about the nanoscale?

Scale, Proportion and Quantity - *Crosscutting Concept, NGSS*

"The large idea is that ***the way in which things work may change with scale***. Different aspects of nature change at different rates with changes in scale, and so the relationships among them change, too."

Source: A framework for K-12 science education: Practices, crosscutting concepts, and core ideas, p. 89

Property changes with scale

Objects behave differently…

- Light-matter interactions change
- Gravity becomes insignificant, intermolecular forces dominate
- Surface effects become important due to large surface area
- Motion becomes complicated
- Quantum effects dominate

Nanoengineering is about understanding these characteristics and using them to manipulate matter at the nanoscale.

Property changes with scale

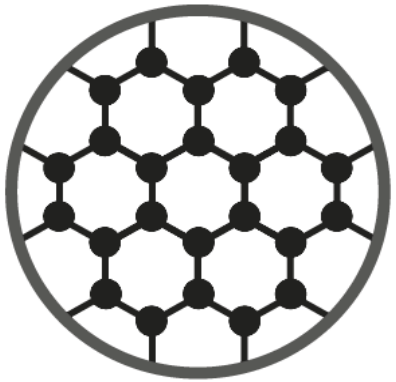
GRAPHENE: THE CARBON-BASED 'WONDER MATERIAL'

Since its discovery in 2003, graphene has been a hot topic in chemistry and materials science research. It's been linked with water purification, electronics, and biomedical applications. However, how close are we really to using graphene in our day-to-day lives? This graphic looks at its properties, uses, and future.

WHAT IS GRAPHENE?

- SINGLE LAYER OF CARBON ATOMS
- HONEYCOMB-LIKE STRUCTURE
- GRAPHITE IS LAYERS OF GRAPHENE
- ISOLATED IN 2003 IN MANCHESTER

Graphene is a single layer of graphite, the carbon-based material found in pencil leads. Graphite has been known for centuries, but graphene was only isolated in 2003, by shearing layers off of graphite using sellotape. It's a single atom-thick layer of carbon atoms, that are arranged in a flat, hexagonal lattice structure.

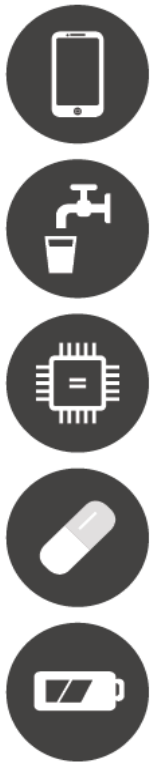


THE PROPERTIES OF GRAPHENE

- HIGH ELECTRICAL CONDUCTIVITY
- 200X STRONGER THAN STEEL
- THIN AND LIGHTWEIGHT
- HIGH THERMAL CONDUCTIVITY
- VERY HIGH TRANSPARENCY

Graphene's 'wonder material' reputation stems from its superlative properties. It is a million times thinner than a piece of paper, yet stronger than diamond, and 200 times stronger than steel, due to the strong carbon-carbon bonds. It's also a flexible material, and conducts heat and electricity better than copper. Being only one atom thick, almost 98% of visible light passes through graphene, making it transparent.

POTENTIAL USES OF GRAPHENE



TOUCH SCREENS IN DEVICES

Graphene's transparency and conductivity means that it can be used in displays and touchscreens. However, currently these are more expensive to produce than the currently used material, indium tin oxide.

WATER FILTRATION SYSTEMS

Graphene allows water to pass through it, but not other liquids and gases, so it can be used in water purification. Researchers are working on a device that could be capable of filtering salt from sea water.

IN ELECTRONIC DEVICES

Graphene has been touted as silicon's successor, and has been used to make very fast transistors. However, its conductivity cannot be 'switched off' as silicon's can. Other 2D materials seem more promising.

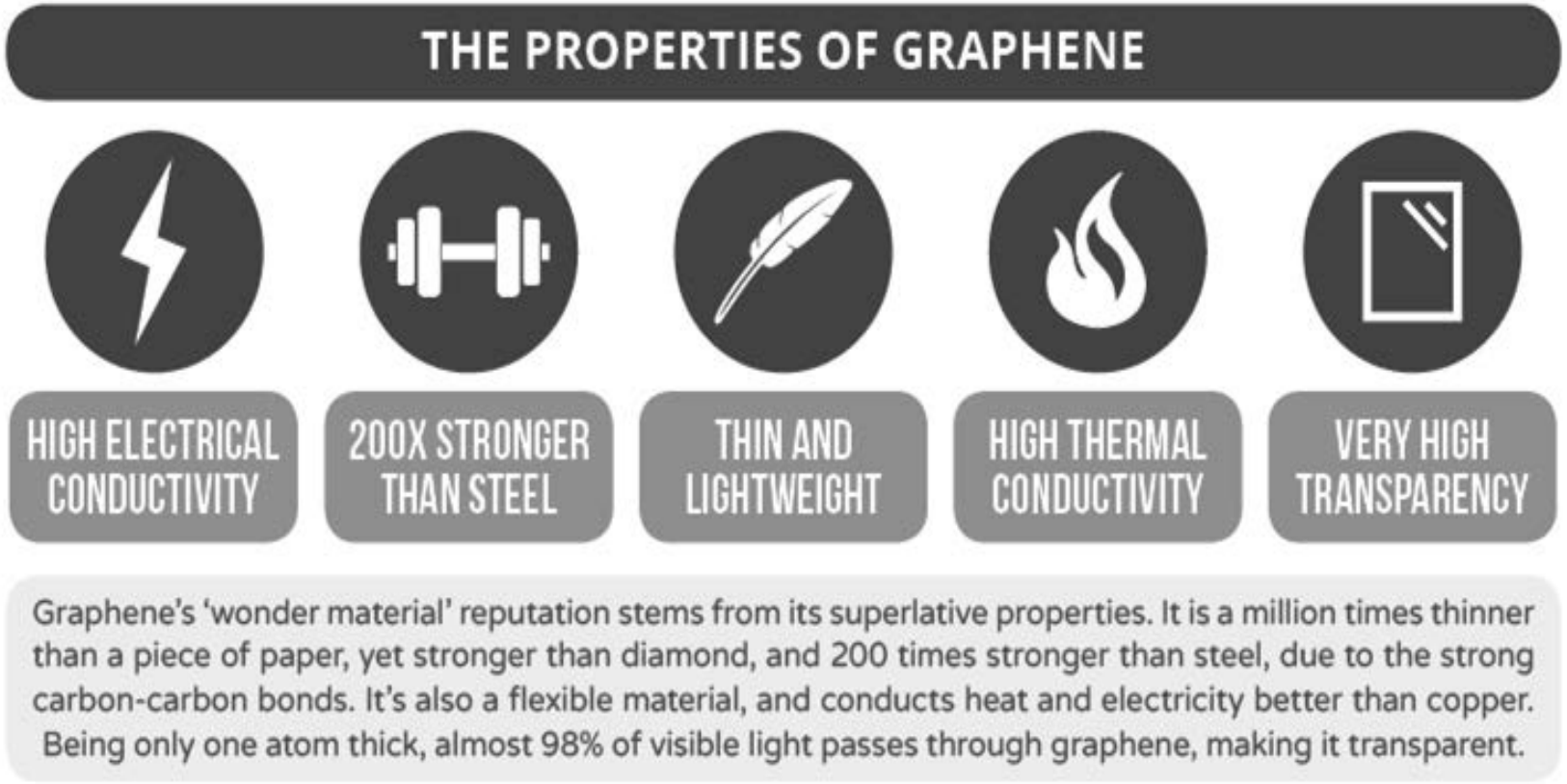
MEDICAL SENSORS & DRUG DELIVERY

Several biomedical applications are being explored for graphene, including drug delivery, cancer therapy, and its use as a sensor. However, its toxicity profile must be investigated before any clinical uses.

