BIOMINERALIZATION: WHY ARE ABALONE SEASHELLS SO STRONG AND SHINY?

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Outline

- Doing one version of activity (another available as handout or through our website)
- Do parts 1 – 2 on your own (10 min)
- Group discussion (5 min)
- Do 3 – 5 with your team (10 min)
- Group discussion of test plan (10 min)
- Do 6 – 9 with your team (20 min)
  - Perform experiment in groups – everyone should do some of the testing and combine the data
- Group discussion (20 min)
- Do part 10 individually (5 min)
- Group discussion and closing (10 min)

Observations

- Why do them?
- What similarities and differences did you observe?

What do these materials have in common?

- Calcium carbonate
  - $CaCO_3$
- Found in a variety of substances:
  - Bone
  - Seashells/Snail shells
  - Coral
- Found in a variety of manufactured products
  - Calcium supplements
  - Antacids
  - Chalk

Why do observation?

- What are some of the similarities and differences found.

- Hypotheses?

- Proposed plans for testing hypotheses

What is “Strong”

- Tensile strength
- Compression strength
- Hardness
- Toughness – how much energy can be absorbed
  - One of the “toughest” materials is natural spider silk
- For real world applications it is important to know what type of “strong” is needed

Nova clip 11 min to ~ 15 min Race cars
http://video.pbs.org/video/1701025927/

Both chemical composition and structure affect properties

NANOSCALE STRUCTURE IS WHAT MAKES ABALONE TOUGH AND STRONG

One Method

- Drop weights, through different length pipes onto materials
- Variables to be aware of
  - thickness
  - how does the weight hit the material, does the material move,
  - curvature of material,
  - use the same material multiple times or a fresh material each time
- Is this quantitative or qualitative?
- What are we measuring?
- What is the physics?

Discussion of results

WHY?

What is Biomineralization?

- Biomineralization is defined as “the process by which living organisms can produce minerals”
- It is very common in nature and is found across all six taxonomic kingdoms
- Examples
  - Bones
  - Seashells

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Effects of Biomineralization

- Most organisms, when forming biominerals, organize the minerals in a form that is much stronger than the substance initially
  - Some of these substances are organized up to the nanoscale, creating significantly stronger structures
- Abalone –
  - Phylum: Mollusca Class: Gastropoda
  - Why do the shells need to be strong?
  - What makes them strong and shiny?

