Nanotechnology in Agriculture and Food Technology

- Food and Agriculture
- Bioengineering

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From fish to fungus, trees to turnips, potatoes to paper, nanobiotechnology is about more than pesticides and genetic engineering.

How can small science have such a big impact?
What is nanotechnology?

A description -

• Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, or nanoscale.

• Unusual physical, chemical, and biological properties can emerge in materials at the nanoscale. These properties may differ in important ways from the properties of bulk materials and single atoms or molecules.

• Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale.

Note: This slide and the next 9 slides are the same for all research areas.

Resource: www.nano.gov
How BIG is nano?

Macrosize
meters, decimeters, centimeters, millimeters

Child
A child is about 1 meter tall
1 meter = 1,000,000,000 nm
(1 billion nanometers)

Hand
A hand is about 1 decimeter wide
1 decimeter = 100,000,000 nm
(100 million nanometers)

Pinky Finger
A pinky finger is about 1 centimeter wide
1 centimeter = 10,000,000 nm
(10 million nanometers)

Freckle
A freckle is about 1 millimeter wide
1 millimeter = 1,000,000 nm
(1 million nanometers)

Strand of Hair
A hair is about one tenth of a millimeter wide
0.1 millimeter = 100,000 nm
(100 thousand nanometers)

Microsize
micrometers

Red Blood Cell
A red blood cell is about 10 micrometers wide
10 micrometers = 10,000 nm
(10 thousand nanometers)

Bacteria
A bacterium is about 1 micrometer wide
1 micrometer = 1,000 nm
(1 thousand nanometers)

Virus
A viron is about one tenth of a micrometer wide
0.1 micrometer = 100 nm
(1 hundred nanometers)

Cell Membrane
A cell membrane is about 10 nanometers wide
10 nanometers = 10 nm

Nanosize
nanometers

Sugar Molecule
A sugar molecule is about 1 nanometer wide
1 nanometer = 1 nm

Atom
An atom is about one tenth of a nanometer wide
0.1 nanometer = 0.1 nm

Accompanying book available for purchase at www.lulu.com
This material is based upon work supported by the National Science Foundation under Agreement No. ESI-0532536. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.
1 nanometer = 1 billionth ($10^{-9}$) of a meter

D

10^9 D

a marble
Why do we care?

Things behave differently at this scale

- Quantum mechanics plays a much more important role
- For example,
  - A brick of gold is shiny and “gold”-colored.
  - A vial of gold nanoparticles in solution can be a range of colors depending on the size of the nanoparticles.
  - This is because of a phenomenon known as quantum confinement.

Suspensions of discrete (separated) gold nanoparticles in clear solution vary in color from pink to purple as the nanoparticle size gets bigger.

Why else do we care?

This is the scale of biological processes

- Human cells and bacteria have diameters around 1-10 \textit{micrometers}
  
  \textbf{BUT}

- Cellular machinery is on the \textit{nanoscale}
  
  - Diameter of DNA is \sim2 nanometers
  
  - Hemoglobin, the protein that carries oxygen through the body, is 5.5 nanometers in diameter

\begin{itemize}
  \item \textbf{Structure of DNA} \quad \text{PDB ID: 1BNA}
  \item \textbf{Structure of hemoglobin} \quad \text{PDB ID: 1BUW}
\end{itemize}
One more reason: surface area

Another reason nanomaterials behave differently from bulk materials of the same chemical is because of surface area – or the area of an object that is an exposed surface.

For this cube, each edge is 1 meter in length.

Volume (in cubic meters):

\[ 1 \text{m} \times 1 \text{m} \times 1 \text{m} = 1 \text{ m}^3 \]

Surface Area (in square meters):

\[ (1 \text{m} \times 1 \text{m}) \times 6 \text{ sides} = 6 \text{ m}^2 \]

For these cubes, each edge is 0.1 meters in length, but there are 1000 cubes.

Volume (in cubic meters):

\[ (0.1 \text{m} \times 0.1 \text{m} \times 0.1 \text{m}) \times 1000 \text{ cubes} = 1 \text{ m}^3 \]

Surface Area (in square meters):

\[ (0.1 \text{m} \times 0.1 \text{m}) \times 6 \text{ sides} \times 1000 \text{ cubes} = 60 \text{ m}^2 \]
Surface Area and Reactions

• This increased surface area allows chemical reactions to go much faster.

• Think about it this way:
Which dissolves faster in your coffee or tea, a sugar cube or a teaspoon of granulated sugar?

Answer: Granulated sugar
Nano-enabled Consumer Products

As of the March 10, 2011, there are over 1300 consumer products around the world that are manufacturer-identified as nanotechnology-based.

• Touch screens (iPhone)
• Bicycles
• Sunscreens
• Fabric
• Cosmetics
• Computer memory
• Tennis rackets
• Many more...

These products are here, ready to buy today!

Resources: The Project on Emerging Nanotechnologies website: http://www.nanotechproject.org/
Activity Description

• You have been assigned an area of nanotechnology research to support.

• Go through this presentation and any other credible sources to identify three benefits of research in nanotechnology toward your area of interest and up to three potential risks you perceive in your area of interest.