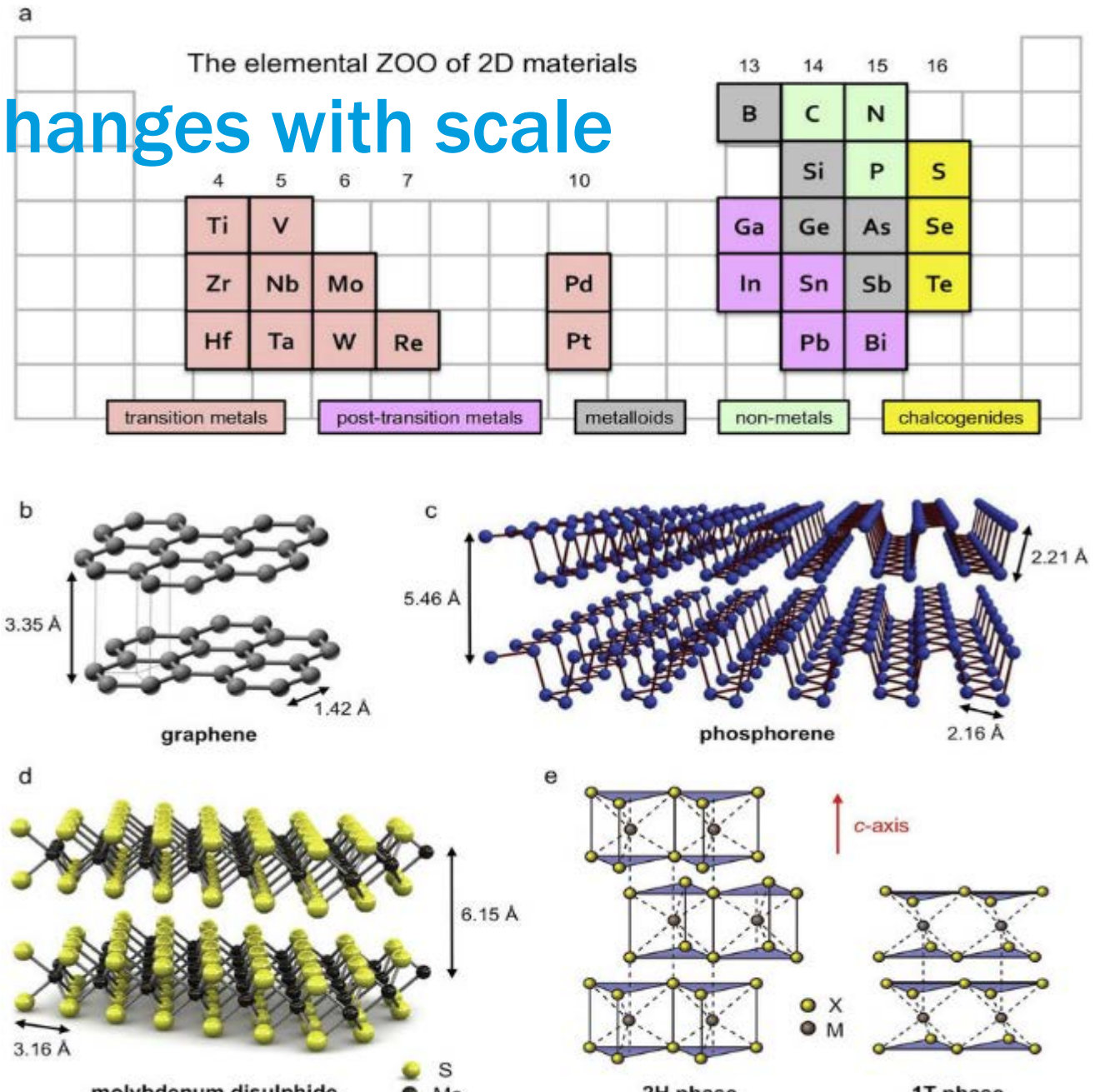
ENERGY STORAGE & COMPOSITES

Graphene-based energy storage devices are possible. It can also substitute for graphite in normal batteries, improving efficiency. Additionally, it can be added to materials to make them stronger and more lightweight.

Property changes with scale



Property changes with scale



Source: https://www.researchgate.net/figure/Two-dimensional-ZOO-a-Simplified-periodic-table-highlighting-the-elements-which-form_fig1_317161382

Light-matter interactions at the nanoscale

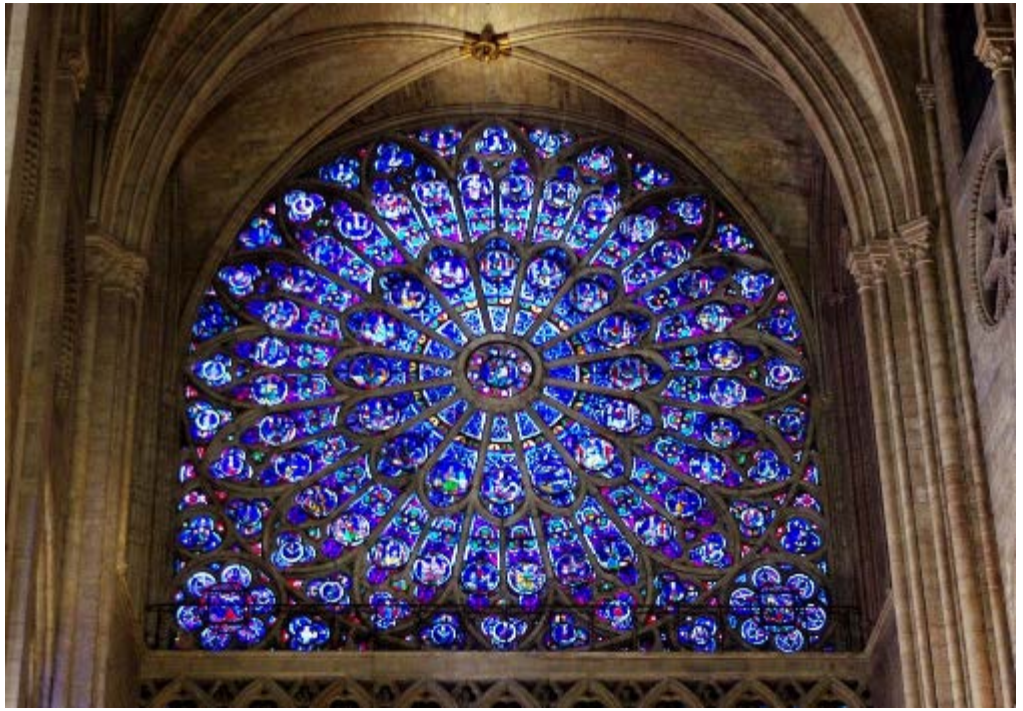
Macroscale Gold

Nanoscale Gold

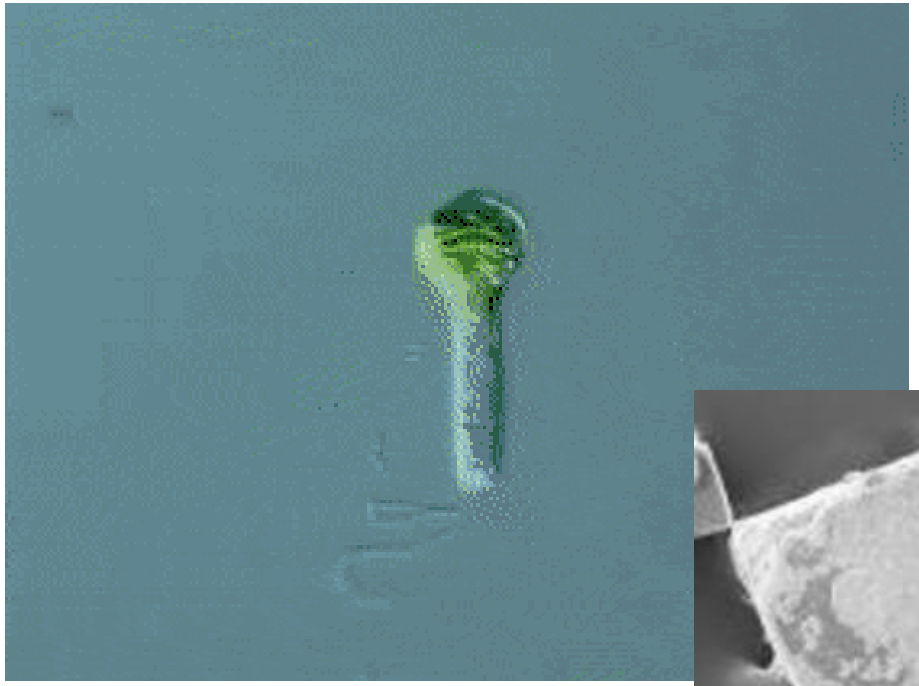
Material properties change with the size of the gold nanoparticle.