NOVA VIDEO CLIP Strength in nature Ch. 6 starts at ~ 41 min

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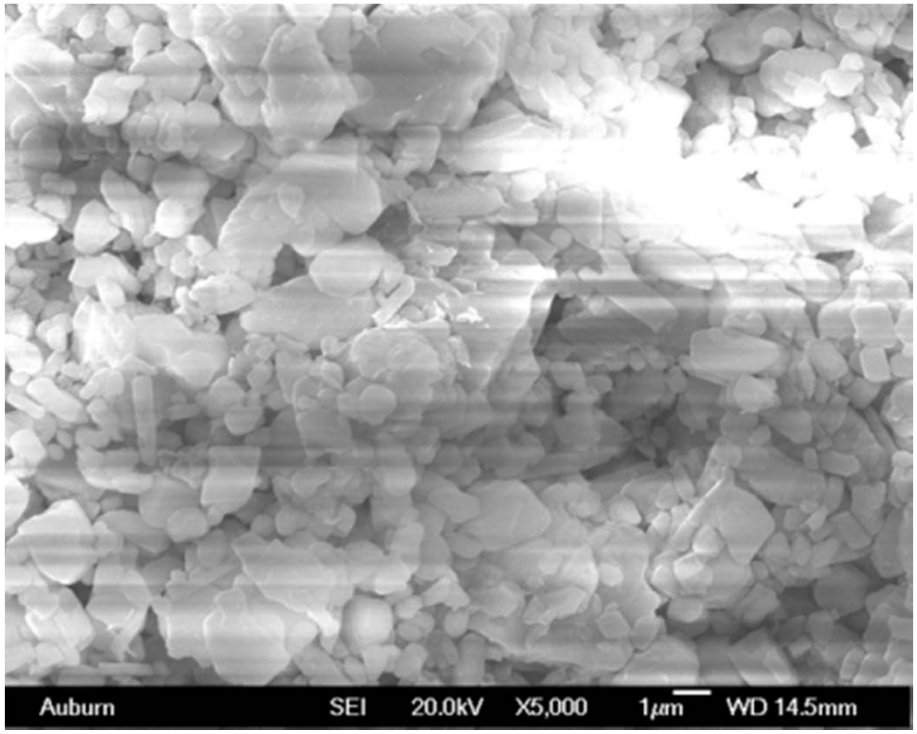
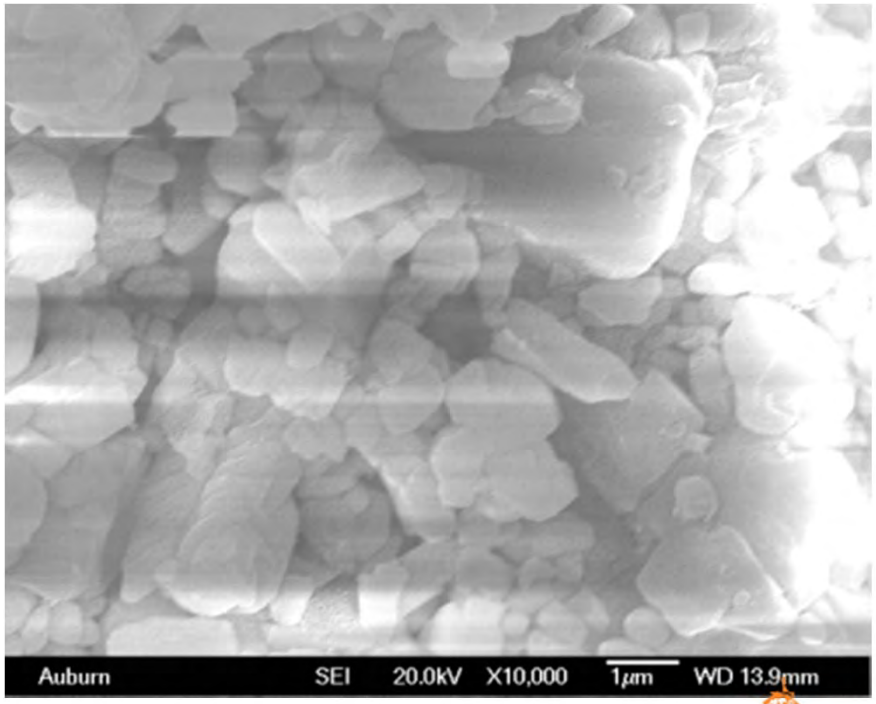


