



Welcome to the:

INTRODUCTION TO NANOTECHNOLOGY EDUCATORS WORKSHOP

January 22, 2021



PennState

Welcome

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Career Knowledge (NACK) NSF
ATE Resource Center

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www.nano4me.org

www.cneu.psu.edu



PennState

Penn State Center for Nanotechnology Education and Utilization (CNEU)

Welcome

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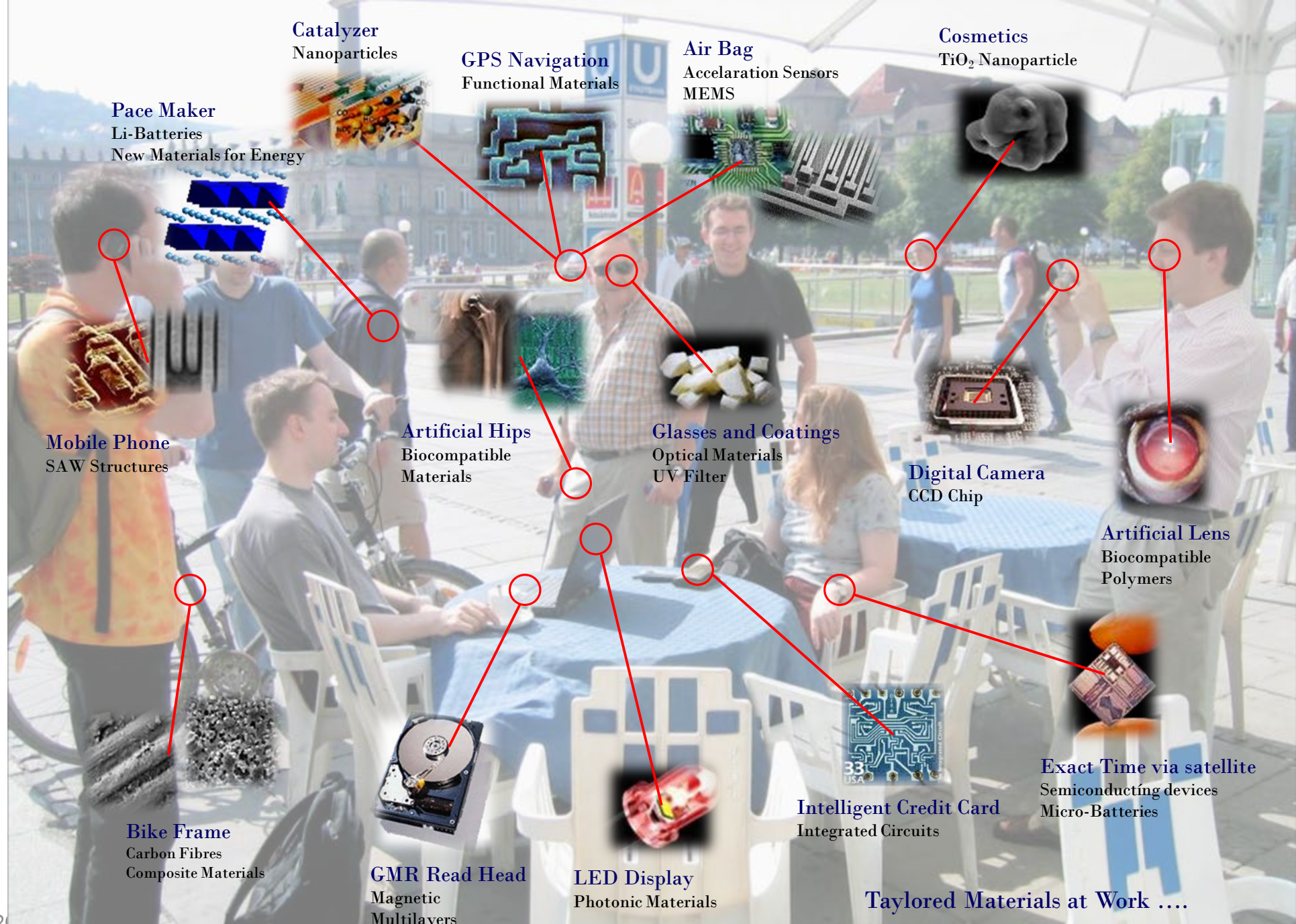
What is nanotechnology?

And why should I care about it?

On a typical day...

Anywhere in
the world....





Nano's contribution to fighting COVID-19

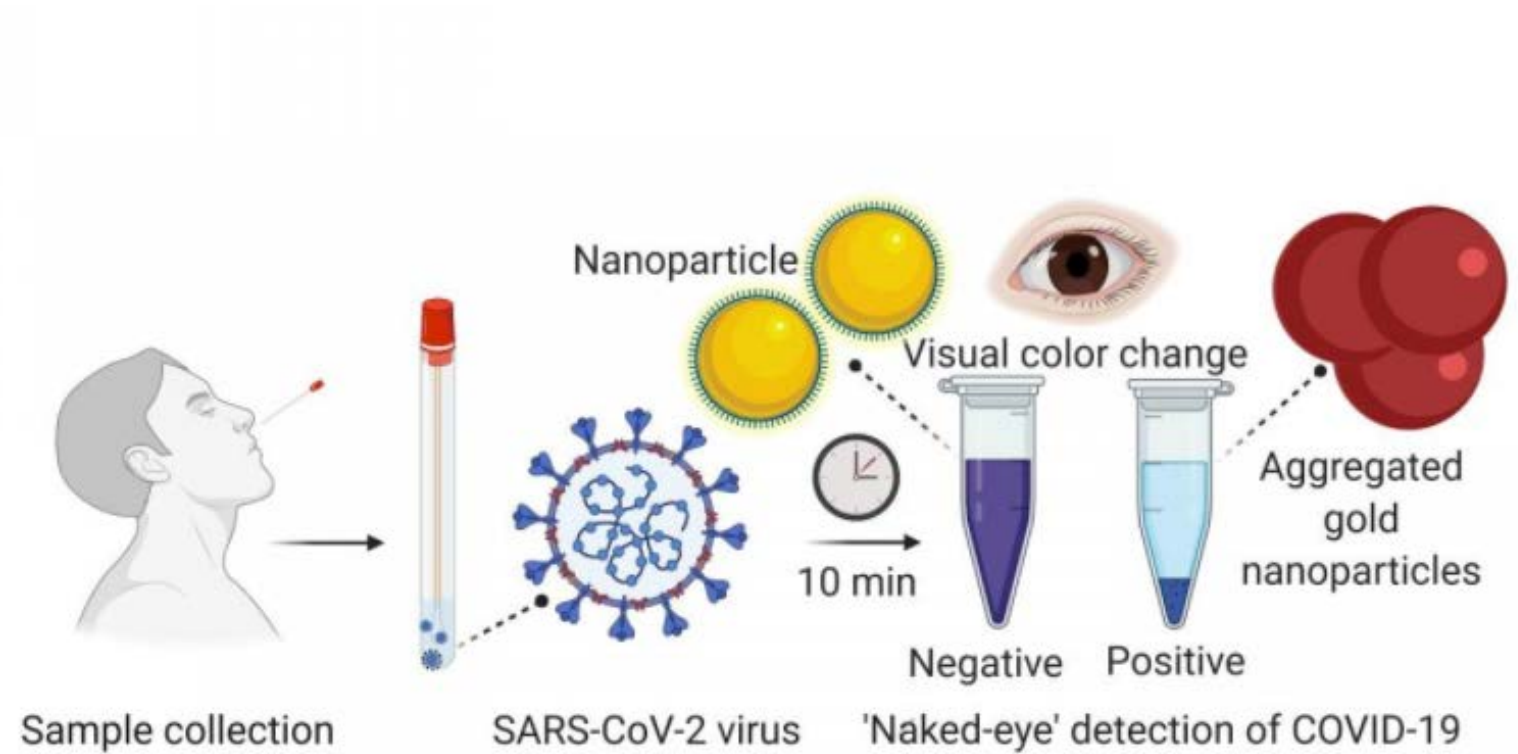
- Point of Care and Laboratory Testing
- At-home tests
- PPE
- Oxygen generators
- Sensors
- Antimicrobial Coatings
- Antibody testing
- Vaccine development
- Vaccine delivery systems
- Medical research (virus understanding)
- EVERYWHERE you can think of

Gold np's enabling rapid COVID testing

UMSOM

5-29-20

Rapid COVID-19 Test

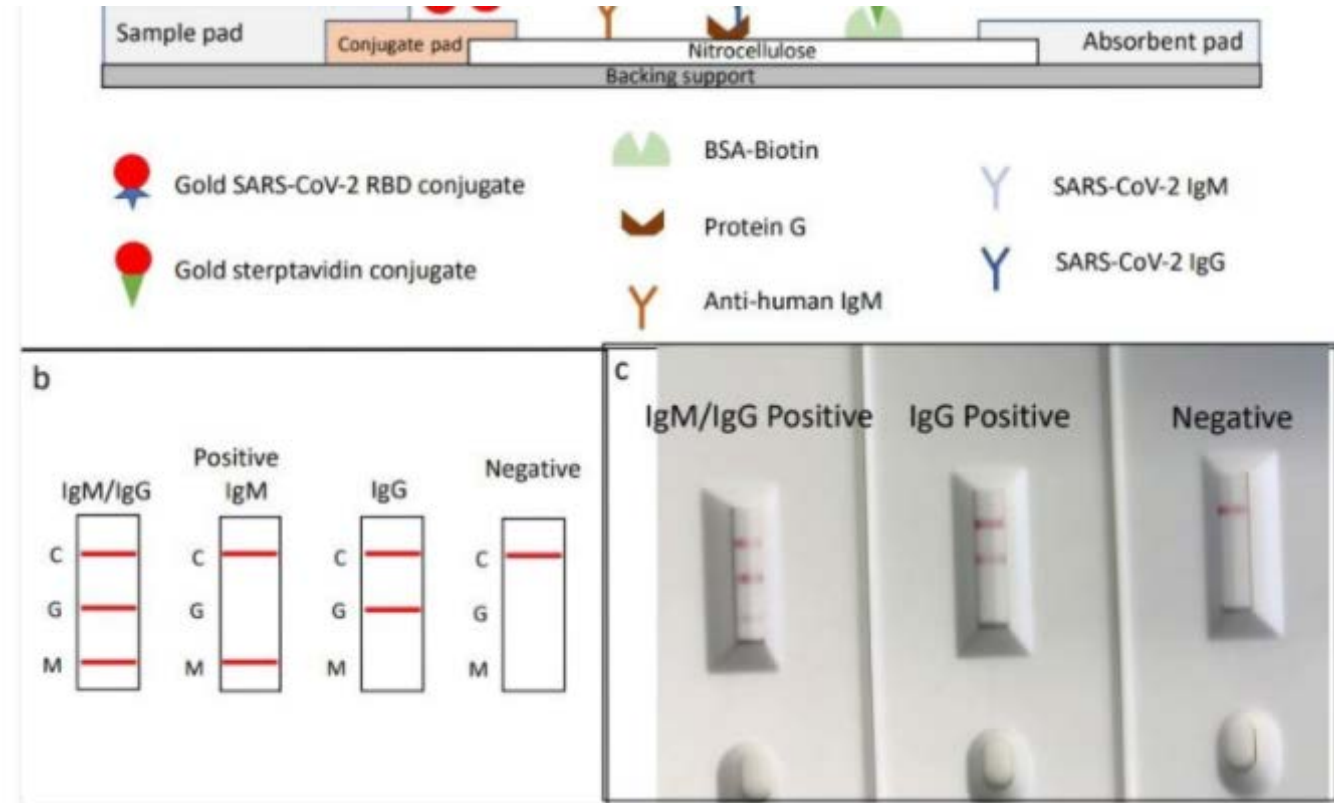


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Gold np-enabled COVID antibody test

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.