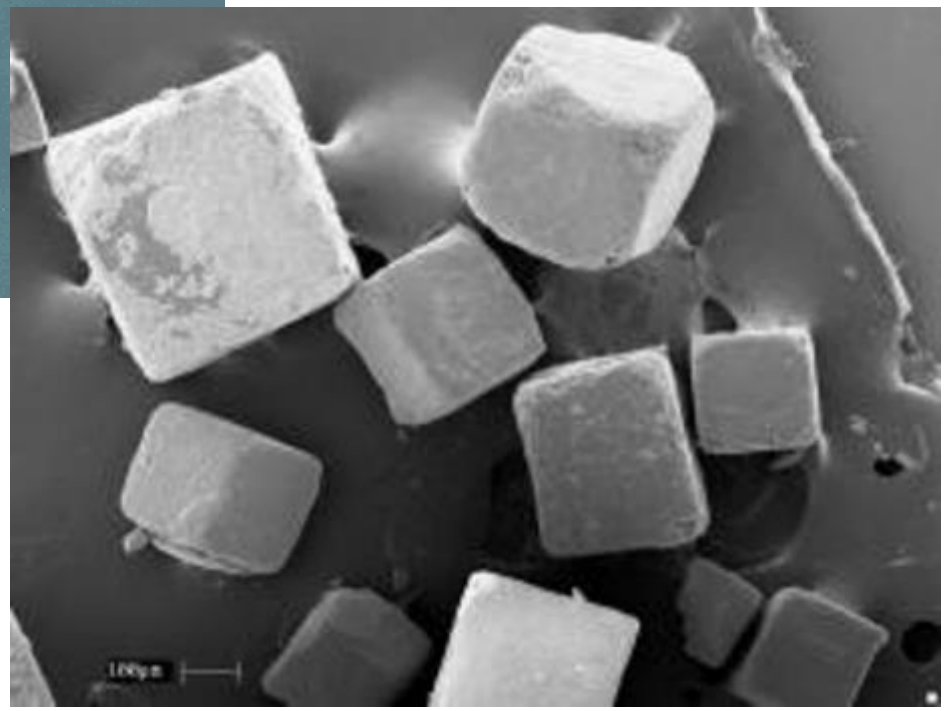
- reactivity
- melting point
- optical absorption
- conduction

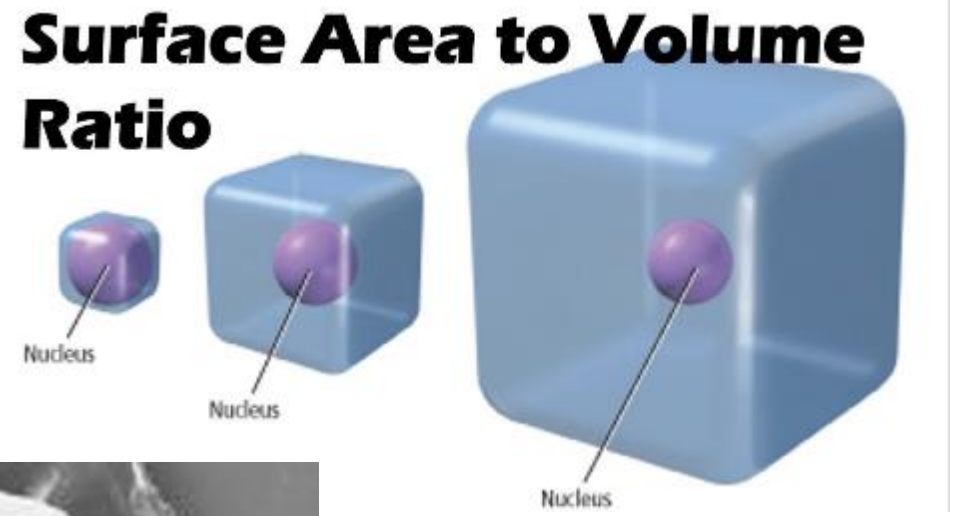
Light-matter interactions at the nanoscale