Scanning electron micrograph (SEM) of TUMS



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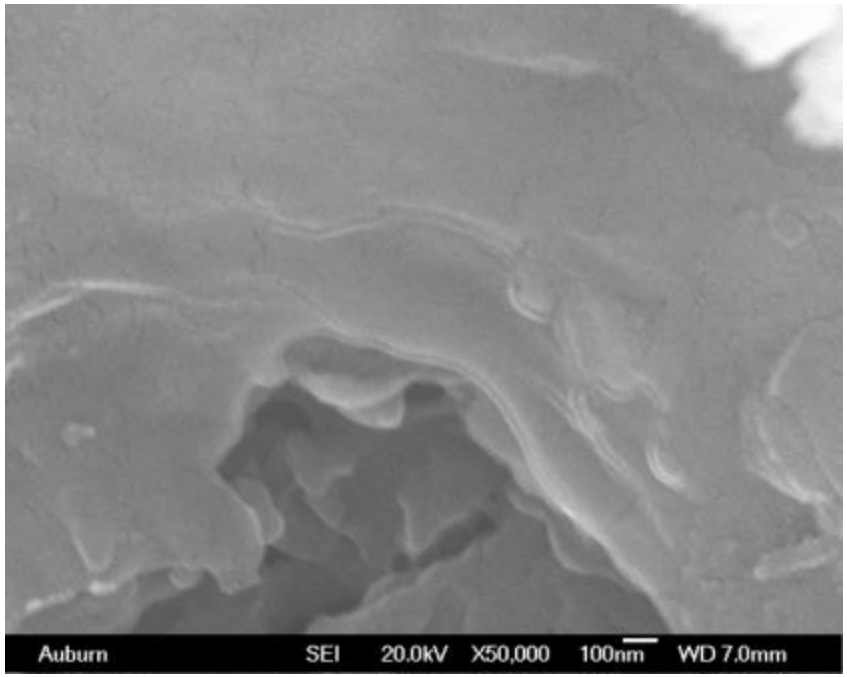
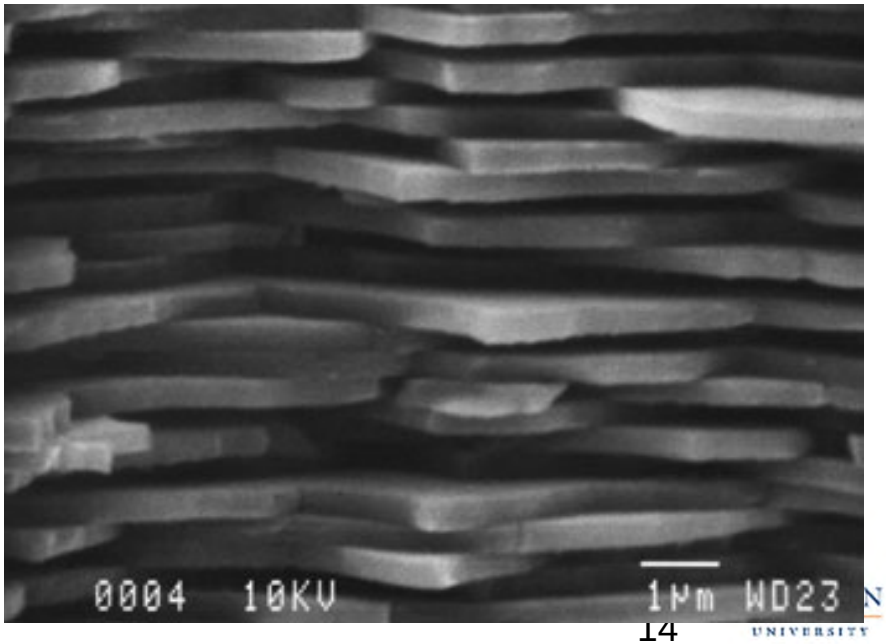
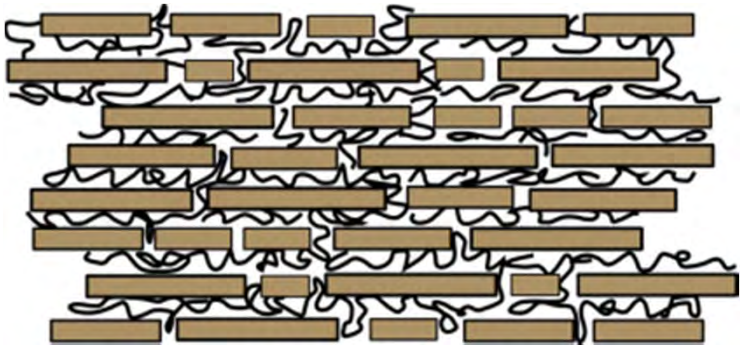


Scanning Electron Micrographs (SEM) of Abalone



Abalone Structure



- Abalone is a composite made of inorganic and organic materials called nacre
  - Inorganic part is $CaCO_3$ Organic part is elastic proteins
  - Super-sized analogy to abalone structure is brick and mortar
    - The bricks are the calcium carbonate $CaCO_3$ plates
    - The mortar is the protein layer that sticks everything together
- What would happen to a brick wall without the mortar ?
- What if all the brick stacks were straight up and down ?
- What would happen to abalone toughness without its protein

: http://commons.wikimedia.org/wiki/File:Nacre_microscopic_structure.png
http://commons.wikimedia.org/wiki/File:City_wall_close.jpg

Baked versus not baked abalone demonstration

HOW IS ANY OF THIS NANOTECHNOLOGY?