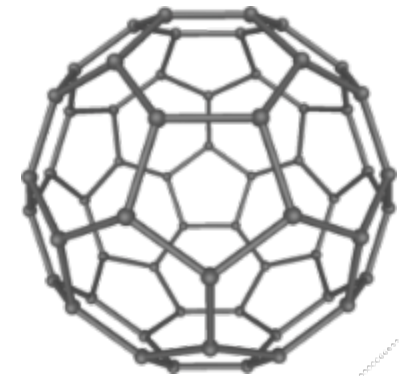
Later, if you are exposed to the real virus, these antibodies are then able to attack it and prevent you from getting sick. The antibodies' ability to prevent sickness is what is meant when people say a vaccine provides immunity.

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.

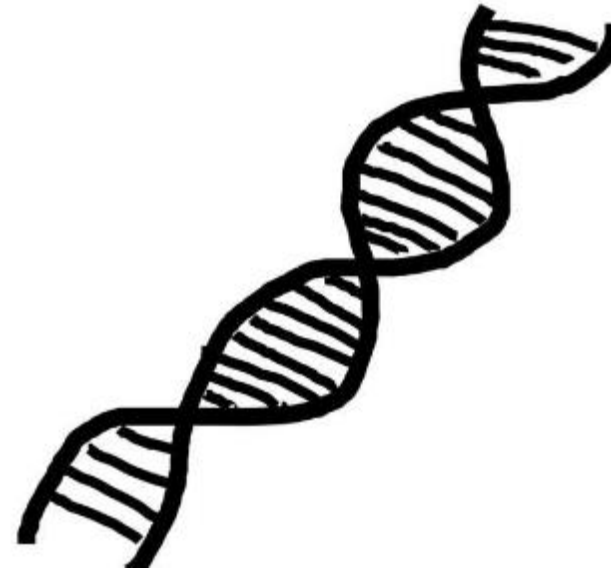


How Small is a Nanometer?

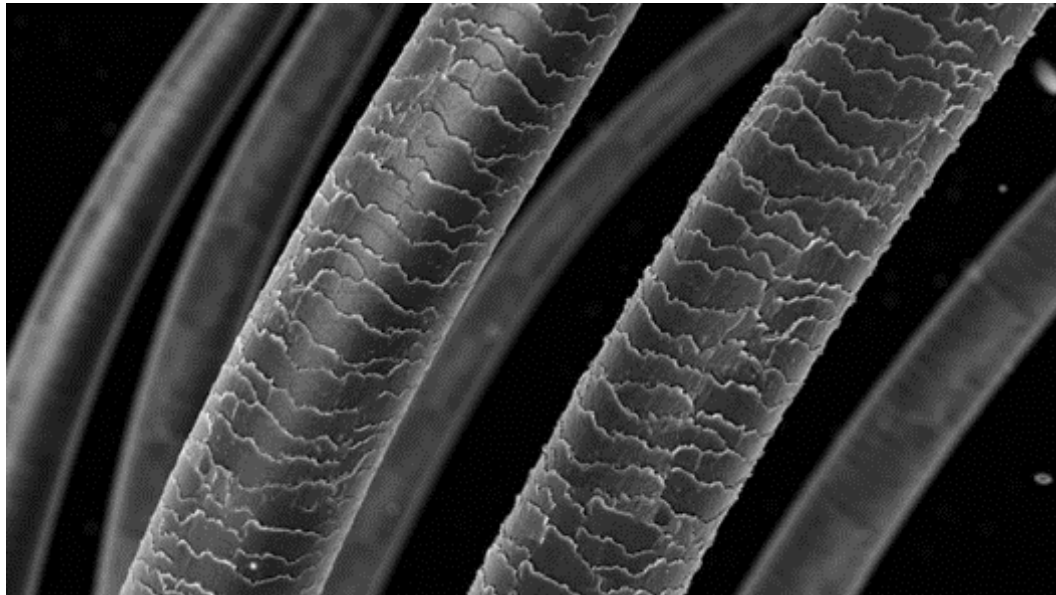
Size & scale

How small is a nanometer?

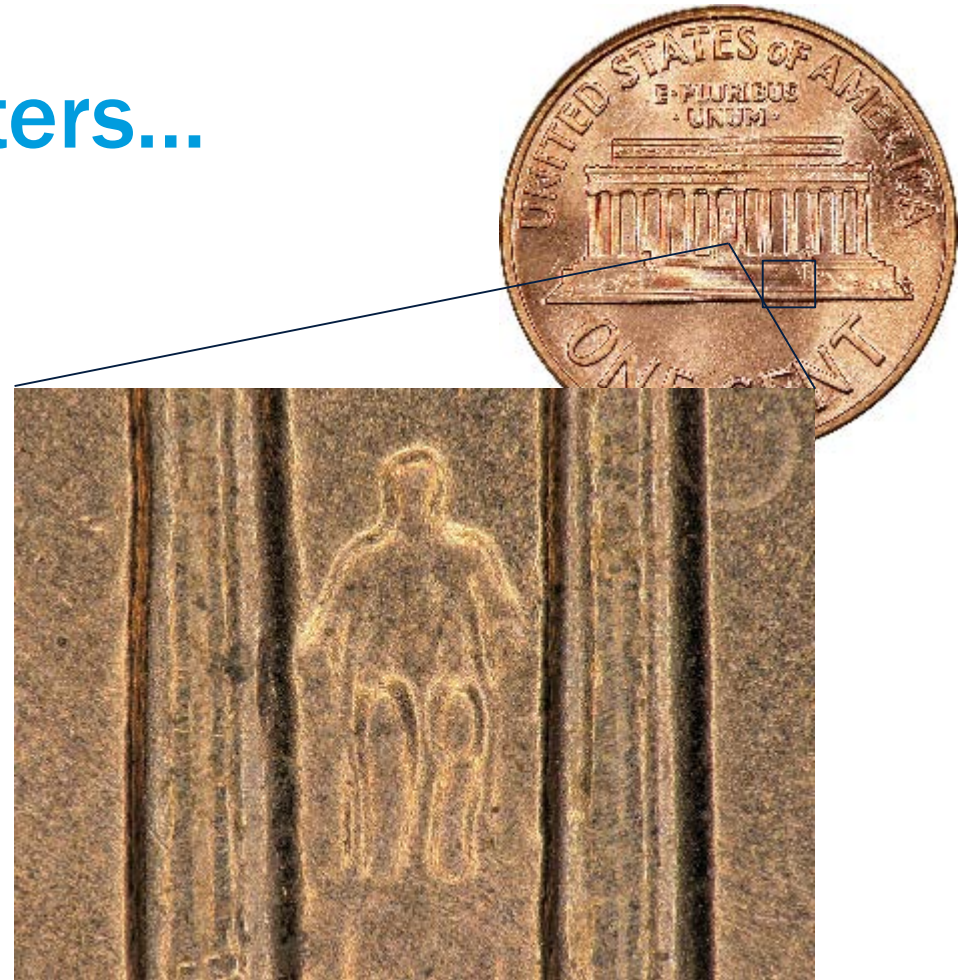
One nanometer is a billionth of a meter.



If we measured in nanometers...



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



Source: <https://www.ngccoin.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

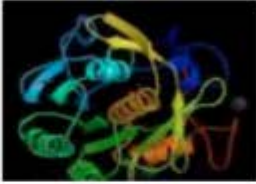
How long ago was 1 billion seconds?