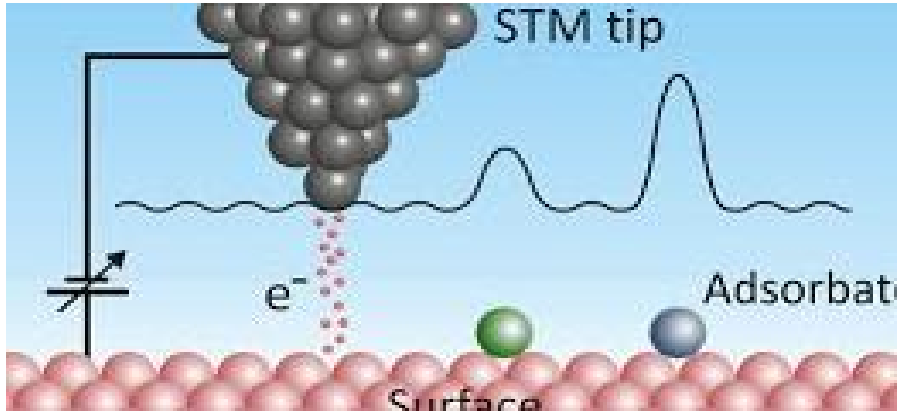
Surface effects at the nanoscale

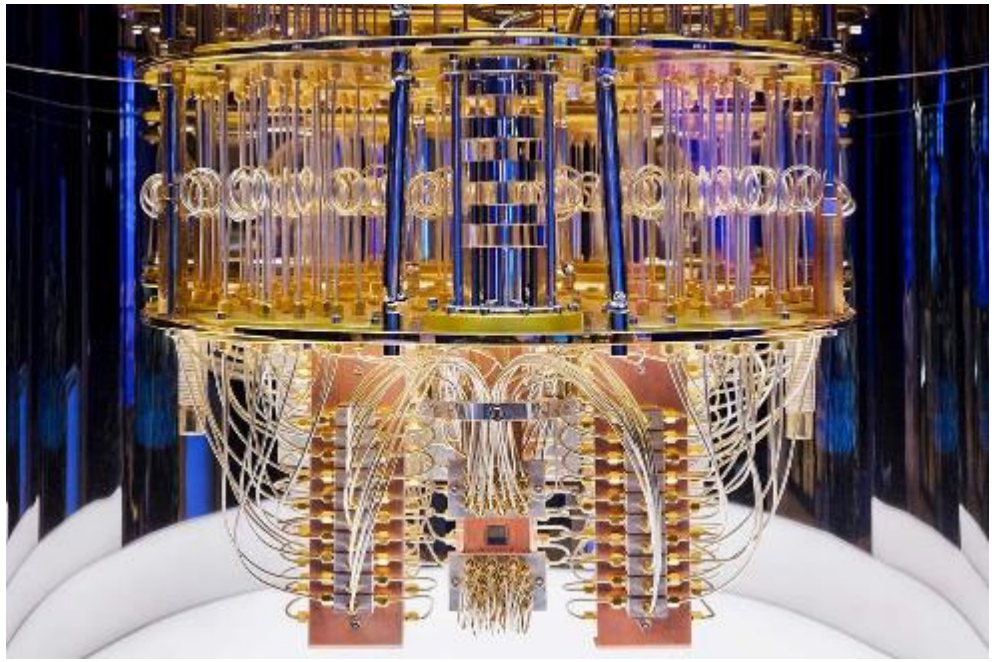


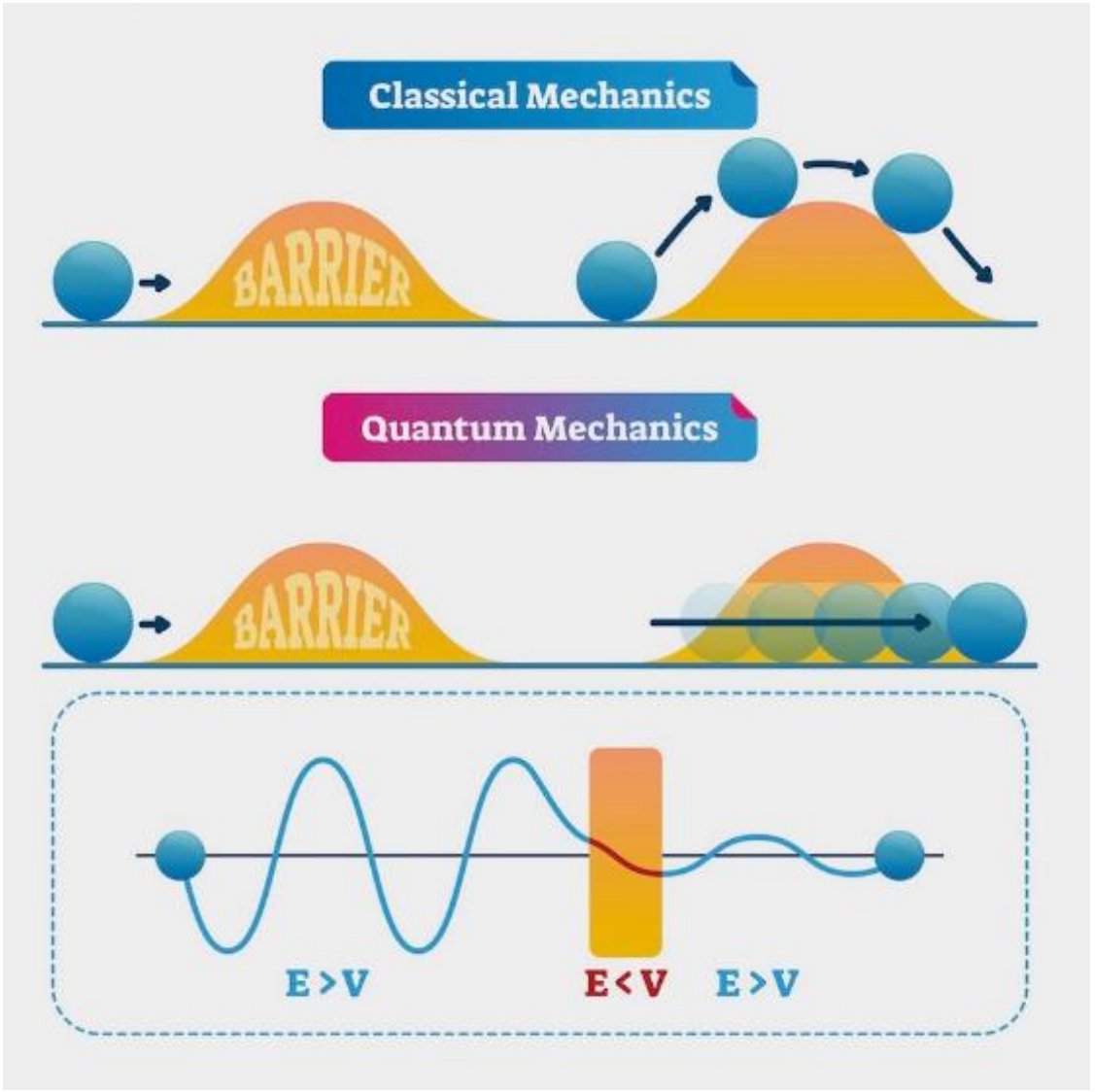




Quantum effects at the nanoscale







Q:How did we get here?

A: Things just kept getting smaller and smaller

Fabrication

Modern Electronics

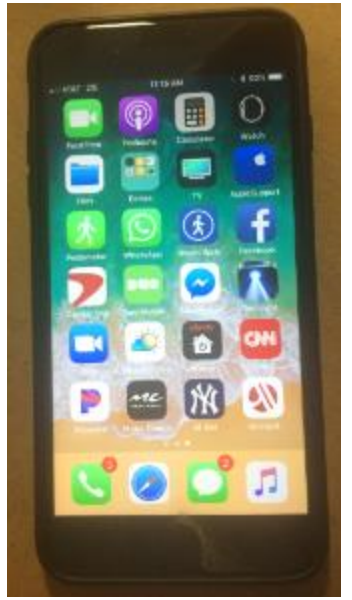
(circa 1991)

http://consumerist.com/2014/01/17/the-smartphone-has-effectively-replaced-all-the-technology-offered-in-this-1991-radio-shack-ad/

One Example of the Impact of Nanotechnology: Cell Phones

1993

2004



2016

What fits in a cell phone?

Nanotechnology and Computers

1986

First IBM-compatible Laptop

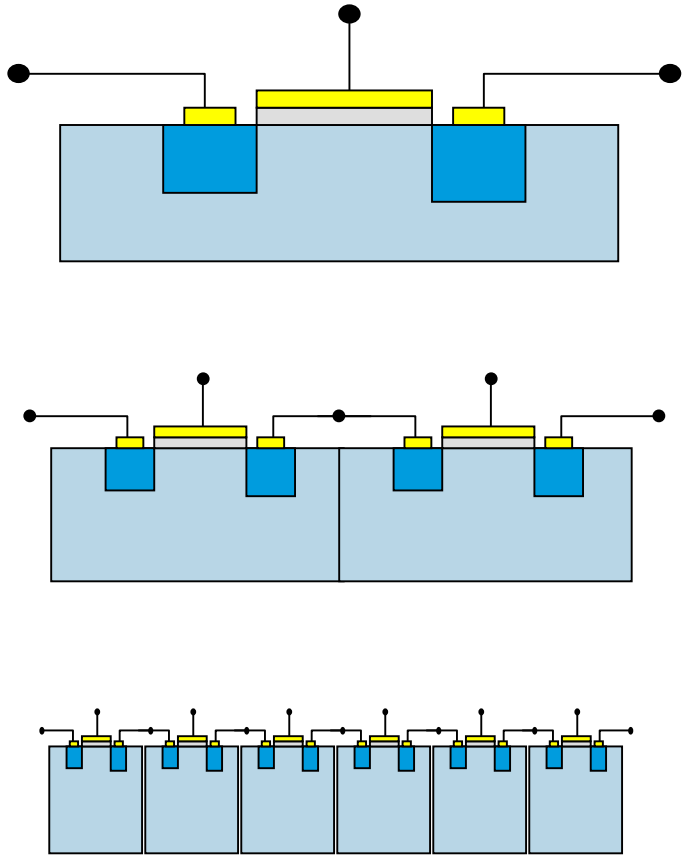
Toshiba T1100
CPU 80C86 -- 7.16 MHz
640K RAM
2 - 5 ¼ " Floppies
9 lbs

2019

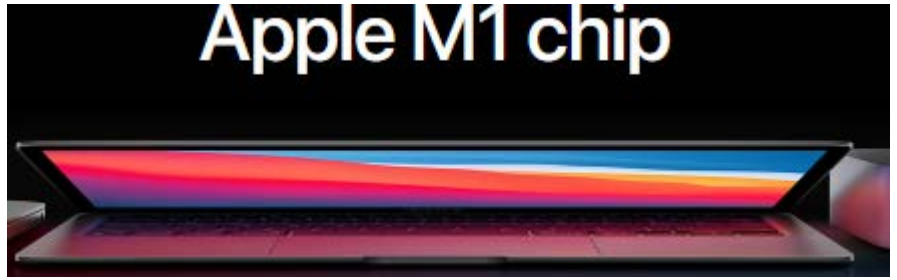
Lenovo ThinkPad X1 Laptop - 14"
Intel Core i5 8250U --- 1.60 GHz
8 GB RAM
256 GB SSD
2.5 lbs

Micro to Nano- electronics

- 100's of transistors on a chip in the 1960's
  - 10-30 micron gate length
- 1988
  - **1 micron** gate length
- To millions in the 1990's
- To > 10 billion in 2019
  - 7 n*anometer* gate length
- 2020
  - 5 *nanometer* gate length (predicted)



Breaking News:



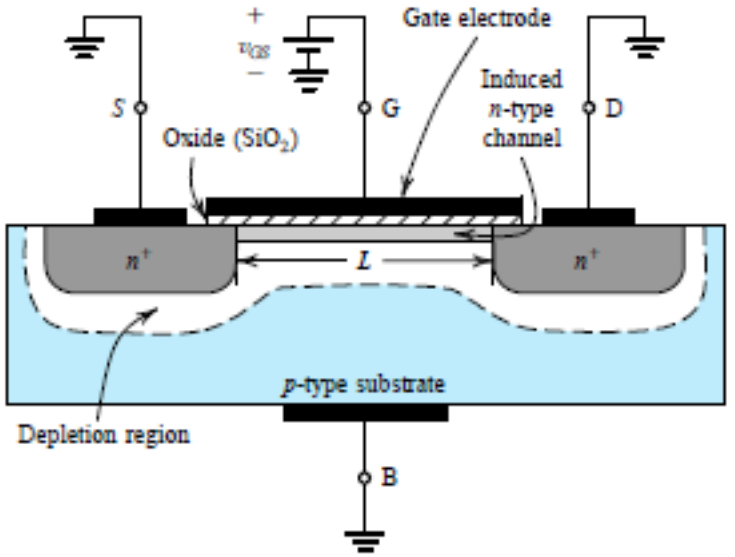
Packed with an astonishing 16 billion transistors, the new M1 chip integrates the CPU, GPU, Neural Engine, I/O, and so much more onto a single tiny chip. Combined with the new macOS Big Sur, M1 delivers category-smashing speed, mind-bending graphics, and power efficiency and battery life that defy belief.