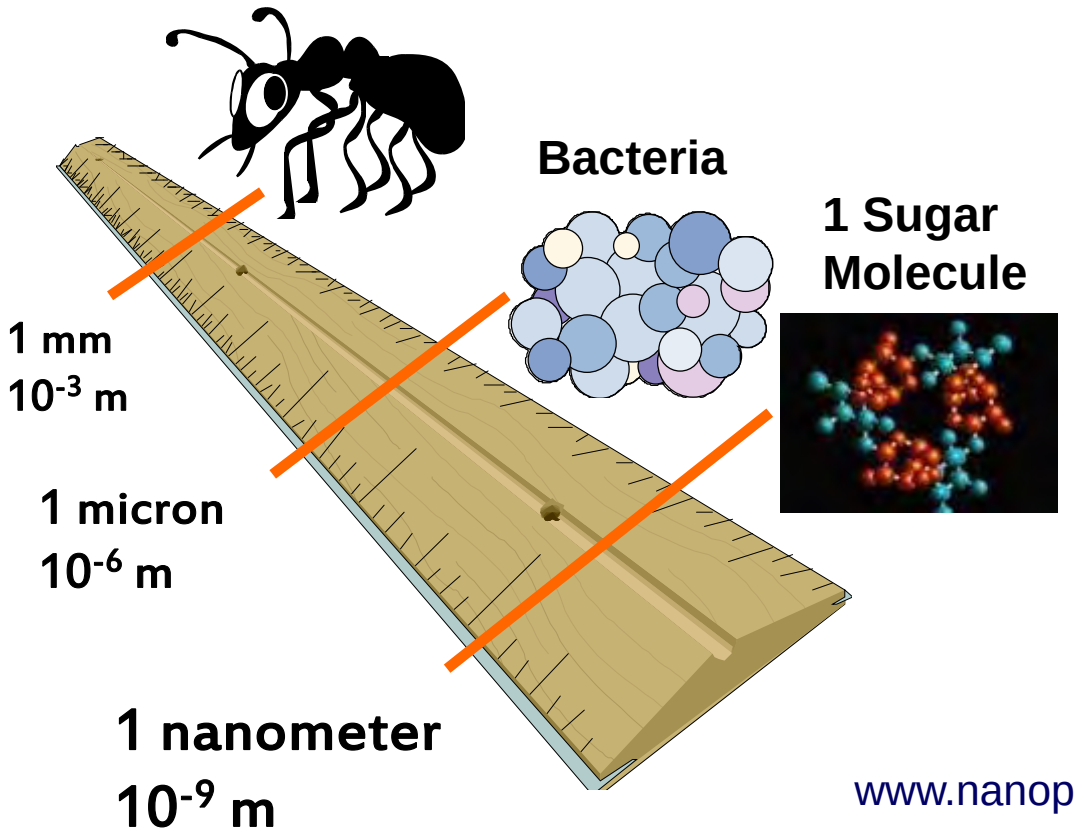
WHAT ABOUT THE APPEARANCE?

NANOTECHNOLOGY

Nanotechnology is the study and use of materials with 1 dimension less than 100 nanometers (nm)

"If I were asked for an area of science and engineering that will most likely produce the breakthroughs of tomorrow, I would point to nanoscale science and engineering."

- Neal Lane, Former NSF Director and Assistant to President Clinton for Science and Technology



Global Nano-enabled products:

2006:
$60 billion

2014 Projection:
$2.6 trillion or ~ 15% of total global manufactured goods

www.nanoproject.org

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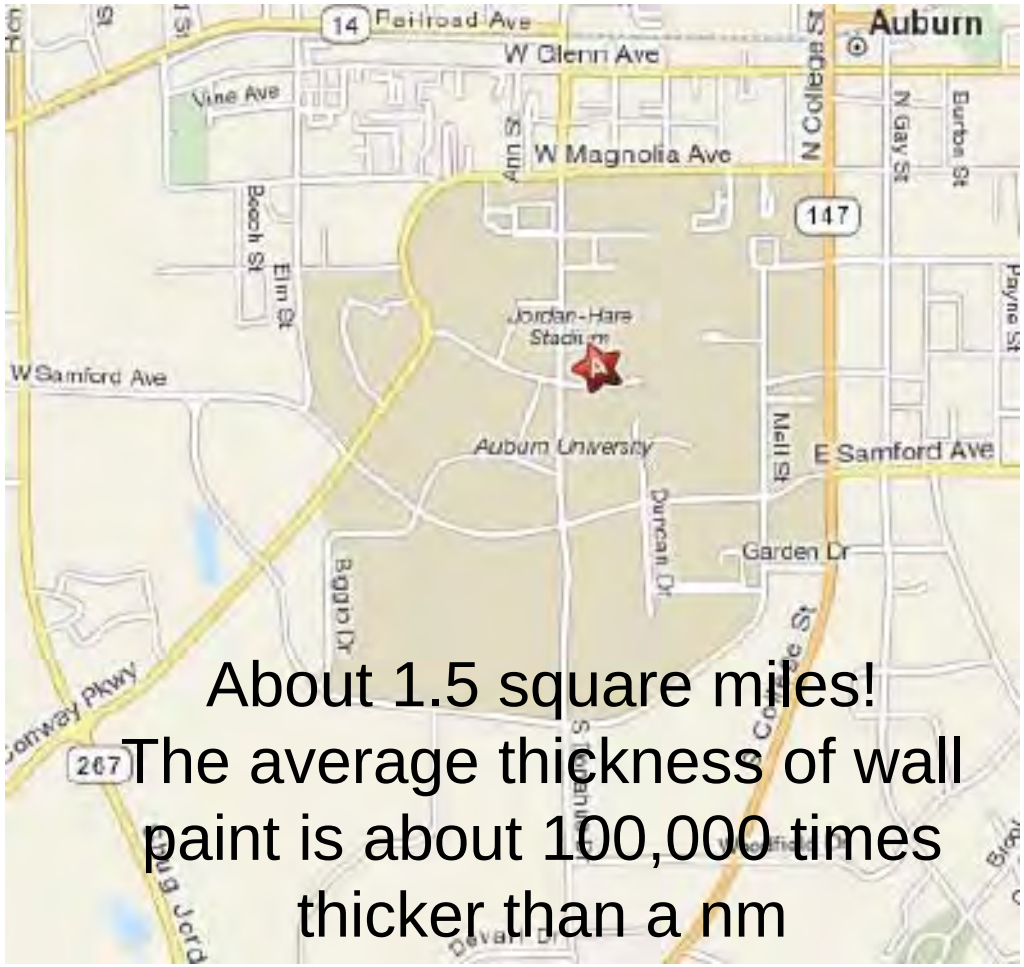
HOW SMALL IS NANO?

Coverage with normal use: 250-400 sq. ft

How big an area could you paint if you could make it only 1 nm thick?



Google maps

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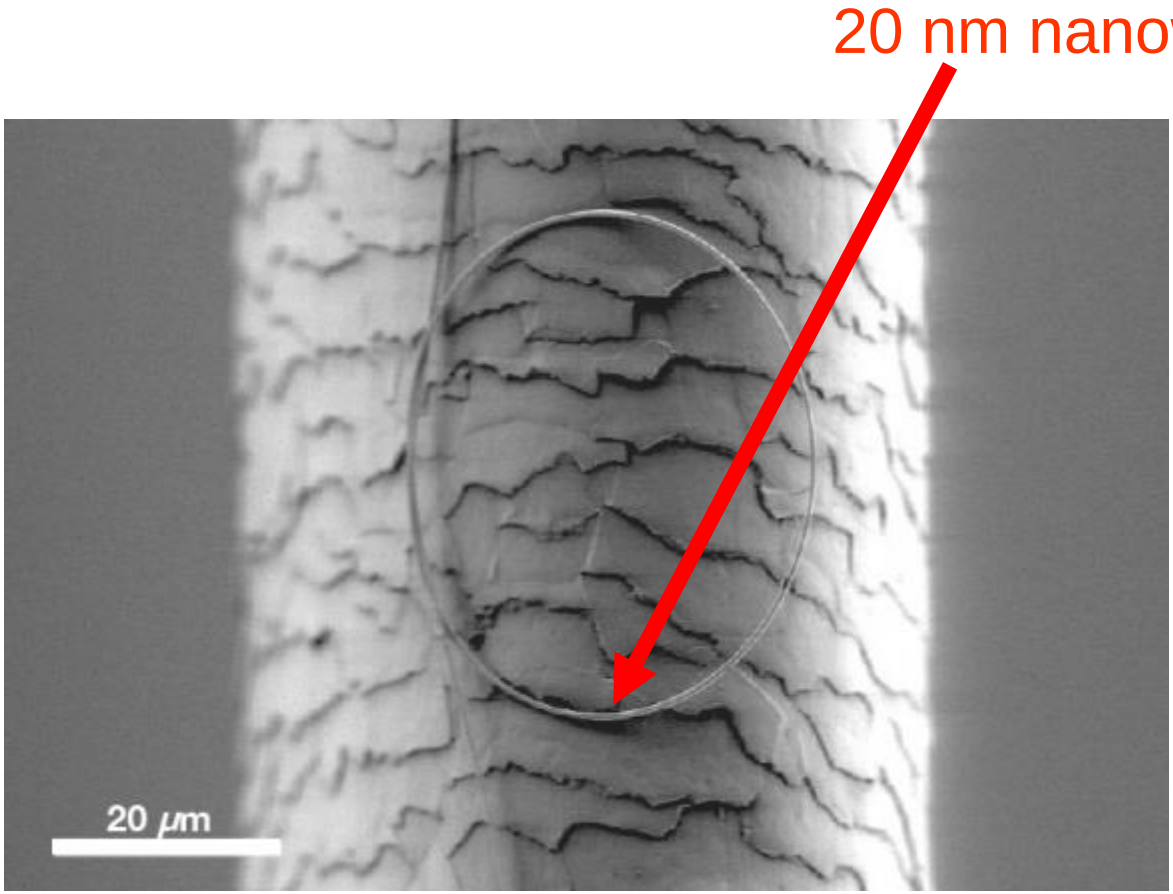
A human hair is about 100,000 times bigger than 1 nm !