• As a group, we will weigh the risks and benefits of each area to decide how much of our federal nanotechnology budget should go to each research area.
Disclaimer: this is a contrived scenario

- There are no federal nanotechnology budget cuts
  - $1.7 billion estimated for FY2012 (fiscal year 2012)
  - Increased investment proposed for FY2013 (nearly $1.8 billion)
- Nanoscale Science, Engineering and Technology (NSET) subcommittee of the National Science and Technology Council's Committee on Technology is an actual government entity
  - Composed of representatives from 25 federal agencies (NIH, DOE, DOD, etc.)
  - Purpose is to coordinate planning, budgeting, and implementation of the National Nanotechnology Initiative (NNI)
  - These representatives work together to create an integrated federal program.
- Actual nano “budget” is different from what is proposed in this activity
  - Actual “budget” is given as a supplement to the President’s 2013 Budget Request submitted to Congress
  - It represents the sum of the investment in nanotechnology and nanoscience planned for 2013 by federal agencies
  - The agencies submit how much they are planning to spend on nanoscience
  - In the activity scenario, we’re doing the opposite of what the actual NNI Budget represents in that we’re distributing a pre-determined amount amongst these research areas.

Resources: NNI Budget website: http://www.nano.gov/about-nni/what/funding
In this presentation, you will learn about some of the developments in nanotechnology in the research areas of food science and agriculture.
Consider the following when learning about these developments:

1. Might these nanotechnology developments infringe on human rights to privacy and freedom?

2. Is it safe for me? Is it safe for others?

3. Could the use of this nanotechnology development have unwanted and negative environmental effects?

4. What economic impact could the use of this nanotechnology development have on producers, consumers, and other industries? Might they be negative or positive?
What About Your Rights?

If so, are these developments more important than

- Your privacy?
- Your rights as a citizen?
- Your rights as a human being?

Are the answers somewhere in between?

Image source: http://www.info4security.com/Pictures/web/w/v/m/iStock_Law.jpg
Within this presentation will be many underlined words. If you click on the underlined text, your browser will take you to other websites, videos, or other resources to learn more about what is on the slide.

These links are chosen to give you additional information, but these presentations can stand alone. It is unnecessary to go to the links for the purpose of this activity.

We try to make sure the links are active, but given the ever-changing nature of the internet, you might find a few that take you to a location that is no longer active. Please let the facilitator know if you find an inactive link.
Where is Nanoscience in Agriculture and Food Science?

Areas of Nanoscience Research in Agriculture and Food Science

As outlined in the previous slide, contribution of nanoscience research in agriculture will be in the following areas.

1. Food Safety and Biosecurity
2. Material Science
3. Food Processing and Product Development
According to the article cited below –

“Nanosensors for the detection of pathogens and contaminants could make manufacturing, processing, and shipment of food products more secure.

Specific nanodevices could enable accurate tracking and recording of the environmental conditions and shipment history of a particular product.

‘Smart’ systems capable of providing integrated sensing, localization, reporting and remote control of food products could increase the efficacy and security of food processing and transportation.”

In 2008, thousands of people, especially children, got sick as a result of melamine contamination in dairy products from China. Assistant Professor Na Li at the University of Miami and her collaborators developed a quick and easy way to detect melamine in milk using gold nanoparticles. In the presence of melamine, the mixture changes from pink to blue. [1, 2]

Nanotechnology can provide us with sensors which can detect pathogens.

Resources:
Detecting Mad Cows

- Bovine spongiform encephalopathy, also known as mad cow disease, is a neurodegenerative condition in cattle that has caused over 200 human deaths worldwide as a result of eating contaminated food. [1]
- The disease is caused by harmful prions which are proteins that damage the central nervous system of infected cattle. [2]
- Prof. Harold Craighead of Cornell University and his colleagues have developed nanoscale resonators that can detect prions at amounts lower than what could be detected to date. [1, 3]
- The hope is that this will lead to faster more efficient testing for the national food supply. [1]

Resources:
The idea behind intelligent or smart packaging is to communicate the quality of the food within the package through devices either incorporated in the packaging or attached to the packaging.

Potential nanosensors could indicate

- Temperature
- Freshness
- Ripeness
- Contaminants/pathogens

right on the package!

Imagine using nanotechnology to create packaging that prevents microbial contamination. Kinect sells food storage containers that contain silver nanoparticles, which are antimicrobial, to keep foods fresher longer.