Apple Event
November 10, 2020

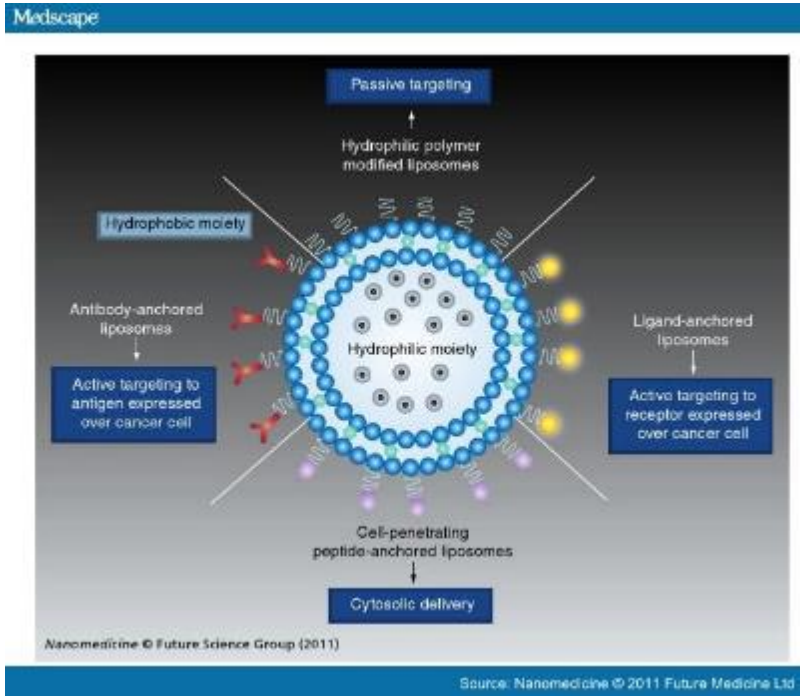
5 nm gate length - >> 16 billion transistors per chip

Nano Fabrication

- On 2-19-21
  - Ter will be sharing an overview of different manufacturing approaches on the nanoscale. This topic will define and give examples of top down and bottom-up manufacturing.
    - Microelectronics via top-down methods
    - Nanoscale drugs via bottom-up techniques



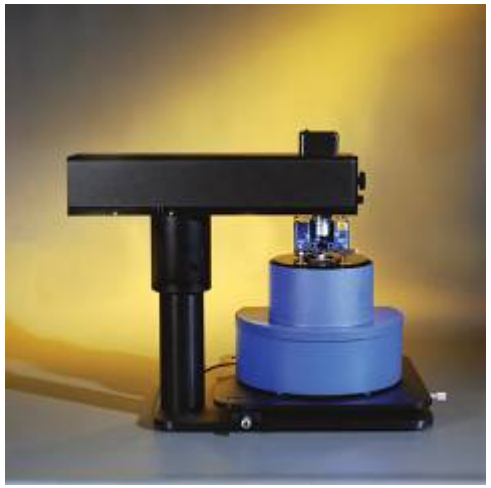
5.2 The enhancement-type NMOS transistor with a positive voltage applied to the gate.



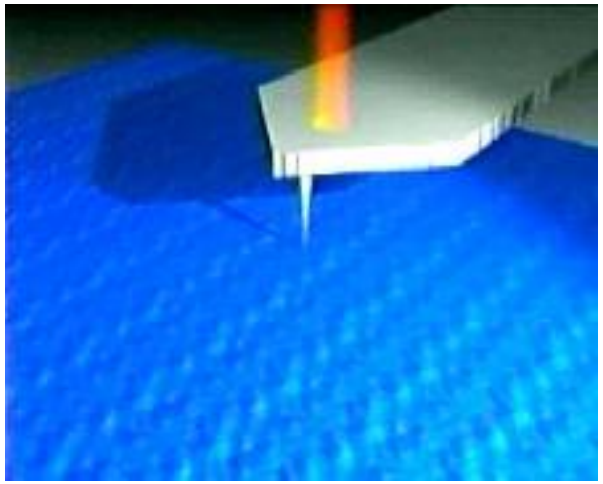
How do we see what we cannot see?

Characterization

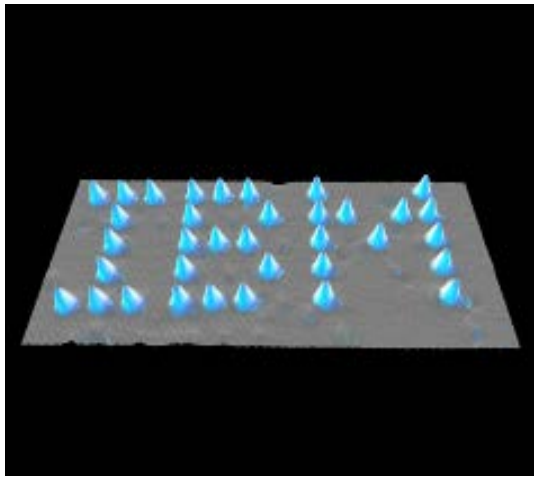
Nano: Enabling Technologies



Atomic Force Microscope (AFM)
Veeco Model CP-II



Depiction of AFM probe tip



I B M spelled out with Xenon Atoms on a Nickel Surface by an STM-based tool

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Nano: Enabling Technologies

- Using nano-scale materials and understanding them are two different things!

Zeiss Ultra 60

Scanning Electron Microscope (SEM)

Modern tools:

- Help us to see and manipulate matter at the nano-scale
- Allow us to understand how (and why) the small structures work

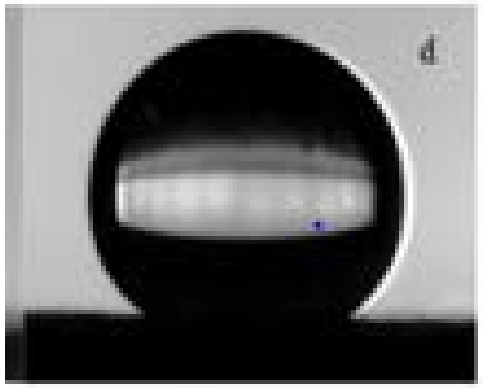
Let’s look at an example of how our understanding of the nano-scale can change our lives……

Lotus Effect

Video link: https://youtu.be/MFHcSrNRU5E

Hmmm ??????

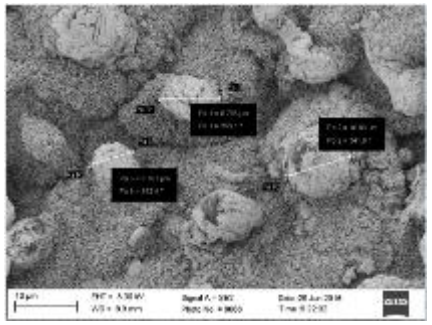
- The surface of a lotus leaf is hydrophobic ---- which means it fears water?

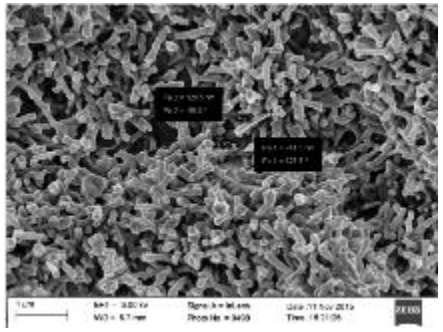


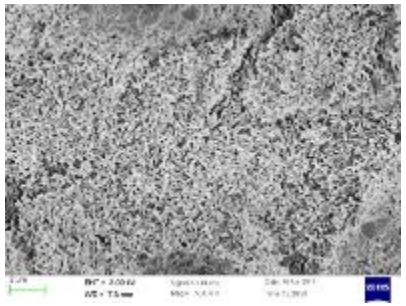
- Why does this leaf exhibit those properties?

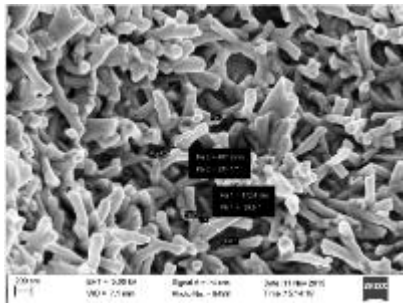
What does the lotus leaf look like?

What does the lotus leaf look like?