www.nisenet.org

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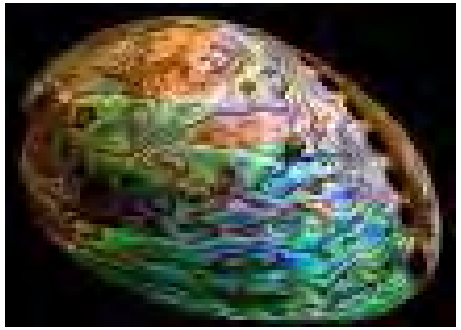
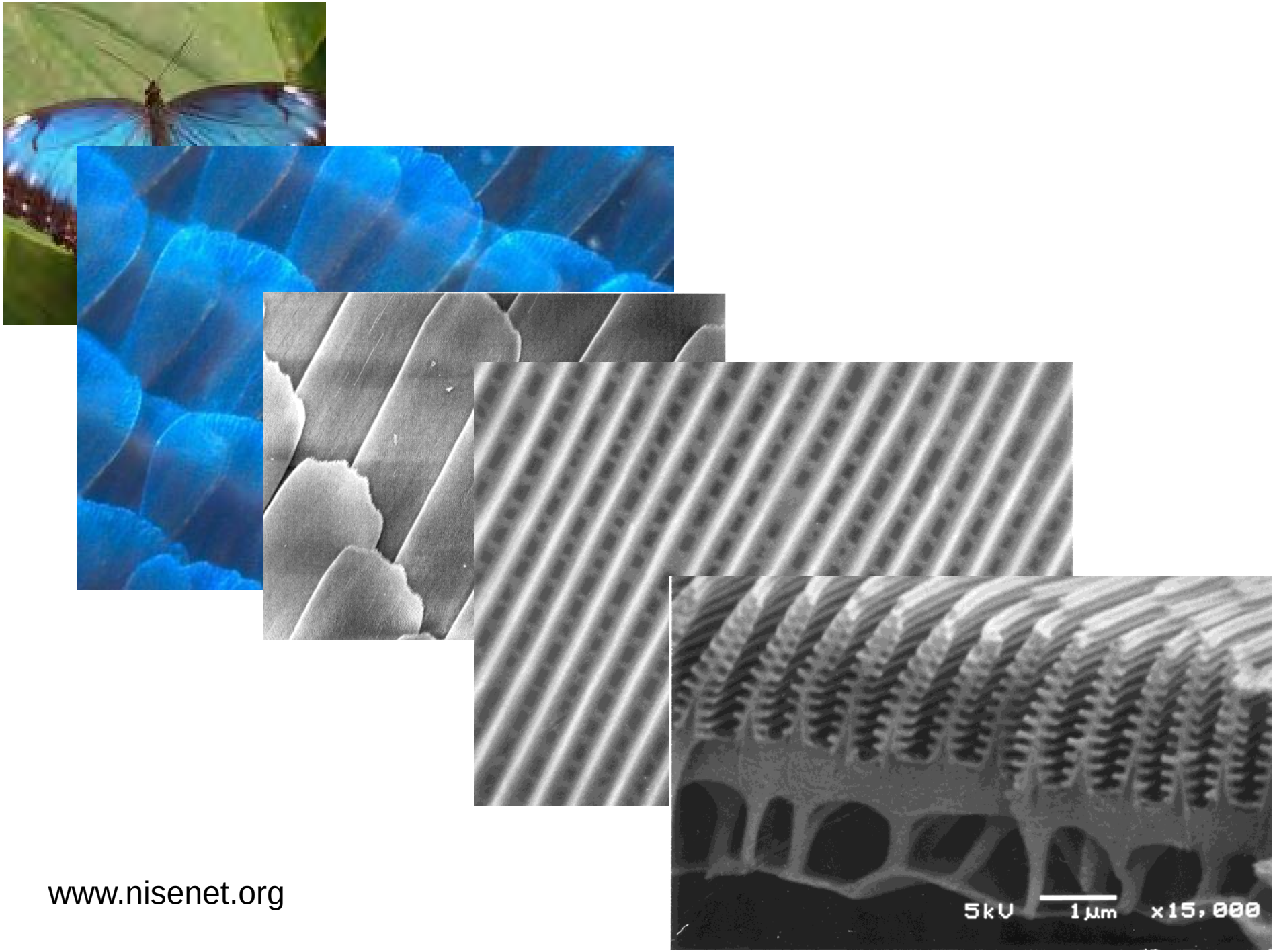
NANO AND COLOR