May 16th 1989

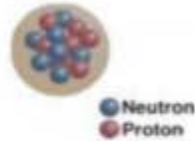
Size and Scale Challenge

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



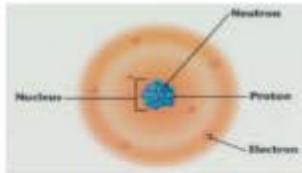
19. diameter of a carbon nanotube



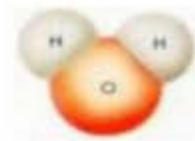
4. height of a typical 5-year-old child



22. diameter of a nitrogen atom



12. width of a water molecule



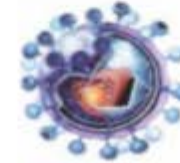
10. diameter of a ribosome



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



2. nucleus of an oxygen atom



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



1. thickness of a penny



5. width of a proteinase enzyme



3. diameter of a red blood cell



6. length of a dust mite



15. diameter of a virus



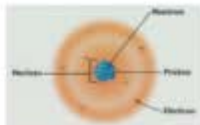
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Visible Light Spectrum

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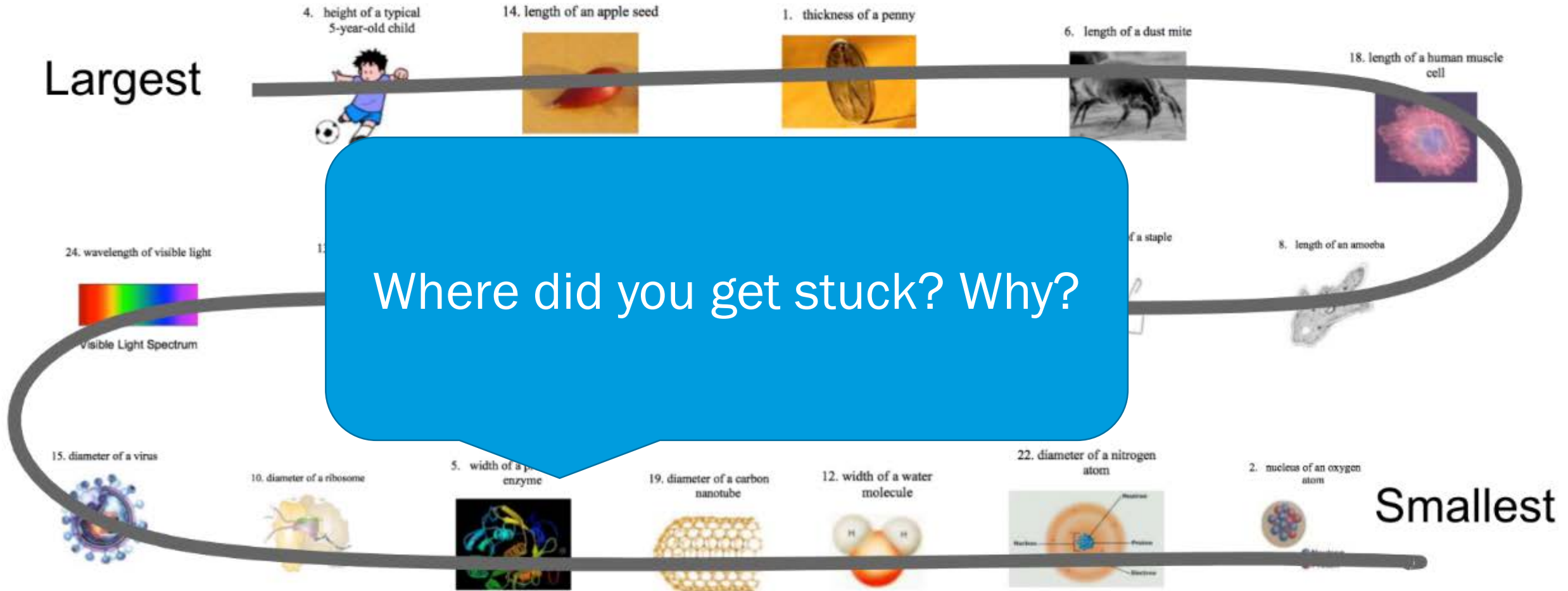
11. thickness of sewing thread



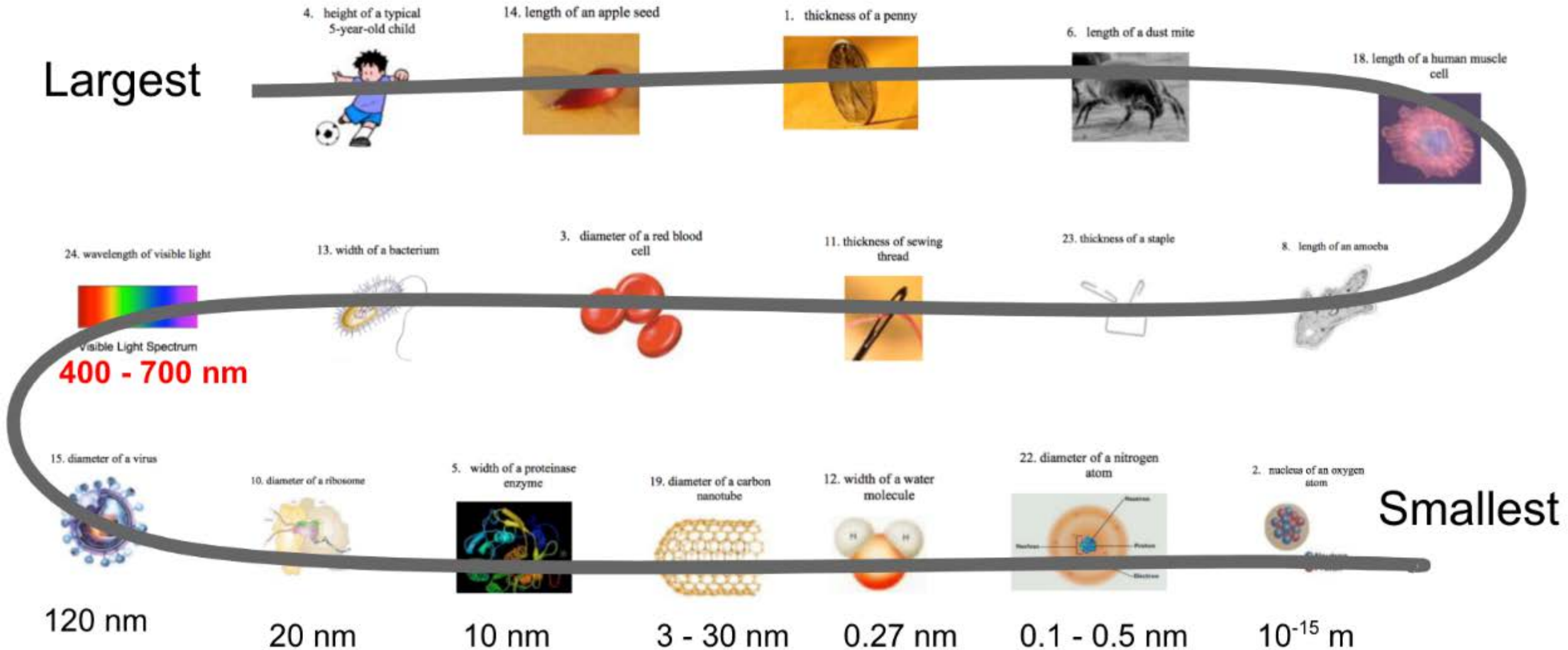
12. width of a water molecule



How small is small?

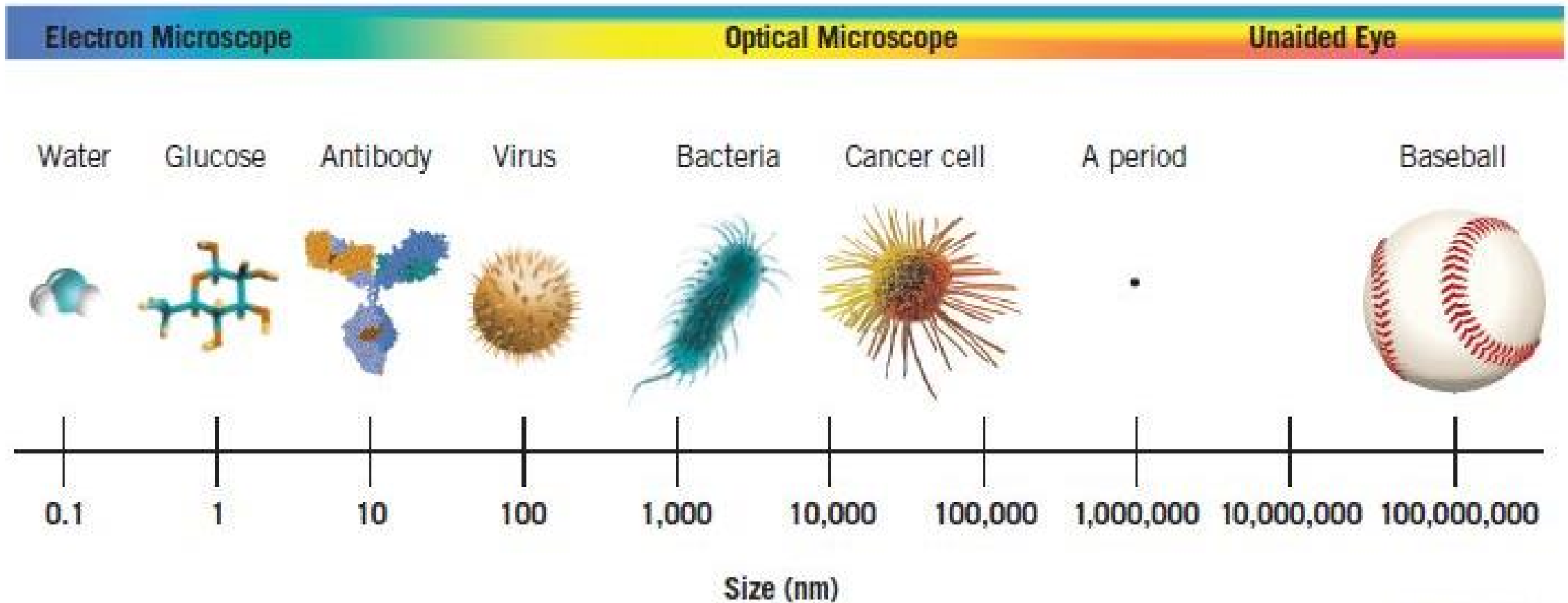


How small is small?



How small is small?

SIZE COMPARISON



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.”

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?



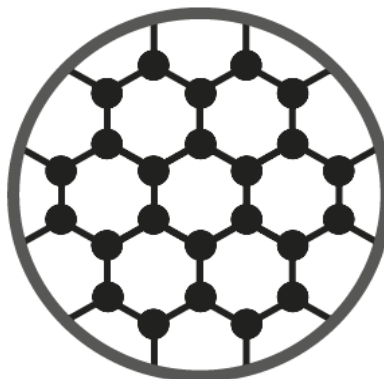
SINGLE LAYER OF CARBON ATOMS

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.



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.

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.