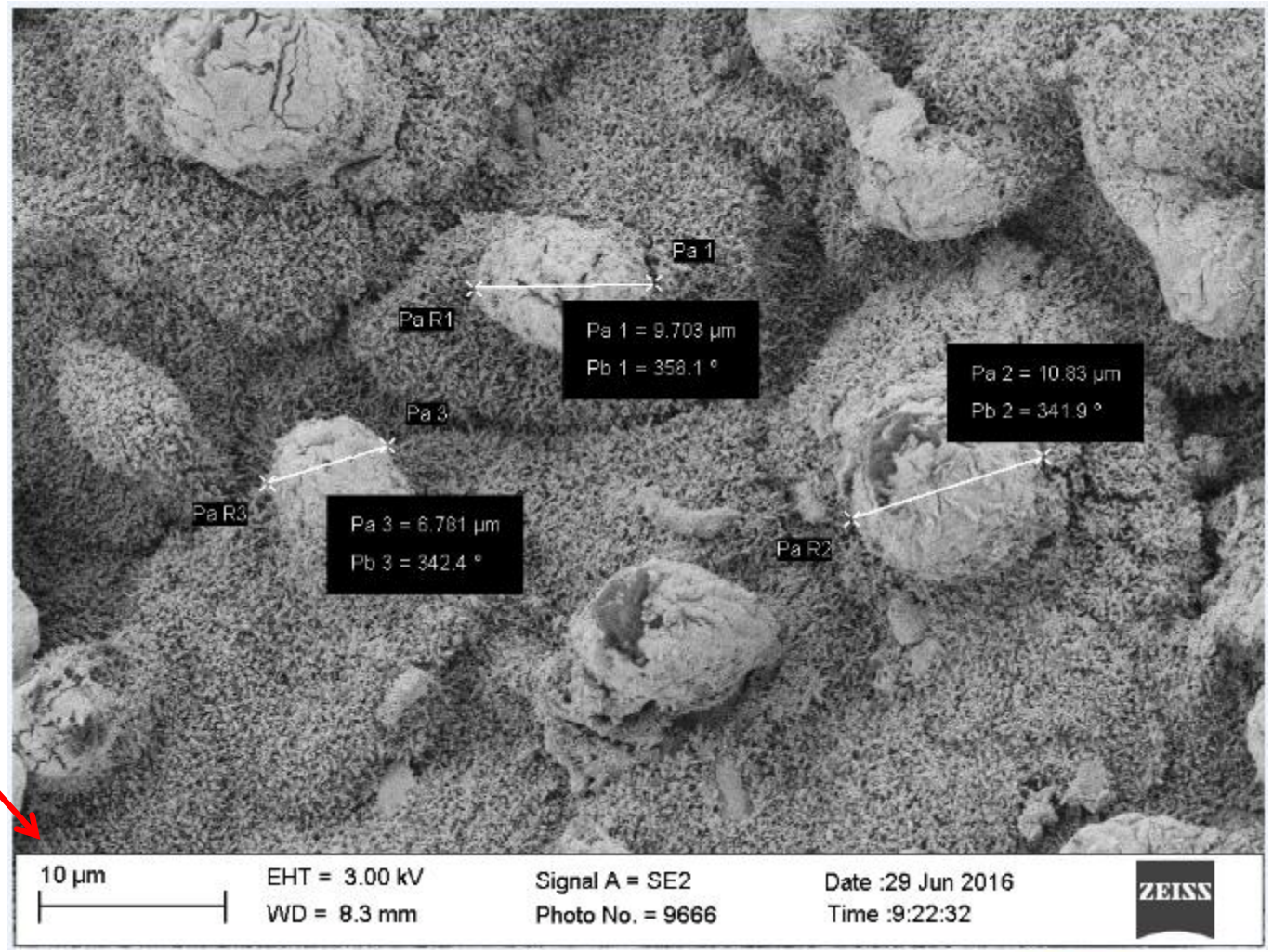








What does the lotus leaf look like?



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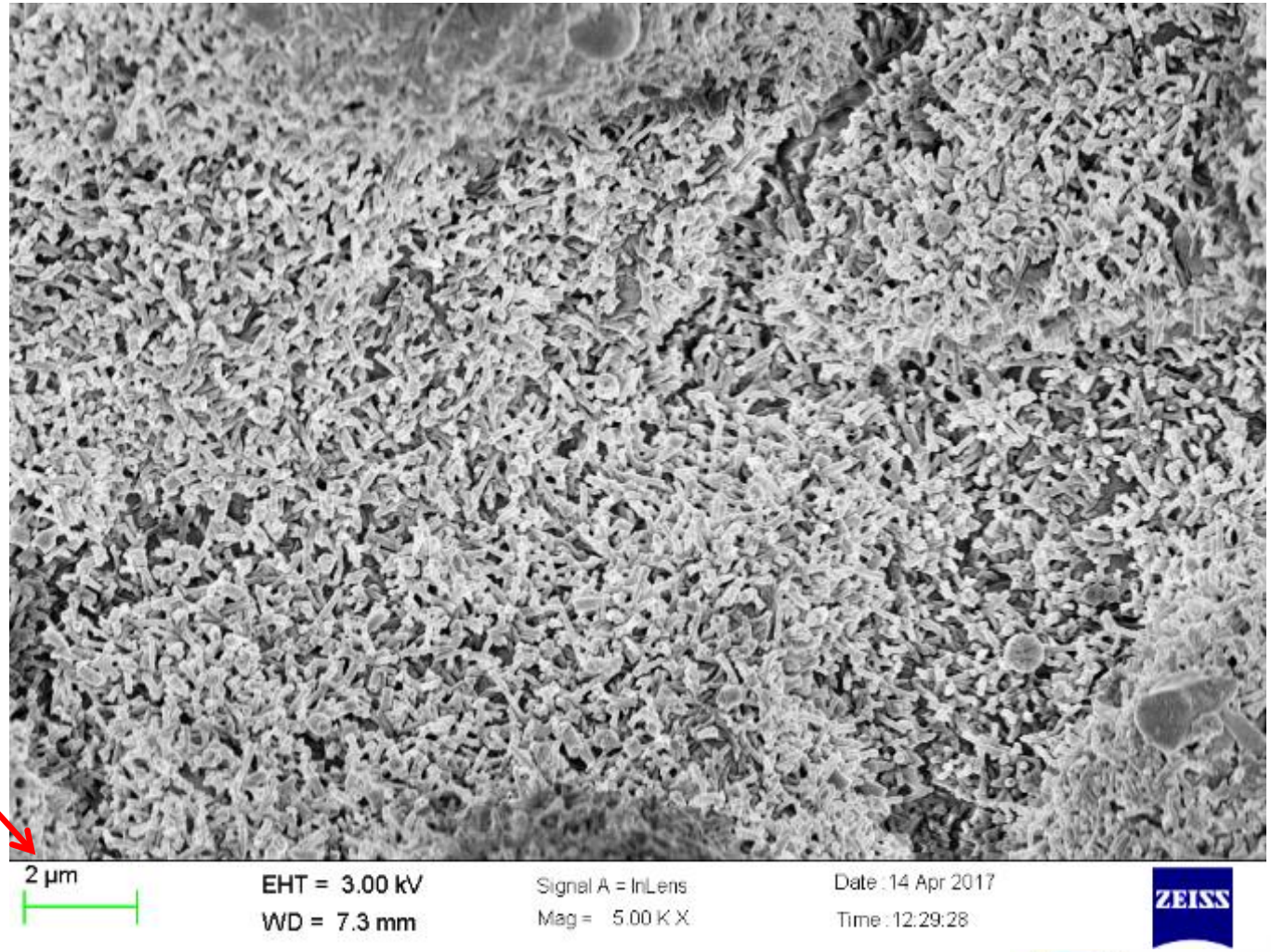