Eat ‘em Up, Then…

Prof. Jeremy Tzeng of Clemson University is experimenting with new pathogen-disabling nanoparticles to keep chickens healthy. Nanoparticles are added to feed and mimic cell surfaces inside the chicken. The tiny pathogens (germs) get confused and bind to the particles instead of real cells, then “flush” – out as they go through the digestive system—keeping chickens safer and healthier for human consumption. [1, 2]

Check out this video on Prof. Tzeng’s Intelligent Chicken Feed:
http://www.youtube.com/watch?v=ZuRH9psTJ9M&feature=player_embedded

Resources:
http://www.popularmechanics.com/science/research/4270075.html
http://www.clemson.edu/public/psatv/ag/intelligent_chicken_feed.html

If it works on chickens, who’s next?
According to the European Nanotechnology Gateway forum report on nanotechnology in agriculture and food, nanotechnology-enabled devices will increase the use of sensors linked to global positioning systems (GPS) for real-time monitoring of crops. [1]

Accenture, a consulting company, developed a crop management system for Pickberry Vineyard in Sonoma County, California. They used a network of wireless sensors to continuously sense humidity, wind, water, and soil and air temperature over a 30-acre stretch of the vineyard. [2]

They claim that “the technology may make it possible to target irrigation when soil in one area dries, or remove leaves to expose grapes to more sun, or change the schedule for using pesticides.” [3]

Resources:
Dr. Micaela Buteler and Associate Prof. David Weaver of Montana State University tested the use of nanostructured alumina (NSA) on two insect pests common in the milling, food processing and storage of dry grains. Their research showed that NSA may provide a cheap and reliable alternative to commercially available insecticidal dusts.

The potential of nanofertilizers

- Given the high surface area relative to the amount of nanomaterials, fertilizers based on nanotechnology have the potential to surpass conventional fertilizers, but lack of funding and concern over regulation and safety has led to little advancement in this area.

- In nanofertilizers, nutrients can be
  - Encapsulated by nanomaterials,
  - Coated with a thin protective film,
  - Or delivered as emulsions or nanoparticles.

- Nanomaterials could even be used to control the release of the fertilizer such that the nutrients are only taken up by the plant, and not lost to unintended targets like soil, water, or microorganisms.

Healthier French Fries?

Nanoscience can reduce oil use in all types of restaurants, including all fast food establishments.

OilFresh, a company based out of Sunnyvale, California, has created nanoporous ceramic pellets that can be added to the frying oil to prevent oil molecules from clumping together while in use.

As a result of the large surface area at the nanoscale, it can extend the useful life span of the oil.

It also helps heat the oil up more quickly which results in a quicker frying time and less oil content and crispier texture in the fries.

In May 2008, WingZone announced their nationwide adoption of OilFresh 1000SE Frying Oil Extender! [2]

Resources:
Beer: Fresher, Longer

Nanocor sells a product called Imperm that can be used in plastic bottles to improve the gas barrier properties of the bottles and extend product shelf life.

Imperm is a nanocomposite of nylon and nano clay. [1]

Beer can keep in normal plastic bottles for 11 weeks, but with the nanocomposite bottles, it can keep for as long as 30 weeks. [2]

For your favorite beer or carbonated beverage nanocomposites can help keep the oxygen out and the carbonation in.

Resources:
Healthy, Yet Tasty, Donuts?

With the help of nanoscience, some foods might be taken off of the ‘no-no’ list:

• Sherman Industries of Israel sells Canola Active Oil, which uses “nanodrops” to encapsulate and carry vitamins, minerals or phytochemicals which would not dissolve in the oil.

• That way you can get your vitamins while eating your home made fried treats!

Resources: Canola Active Oil http://www.nanotechproject.org/inventories/consumer/browse/products/canola_active_oil/
Let’s Have Some Ice Cream!

Nanotechnology is making ice cream less fattening.

• Ice cream is an emulsion of milk fat in water.
• An emulsion is the dispersion of one liquid in another liquid it wouldn’t normally mix with (think of making a vinaigrette from vegetable oil and vinegar).
• Unilever scientists are working to decrease the size of the emulsion droplets to make ice cream less fattening but still have that creamy texture.
• The result will be a decrease in fat content from 8-16% to about 1%!

Resources:
To find out more about the United States government’s role in nanotechnology in food and agriculture

- Go to this [linked presentation](#) by Dr. Hongda Chen, National Program Leader for the National Institute of Food and Agriculture
- Check out [this video](#) from 2008 by Partners Video Magazine, *The Science of Small*, which features four research projects funded by the USDA’s Cooperative State Research, Education, and Extension Service at Cornell University and the University of Illinois (30 minutes)
- USDA National Institute of Food and Agriculture nanotechnology webpage [http://www.csrees.usda.gov/nanotechnology.cfm](http://www.csrees.usda.gov/nanotechnology.cfm)
Nano-enabled consumer products

To learn more about nano-enabled consumer products in all areas of research visit the Project on Emerging Nanotechnologies

- Established in April 2005 as a partnership between the Woodrow Wilson International Center for Scholars and the Pew Charitable Trusts
- “The Project is dedicated to helping ensure that as nanotechnologies advance, possible risks are minimized, public and consumer engagement remains strong, and the potential benefits of these new technologies are realized.”
- Their website includes news and publications about issues with nanotechnology.
- It also includes inventories of consumer products that are manufacturer-identified as nanotechnology based, and as of the March 10, 2011 update, there are over 1300 products around the world.

Resources: The Project on Emerging Nanotechnologies website: http://www.nanotechproject.org/
More on the website

If time allows, return to the main website and watch some of the videos that provide “expert testimony” in the area of nanotechnology in food and agriculture.

Click here