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Property changes with scale

THE PROPERTIES OF GRAPHENE



HIGH ELECTRICAL
CONDUCTIVITY



200X STRONGER
THAN STEEL



THIN AND
LIGHTWEIGHT



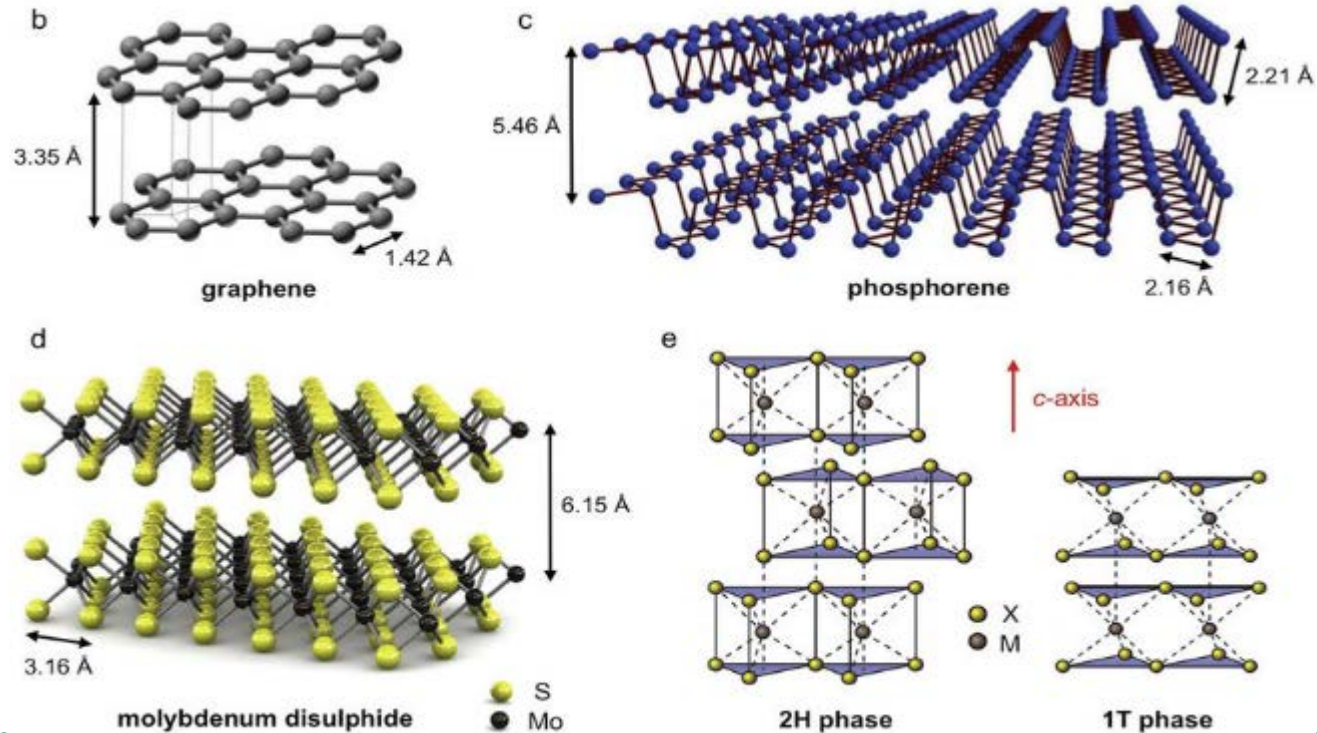
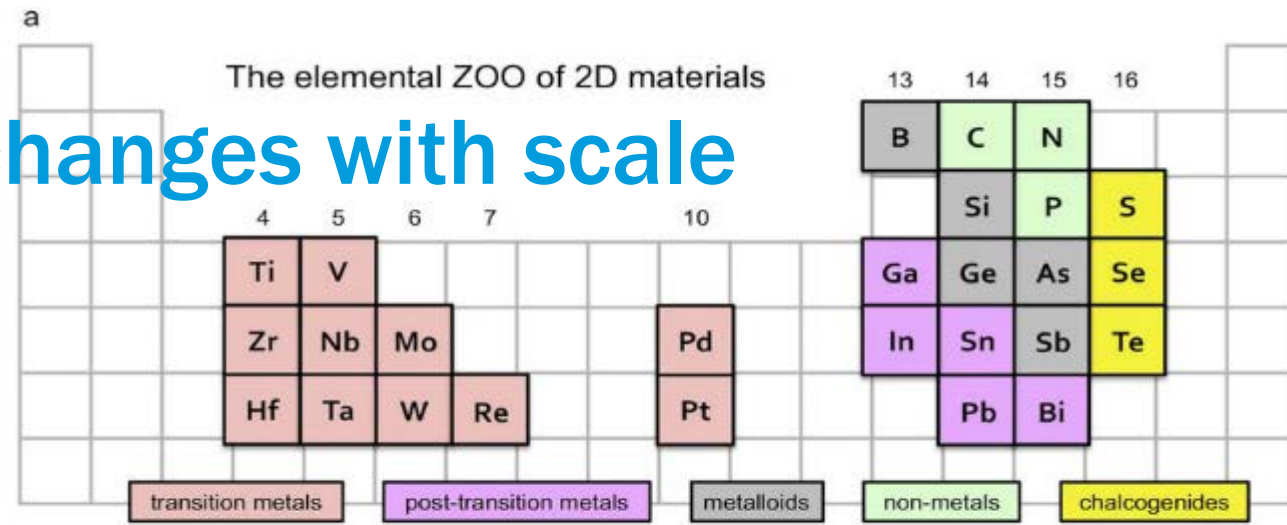
HIGH THERMAL
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VERY HIGH
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Property changes with scale



Light-matter interactions at the nanoscale



Macroscale Gold

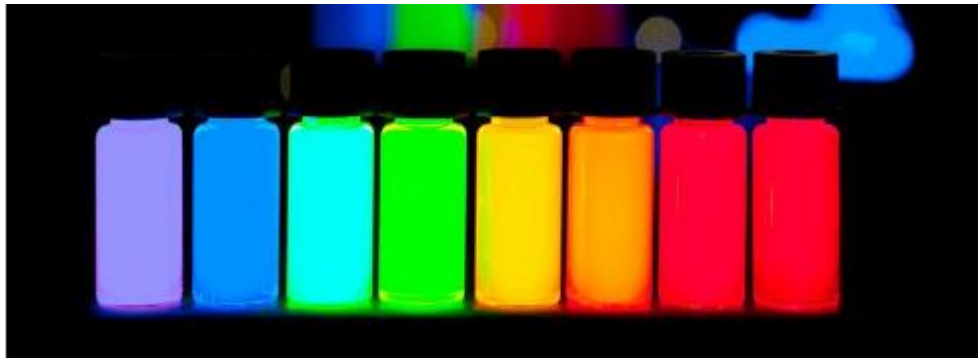


Nanoscale Gold

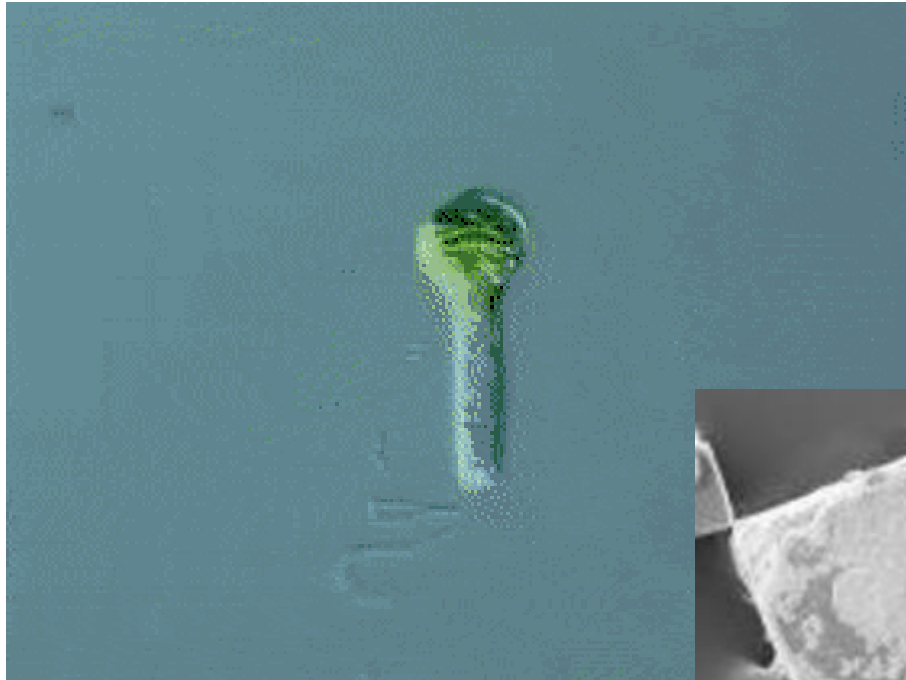
Material properties change with the size of the gold nanoparticle.

- reactivity
- melting point
- optical absorption
- conduction

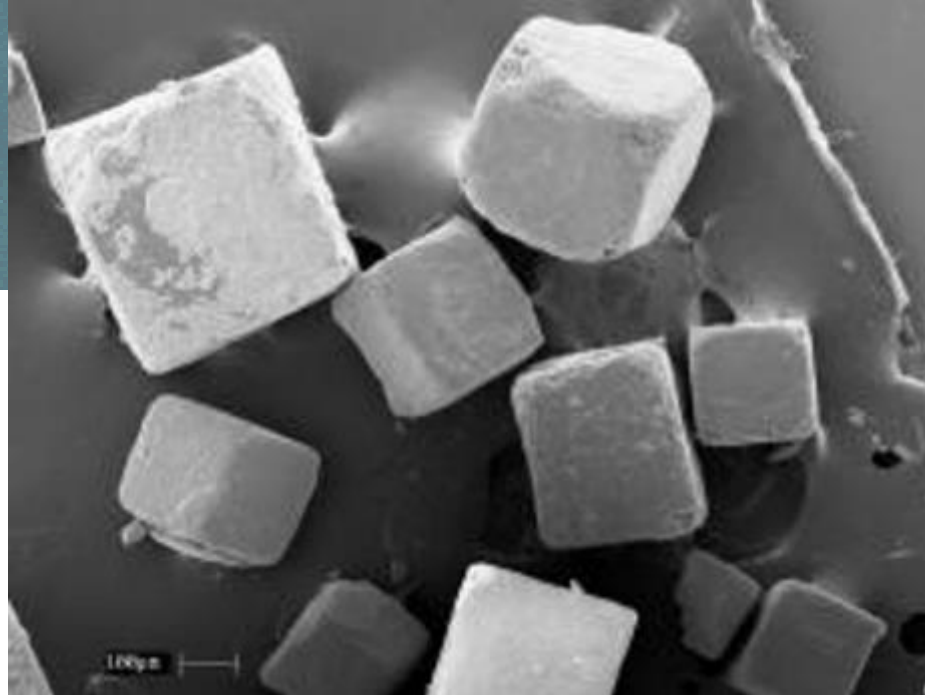
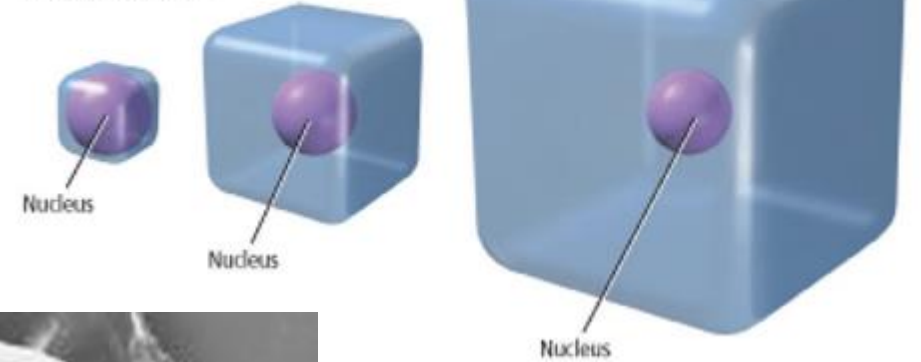
Light-matter interactions at the nanoscale