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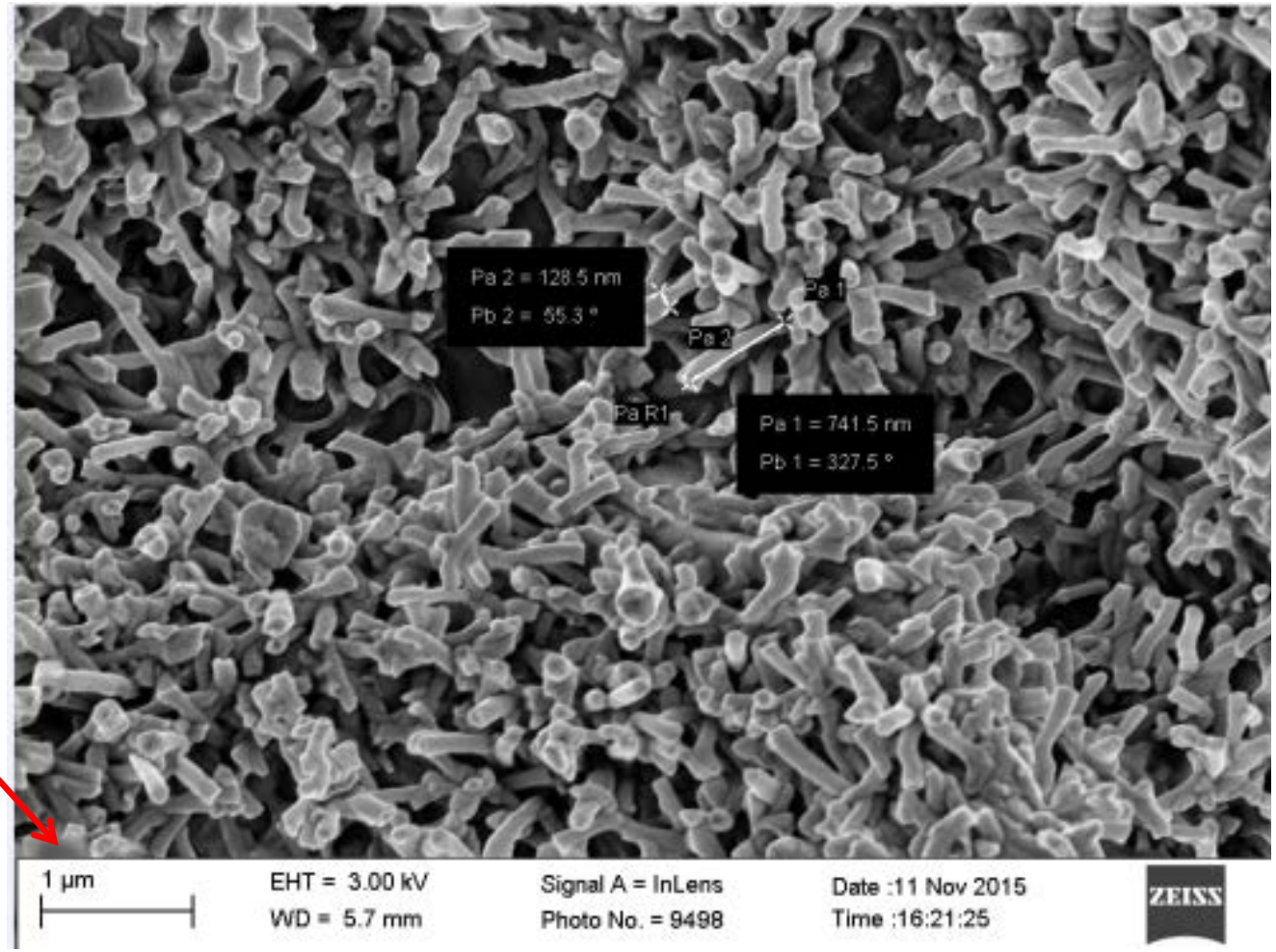
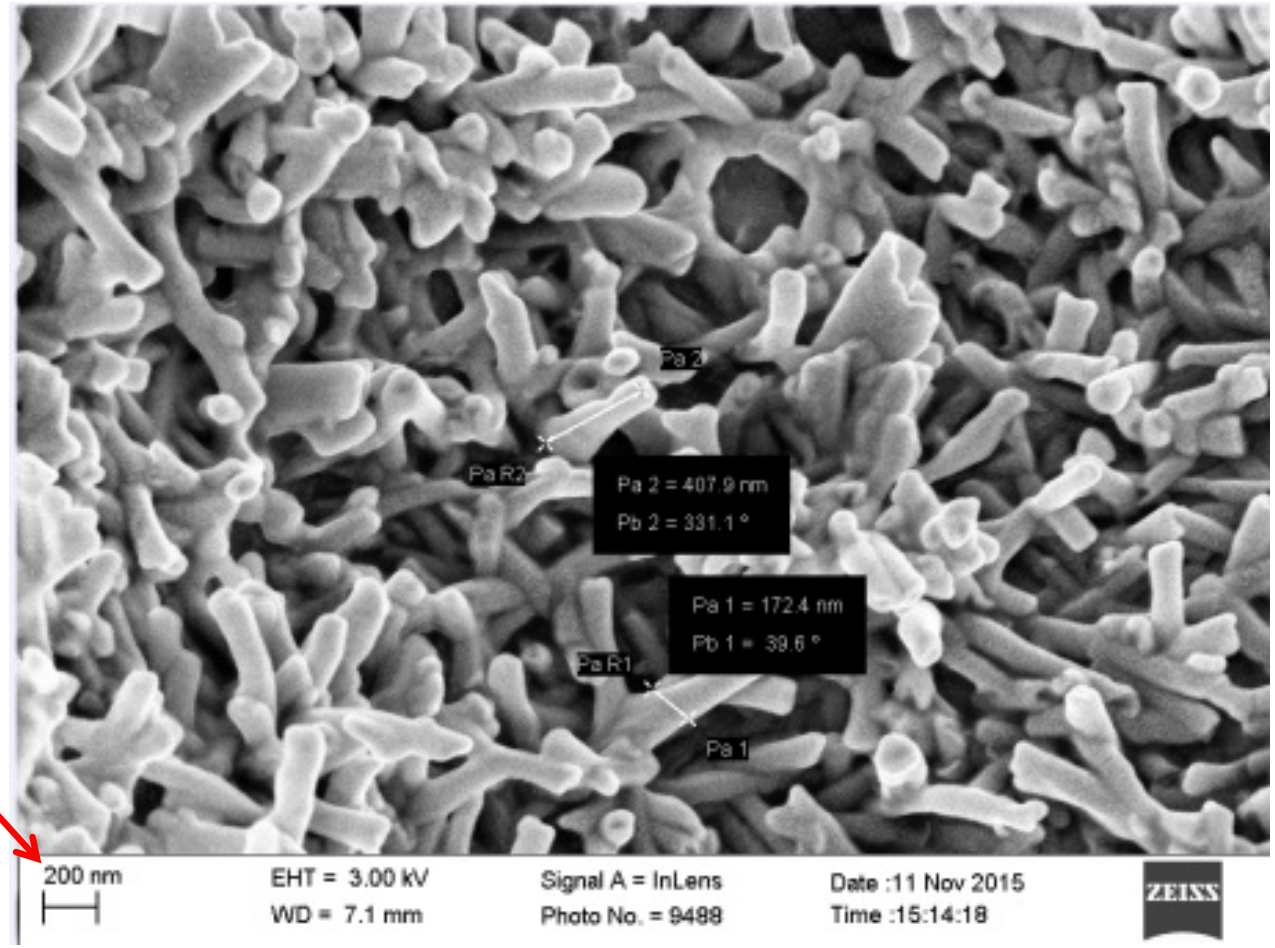
What does the lotus leaf look like?



What does the lotus leaf look like?



Lotus Effect

Video link: https://youtu.be/MFHcSrNRU5E

Nano Characterization

- On 2-12-21
  - Of the many nanoscale characterization tools - Wes and Ozgur will be sharing an overview of two very important characterization techniques
    - SEM or Scanning Electron Microscopy and
    - SPM or Scanning Probe Microscopy

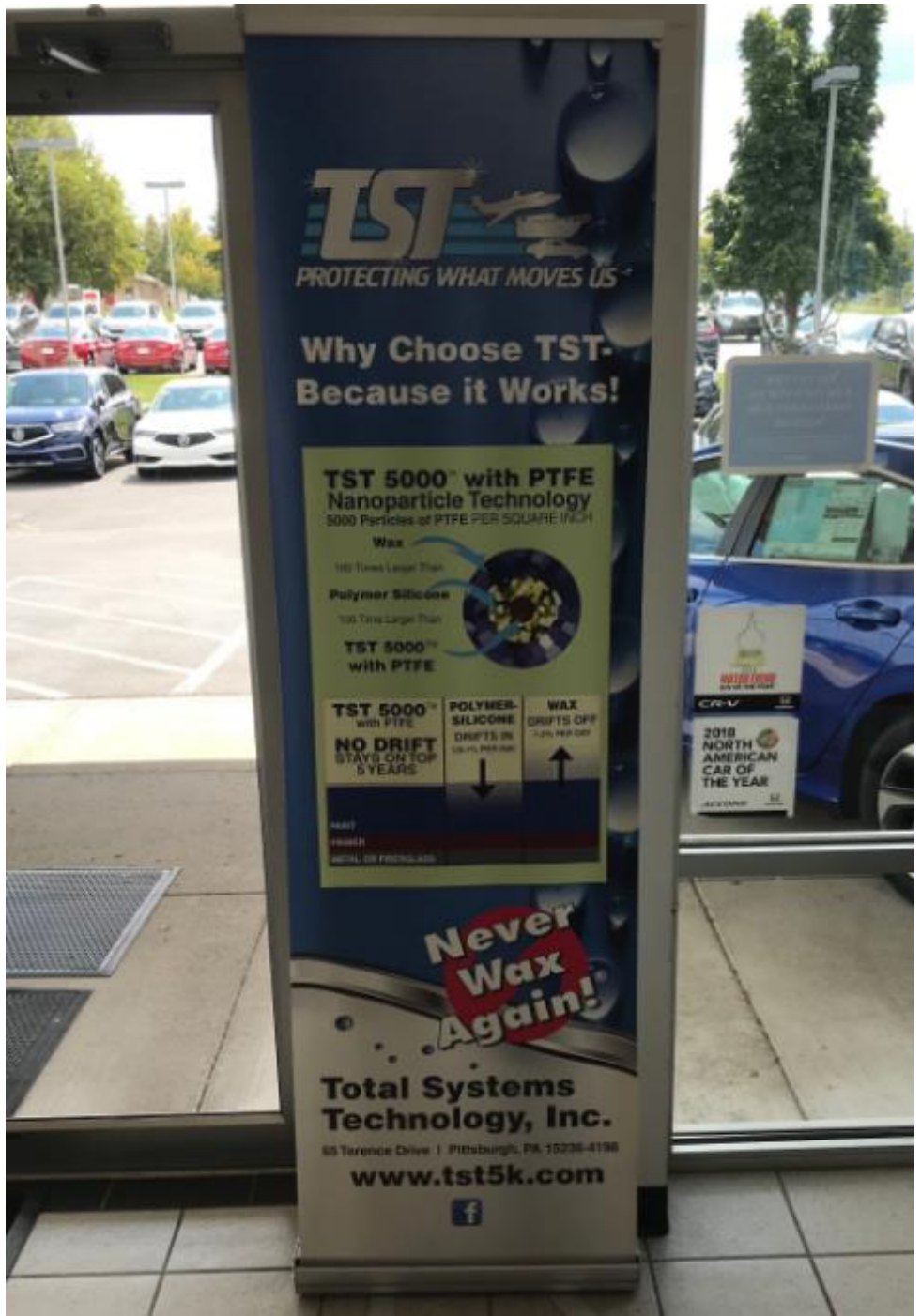
  - They will also introduce you to RAIN