- Visible light is ~390 – 750 nm
- Nanomaterials interact with this light resulting in “structural color”
- The color(s) are due to different size and spacings in natural (and synthetic) materials
- This has been exploited for centuries in art
- Many engineers are trying to learn more about this part of “Nature’s Toolbox” so they can make better materials for applications
  - Displays
  - markings for currency and passports
  - more energy efficient solar panels





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MILESTONES NANOTECHNOLOGY AND ART

- Discovery of glass in Egypt & Sumeria (3000 BC)
- Roman Lycurgus Cup
  - Dichroic (changes color)
  - Wine red with transmitted light
  - Green in reflected light
  - Striking optical properties are due to gold, silver, and copper nanoparticles
- Lustre Glass & Pottery
  - 6th or 7th AD Century Egypt
  - Color varies depending on angles between the object, light source and observer
  - Nanosilver coating near surface
- Medieval Stained Glass (500 – 1400 AD)
- Ming Dynasty Porcelains (1388-1644 AD)

4th Century AD
Roman Lycurgus Cup
British Museum

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MEDIEVAL ARTISANS

ACCIDENTLY DISCOVERED THAT

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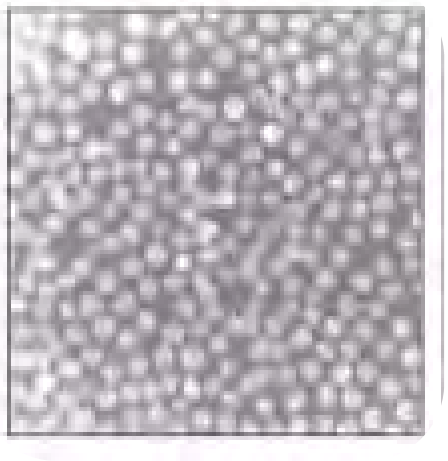
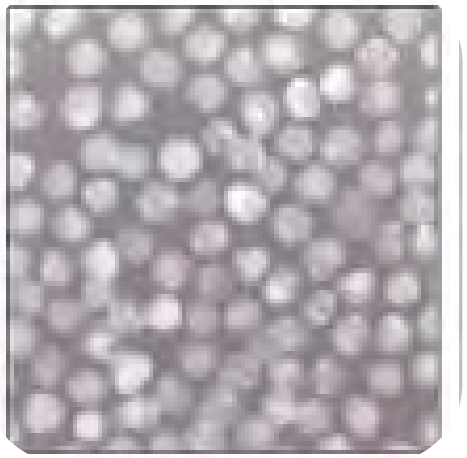
CHANGING THE SIZE OF THE GOLD PARTICLES EFFECTS COLOR