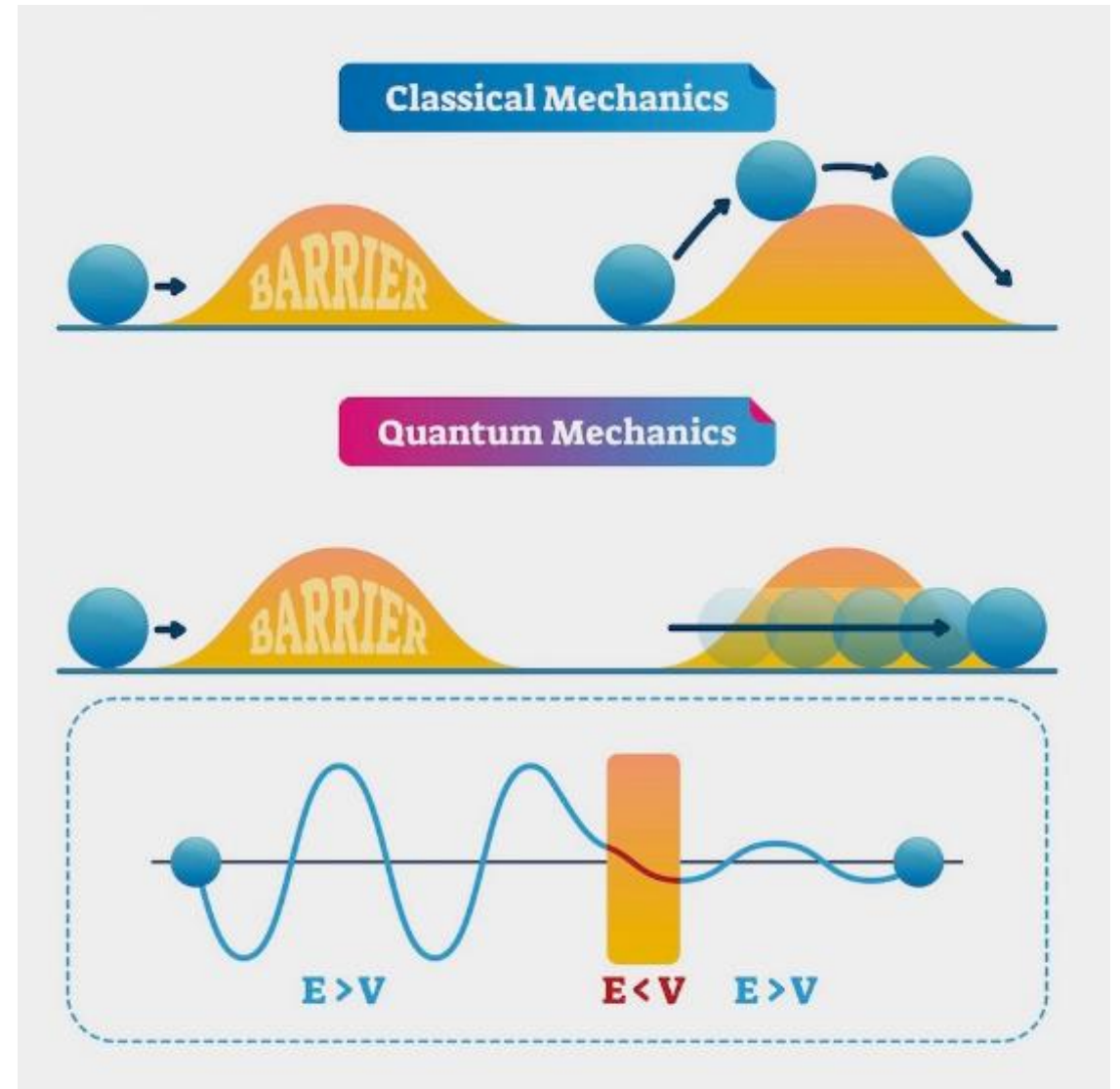
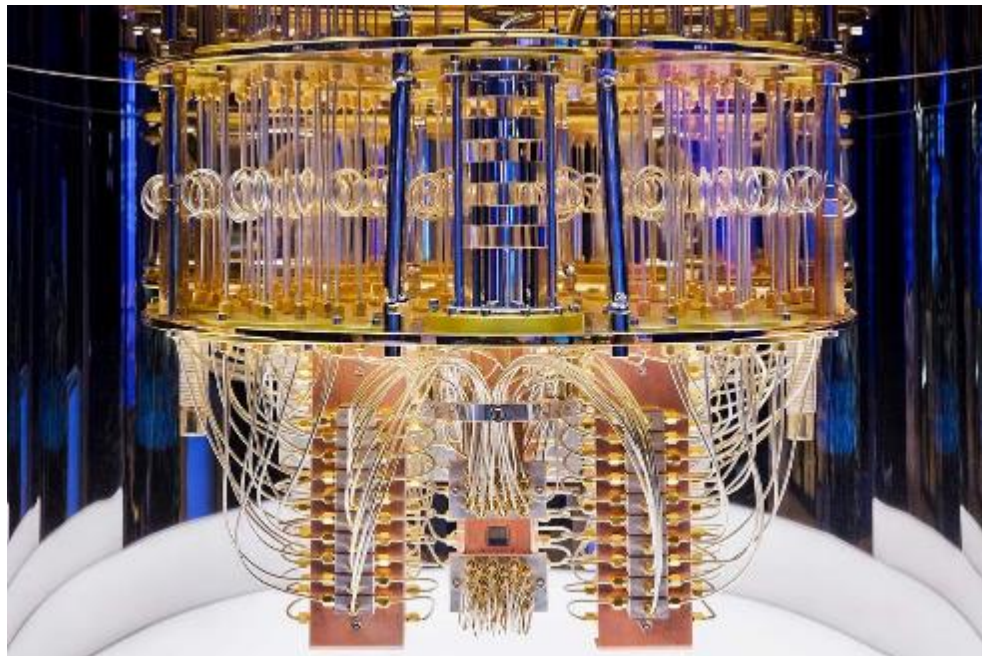
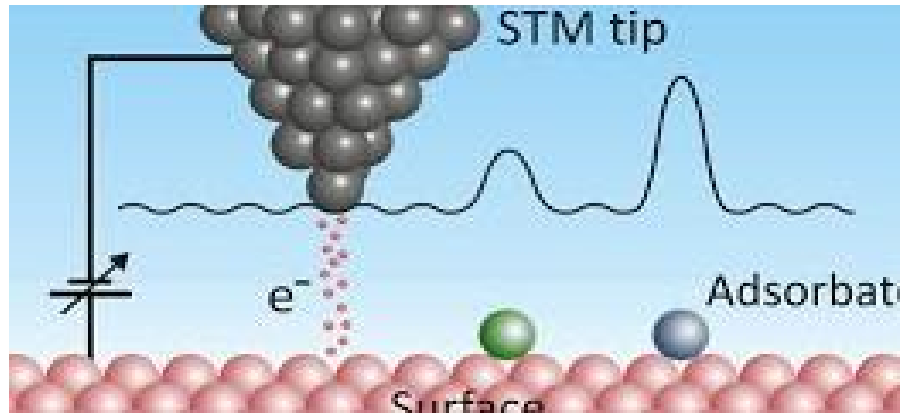
Surface effects at the nanoscale



Surface Area to Volume Ratio



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/>

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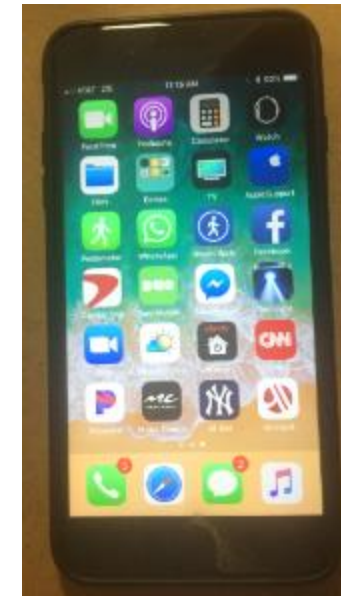
One Example of the Impact of Nanotechnology: Cell Phones



1993



2004



2016



PennState

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

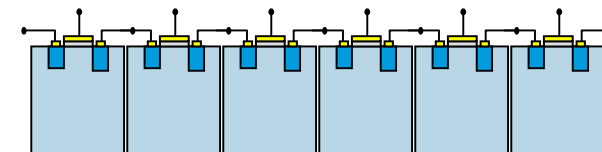
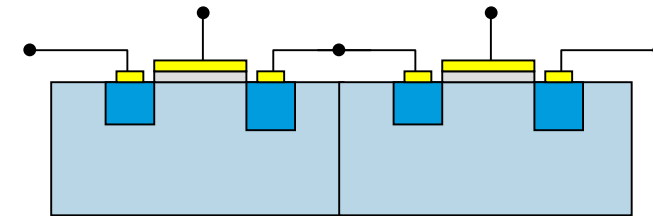
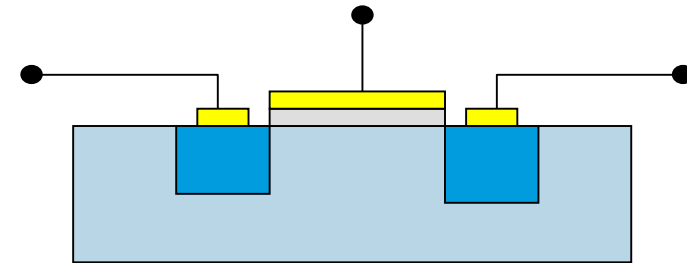
2019



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 nanometer 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.