Nice, but what can you do with it?

Applications

Coated Bowls Demo:
Mya 2.5

Bob’s Car Shopping Story




TST 5000™ with PTFE
Nanoparticle Technology
5000 Particles of PTFE PER SQUARE INCH
Wax
100 Times Larger Than
Polymer Silicone
100 Time Larger Than
TST 5000™
with PTFE
TST 5000™
with PTFE
NO DRIFT
STAYS ON TOP
5 YEARS
POLYMER-
SILICONE
DRIFTS IN
1/2-1% PER DAY
WAX
DRIFTS OFF
1-2% PER DAY
PAINT
PRIMER
METAL OR FIBERGLASS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Again!®
Total Systems
Technology, Inc.
65 Terence Drive | Pittsburgh, PA 15236-4198
www.tst5k.com

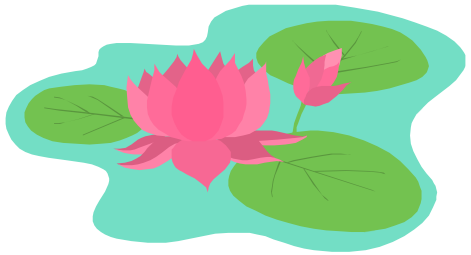
Nanotechnology is Ubiquitous

Diverse Applications

Movie

Cancer: Detection/ Treatment

Textiles



Copying Nature (Biomimetics)

Energy

Household

Clean Water

Sports

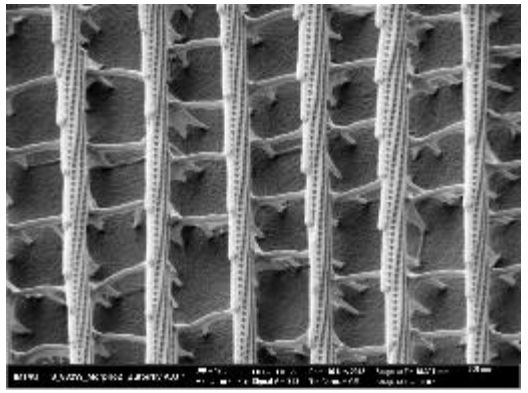
PennState

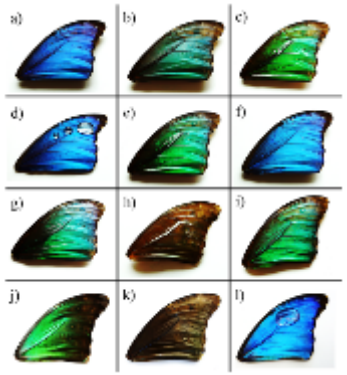
Video links from previous slide

- Cancer Detection and Treatment
  - https://youtu.be/0G7dMUE0rII
- Copying Nature (Biomimetics)
  - https://youtu.be/7is6r6zXFDc
- Household
  - https://youtu.be/50UlSSy7PFE
  - https://youtu.be/1nYNOB3K_wg
  - https://youtu.be/uRfmDoOc60c
- Clean Water
  - https://binged.it/2FWmtKP
- Textiles
  - https://youtu.be/apFyWc-fxO0
  - https://youtu.be/BvTkefJHfC0
- Energy
  - https://youtu.be/1GFst2IQBEM
  - https://youtu.be/Ds3sA1vqx1w
  - https://youtu.be/5AnMsyIT26A
  - https://youtu.be/t7EYQL0lwDM
- Sports
  - https://youtu.be/9VDeJ7rLUYU
  - https://youtu.be/lZ_D2nqqmZQ

Nano Applications

- On 2-5-21
  - Of the incredible number of applications of nanotech – Peter and Jared will be sharing some information on a couple of them:
    - Biomimicry and Nanotechnology and
    - Nanotechnology and Medicine





Why your students should know this

National Nanotechnology Initiative (2000)

Vision: A future in which the ability to understand and control matter on the nanoscale leads to a revolution in technology and industry that benefits society.

Goals:

- Advance a world-class nanotechnology research and development program.
- Foster the transfer of new technologies into products for commercial and public benefit.
- Develop and sustain educational resources, a skilled workforce, and a dynamic infrastructure and toolset to advance nanotechnology.
- Support responsible development of nanotechnology.

Why should we be excited about nanotechnology?

- Global market predicted value: $2,231.4 million by 2025
- Surge in adoption of nanotechnology in medical diagnoses
- Emergence of self-powered nanotech devices
  - Applicable in:
    - Sensing
    - Medical science
    - Defense technology
    - Personal electronics

https://www.alliedmarketresearch.com/nanotechnology-market

A Forecast from 2016:

“By 2020, 70% of all new advanced technology products will incorporate nanotechnology.”

* M. Roco

Market and Jobs Information

- As the market expands, the number of **jobs** needing different skill levels in nanotechnology will increase.

- Thus, it is essential that a sufficient **supply** of qualified **workers** be developed to fill that need.

Nanotechnology Workforce Video

Building College-University Partnerships for Nanotechnology Workforce Development

International Credentialing

ASTM E2996
Standard Guide for Workforce Education in Nanotechnology Health and Safety

ASTM E3001
Standard Practice for Workforce Education in Nanotechnology Characterization

ASTM E3034
Standard Guide for Workforce Education in Nanotechnology Pattern Generation

ASTM E3059
Standard Guide for Workforce Education in Nanotechnology Infrastructure

ASTM E3071
Standard Guide for Nanotechnology Workforce Education in Materials Synthesis and Processing

ASTM E3089
Standard Guide for Nanotechnology Workforce Education in Material Properties and Effects of Size

ASTM E56 Education Standards

- Suite of 6 standards are now published covering basic skill sets for nano workforce
- Can be accessed at https://www.astm.org/COMMITTEE/E56.htm

ASTM Personnel Certificates in Nanotechnology

The current mission is to create 4 certificates which cover the ASTM Nanotechnology Workforce Education Standards that can be attained by individuals completing programs and passing corresponding tests

ASTM Workforce Certificate in Nanotechnology
Health and Safety

ASTM Workforce Certificate in Nanotechnology
Characterization

ASTM Workforce Certificate in Nanotechnology
Fabrication & Processing

ASTM Workforce Certificate in Nanotechnology
Material Properties and Effects of Size

back

ASTM INTERNATIONAL

NACK NETWORK Building College-University Partnerships for Nanotechnology Workforce Development

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The Value of These Nano Workforce Certificates

- Presently working with Industry (across the country) to make them aware of these nano-workforce international certificates
  - Attaining certificates will show that a prospective knowledge has retained relevant nanotechnology workforce knowledge
  - They know their stuff!

Nano Opportunities

- On 2-26-21
  - Bob and Tony will wrap-up the workshop with opportunities in nano education as well as in industry.
  - An all-presenter panel Q&A panel will wrap up the workshop.


Questions ??