Size=25 nm
Shape: spherical
Color: **RED**



Size=50 nm
Shape: spherical
Color: **GREEN**

Size=100 nm
Shape: spherical
Color: **ORANGE**

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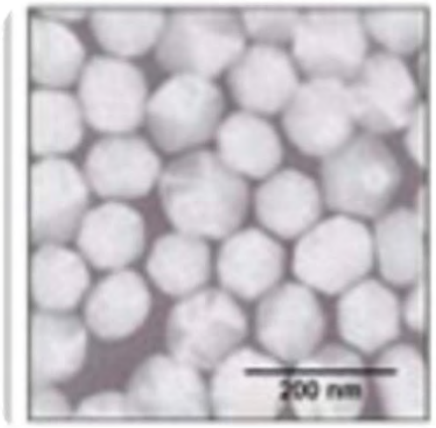
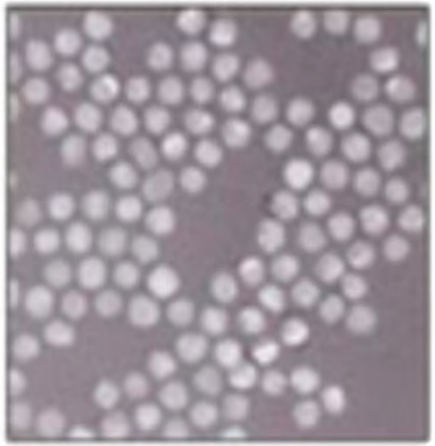
www.Nisenet.org

Chang, Kenneth. "Tiny is Beautiful: Translating 'Nano' Into Practical." New York Times 22 Feb 2005: Science.

CHANGING THE SIZE AND SHAPE OF THE SILVER PARTICLES EFFECTS COLOR



Size=100 nm
Shape: spherical
Color: **YELLOW**



Size=40 nm
Shape: spherical
Color: **BLUE**

Size=100 nm
Shape: triangular
Color: **RED**

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www.Nisenet.org

Chang, Kenneth. "Tiny is Beautiful: Translating 'Nano' Into Practical." New York Times 22 Feb 2005: Science.

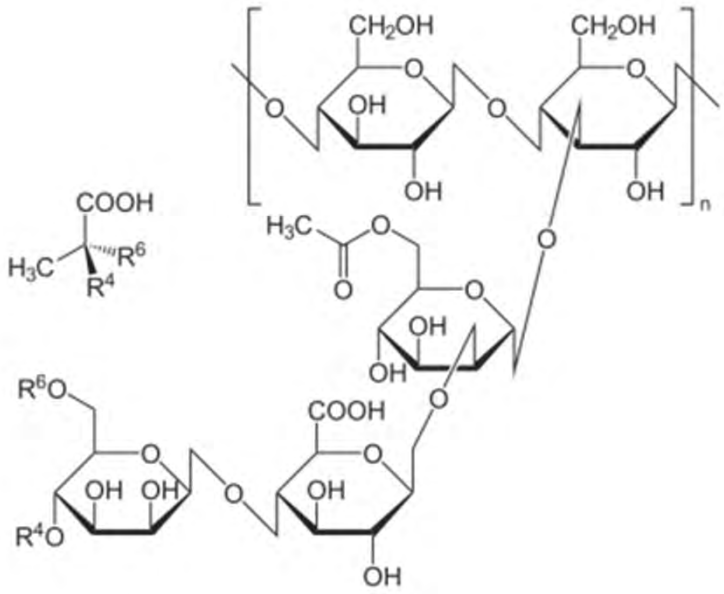
Possible Extensions

- Add “mortar” to a material that broke easily
- Discussion of nanoscale and optical properties: iridescence
- Calculations of Breaking Forces by using different weights at same height: F=ma
  - ***Energy = Mgh***
  - Calculations of energy absorption or toughness:
  - Energy = Force* distance
  - Potential energy = mass * a * height
  - PLEASE TEACH YOUR STUDENTS TO CARRY UNITS AND ORGANIZED WAYS TO USE THEM!
- Dissolution testing of materials at different pH
  - Acidity of soda and wearing teeth enamel
- More on other natural nanostructured forms of calcium carbonate
  - Bones weight bearing ability, breaks, osteoporosis

Can we make a weak material “tougher” by adding an energy absorbing material?

Xanthan Gum

- A polysacchride derived from Xanthomonas campestris – a bacteria that causes plant diseases
- Used as a food additive and rheology modifier – for example to improve texture for gluten free breads
- What happens when we use xanthan gum as mortar between the antacid or supplement tablets?



Wikipedia

What did you learn?

Follow-up

- Auburn MSP website (can link from TU or google)
- Questions: email me davisva@auburn.edu
- We can make and send kits with sufficient notice or you can purchase supplies
  - Fishing weights came from Academy Sports
  - Shells came from Seashellsupply.com
  - Xanthan gum available in specialty groceries or online
  - Everything else was from Walmart

SWNT-H_2SO_4
Dispersion imaged on
Cytoviva Microscope

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SWNT-dsDNA Liquid Crystal

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