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

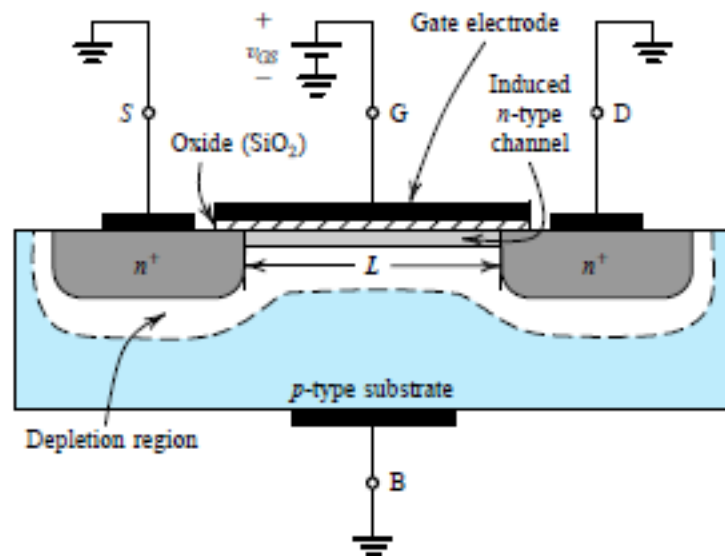
Apple Event
November 10, 2020



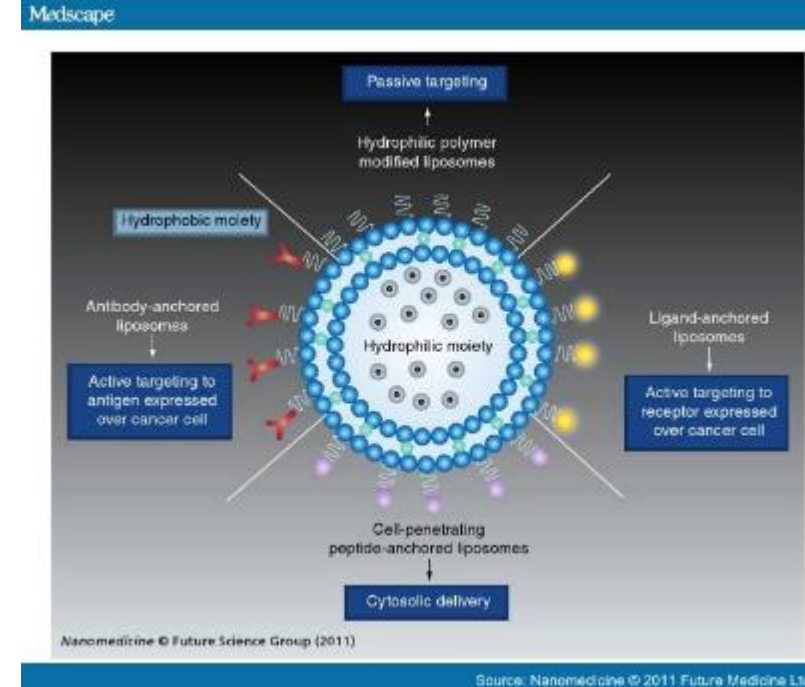
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Nano Fabrication

- 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



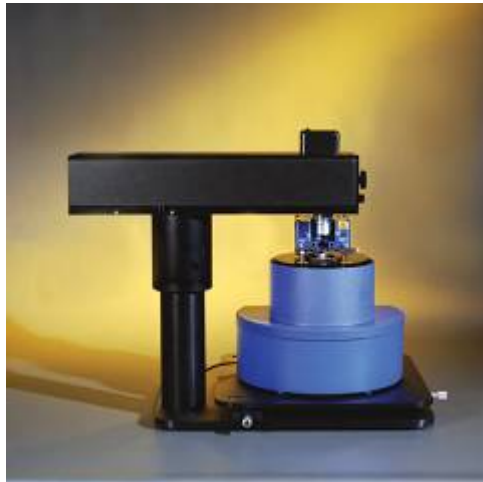
5.2 The enhancement-type NMOS transistor with a positive voltage applied to the gate



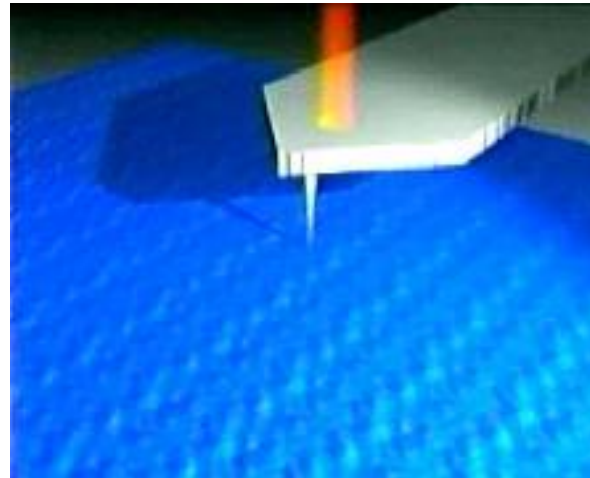
How do we see what we cannot see?

Characterization

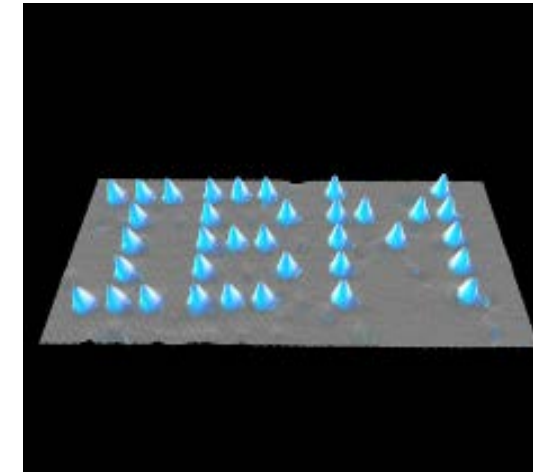
Nano: Enabling Technologies



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

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



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

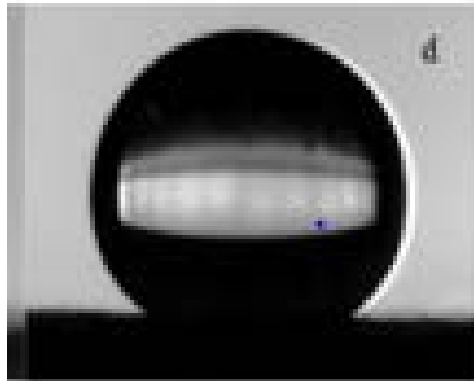
Lotus Effect



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

Hmmm ??????

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

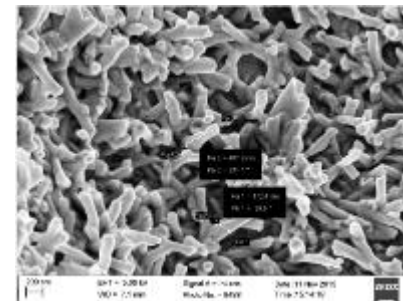
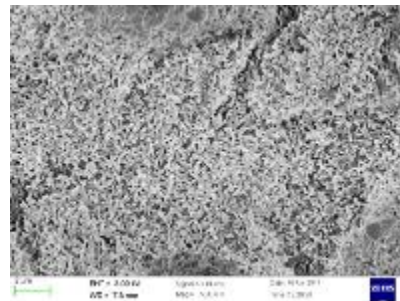
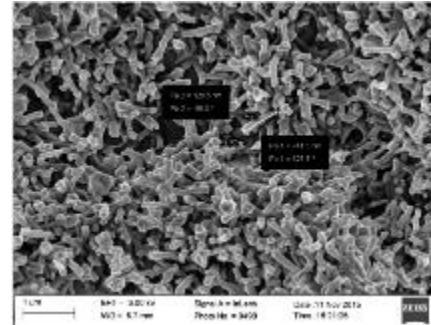
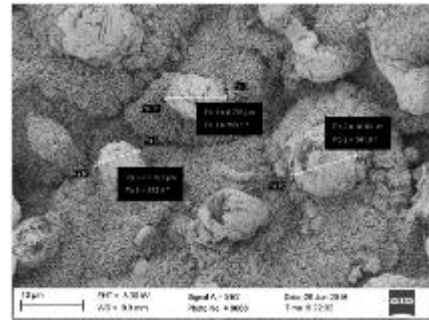


- Why does this leaf exhibit those properties?

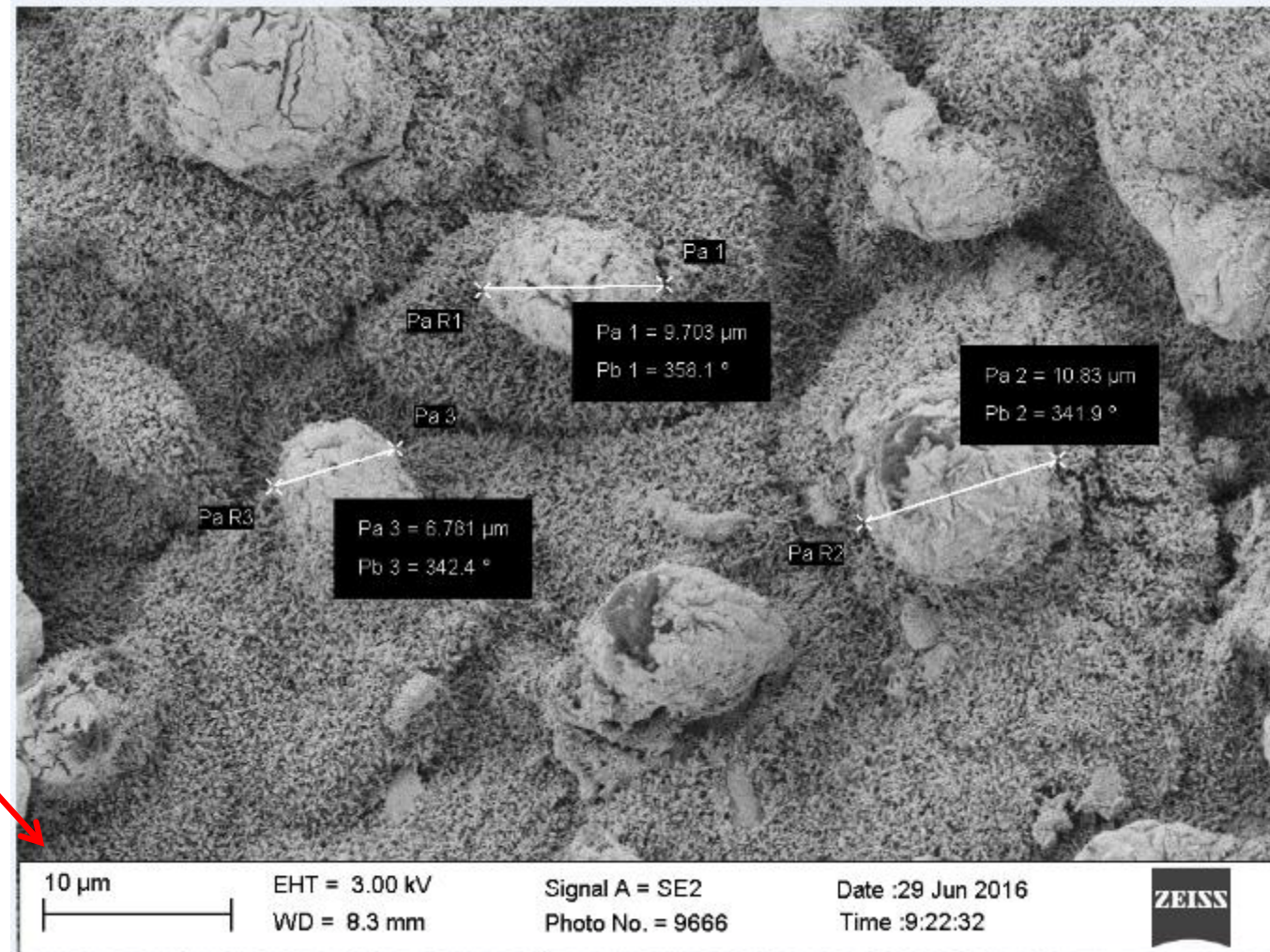
What does the lotus leaf look like?



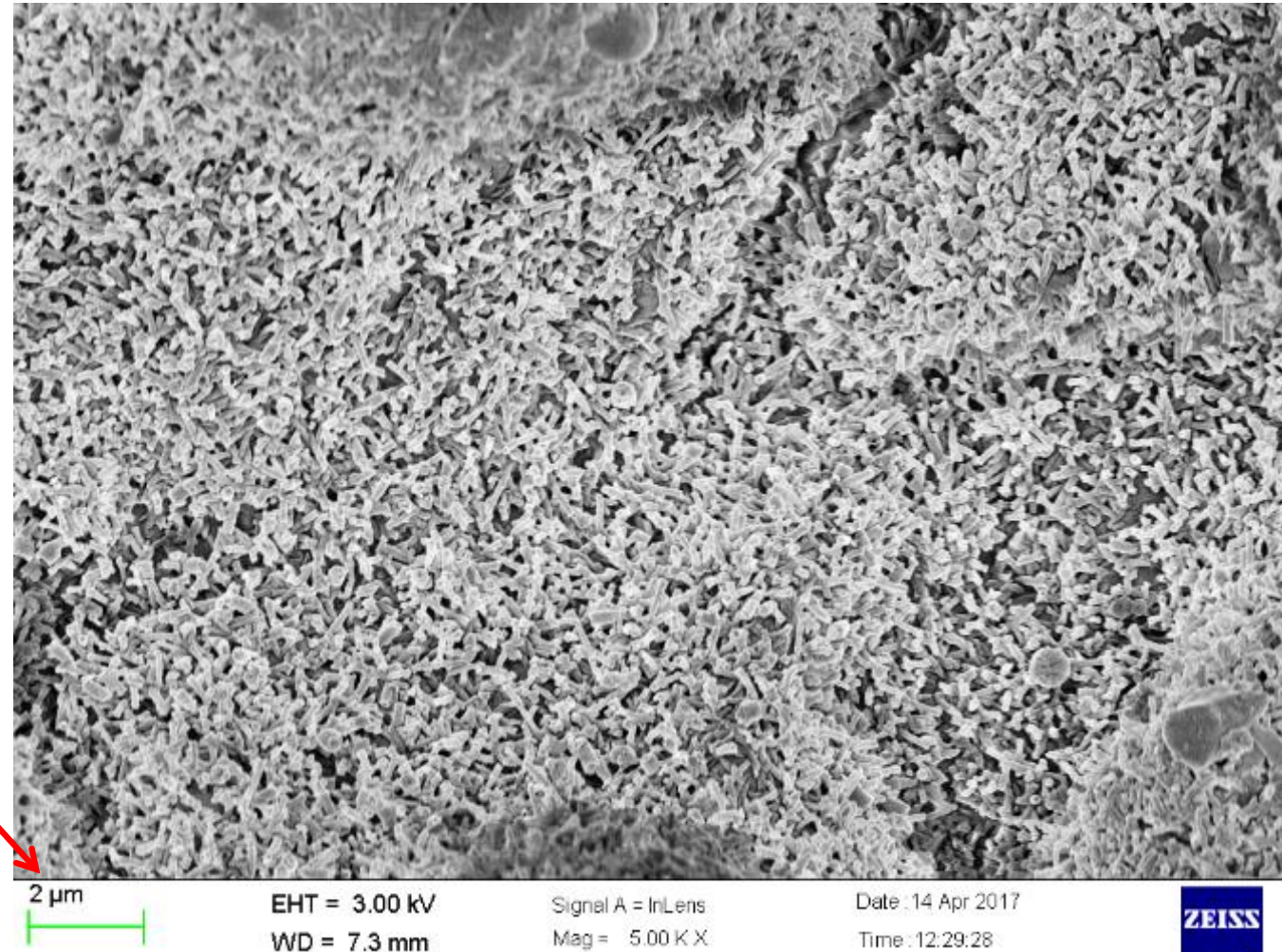
What does the lotus leaf look like?



What does the lotus leaf look like?

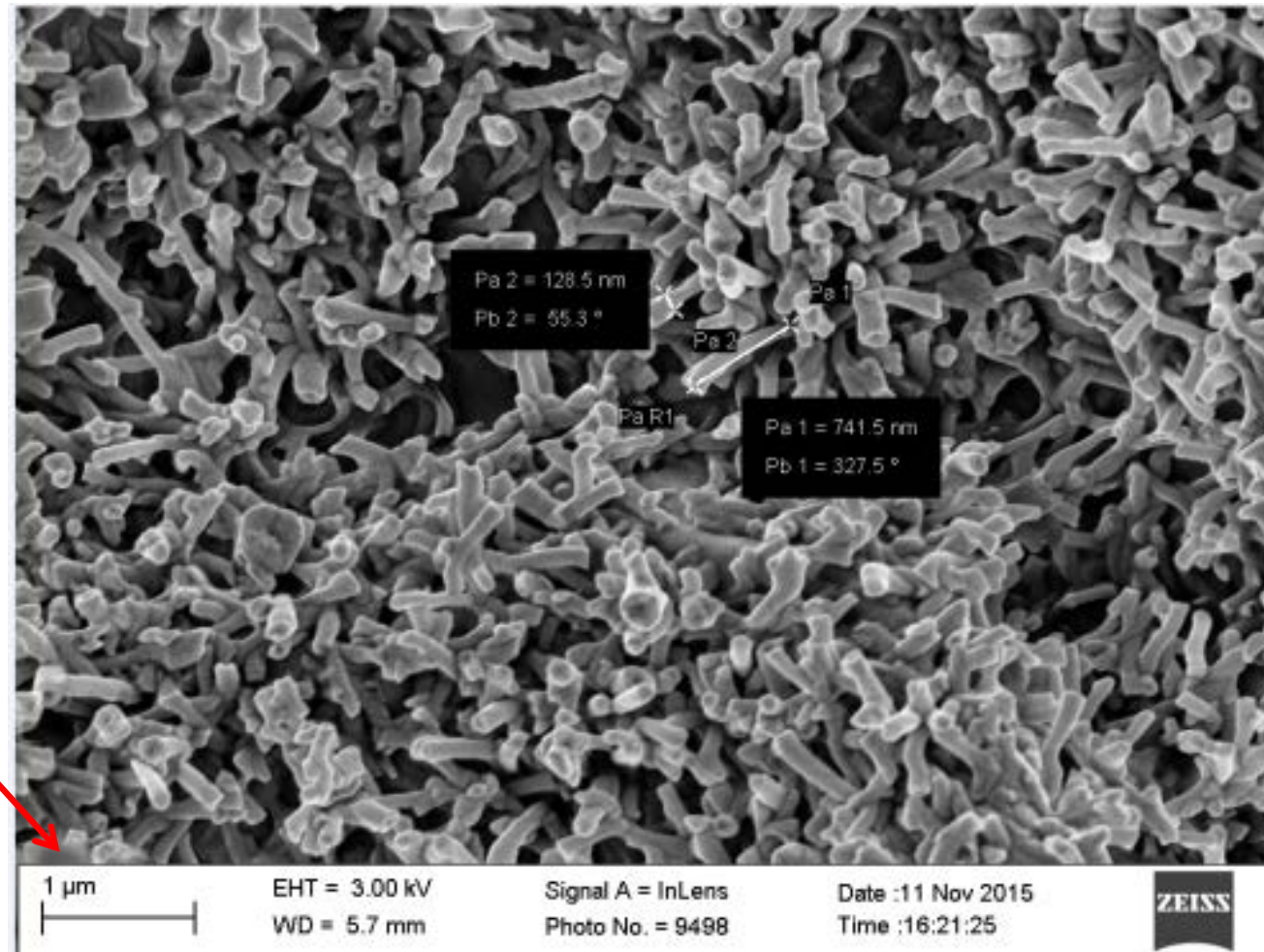


What does the lotus leaf look like?

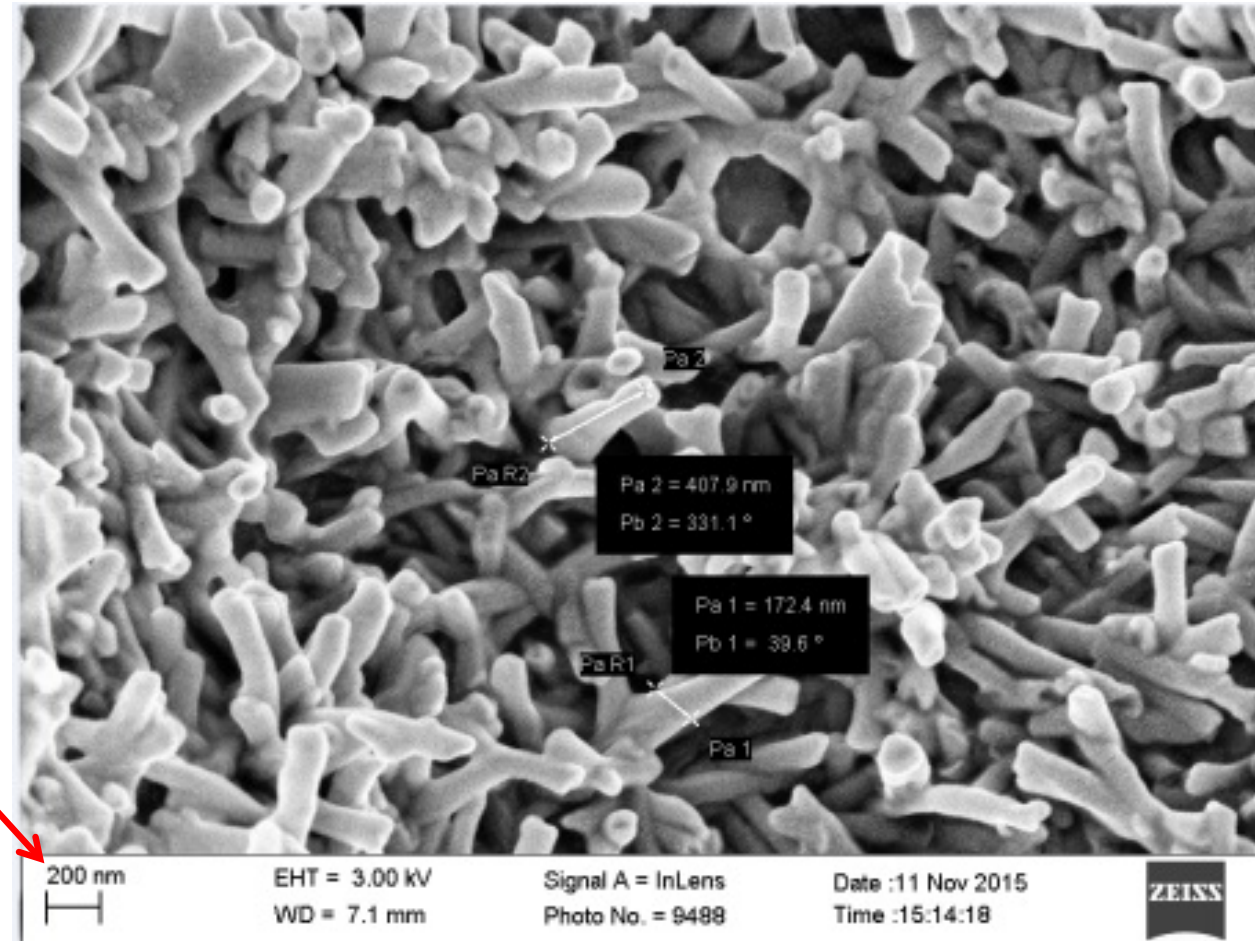


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What does the lotus leaf look like?



What does the lotus leaf look like?



Lotus Effect



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



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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
PROTECTING WHAT MOVES US

**Why Choose TST-
Because it Works!**

**TST 5000™ with PTFE
Nanoparticle Technology**
5000 Particles of PTFE PER SQUARE INCH

Wax
100 Times Larger Than
Polymer Silicone

Polymer Silicone
100 Times Larger Than
TST 5000™ with PTFE

TST 5000™ with PTFE
NO DRIFT
STAYS ON TOP
5 YEARS

POLYMER-SILICONE
DRIFTS IN
10-15 PER YEAR

WAX
DRIFTS OFF
1-2% PER DAY

**Never
Wax
Again!**

**Total Systems
Technology, Inc.**
88 Terence Drive | Pittsburgh, PA 15236-4198
www.tst5k.com

2018 NORTH AMERICAN CAR OF THE YEAR

TST 5000™ with PTFE Nanoparticle Technology

5000 Particles of PTFE PER SQUARE INCH

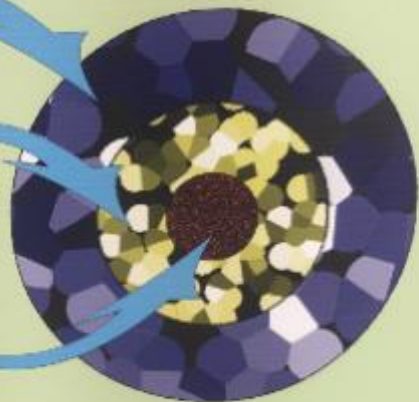
Wax

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



Never Wax Again!®

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Nanotechnology is Ubiquitous



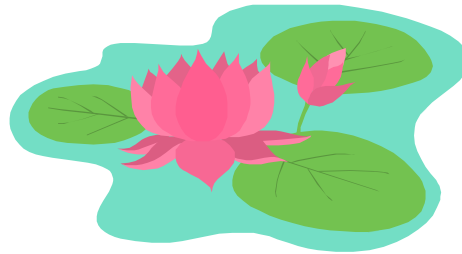
Diverse Applications

Movie



Cancer:
Detection/
Treatment

Textiles



Copying Nature
(Biomimetics)



Energy

Household



Clean Water

Sports



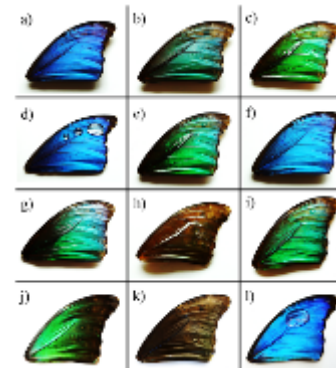
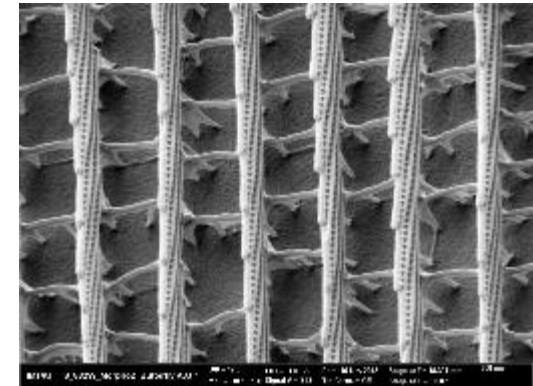
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Video links from previous slide

- Cancer Detection and Treatment
 - <https://youtu.be/OG7dMUE0rII>
- Copying Nature (Biomimetics)
 - <https://youtu.be/7is6r6zXFDc>
- Household
 - <https://youtu.be/50UISSy7PFE>
 - https://youtu.be/1nYN0B3K_wg
 - <https://youtu.be/uRfmDoOc60c>
- Clean Water
 - <https://binged.it/2FWmtKP>
- Textiles
 - <https://youtu.be/apFyWc-fx00>
 - <https://youtu.be/BvTkefJHfC0>
- Energy
 - <https://youtu.be/1GFst2IQBEM>
 - <https://youtu.be/Ds3sA1vqx1w>
 - <https://youtu.be/5AnMsylT26A>
 - <https://youtu.be/t7EYQLOlwDM>
- Sports
 - <https://youtu.be/9VDeJ7rLUYU>
 - https://youtu.be/IZ_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



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



A Forecast from 2016:

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

* M. Roco

Market and Jobs Information

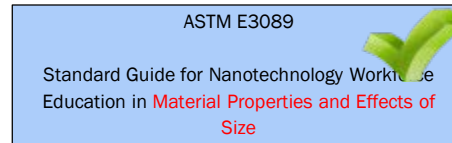
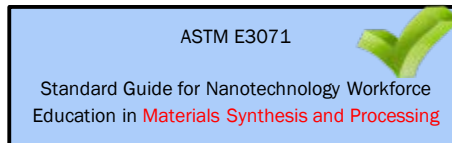
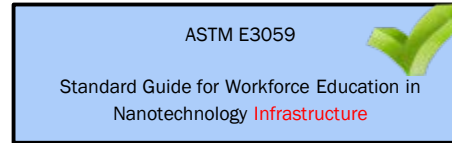
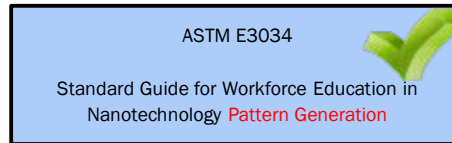
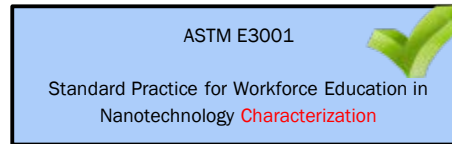
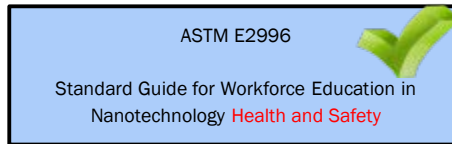
- As the market expands, the number of **jobs** needing different skill levels in nanotechnology will increase.
- Thus, it is essential that a sufficient **supply** of qualified **workers** be developed to fill that need.

Nanotechnology Workforce Video



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International Credentialing

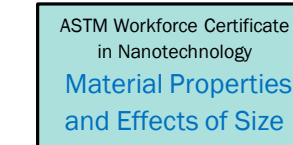
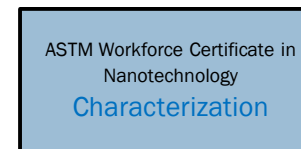
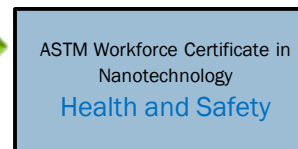


ASTM E56 Education Standards

- 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



[back](#)



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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.



