Lesson 5:
Applications of Nanoscience

Teacher Materials

Contents

Applications of Nanoscience: Teacher Lesson Plan

Orientation

This lesson introduces students to applications of nanoscience, explores how nanoscale science and engineering could improve our lives, and describes some potential risks of nanotechnology.

- The Applications of Nanoscience PowerPoint slides illustrate a variety of current and potential nanotechnology applications.
- The What's New Nanocat project gives students the opportunity to work in groups to research an application of nanoscience, prepare and present it, and give peer feedback.

Essential Questions (EQ)

What essential questions will guide this unit and focus teaching and learning?

(Numbers correspond to learning goals overview document)

3. Occasionally, there are advances in science and technology that have important and long-lasting effects on science and society. What scientific and engineering principles will be exploited to enable nanotechnology to be the next big thing?
6. What are some of the ways that the discovery of a new technology can potentially impact our lives?

Enduring Understandings (EU)

Students will understand:

(Numbers correspond to learning goals overview document)

1. The study of unique phenomena at the nanoscale could change our understanding of matter and lead to new questions and answers in many areas, including health care, the environment, and technology.

Key Knowledge and Skills (KKS)

Students will be able to:

(Numbers correspond to learning goals overview document)

3. Describe an application (or potential application) of nanoscience and its possible effects on society.
4. Compare a current technology solution with a related nanotechnology-enabled potential solution for the same problem

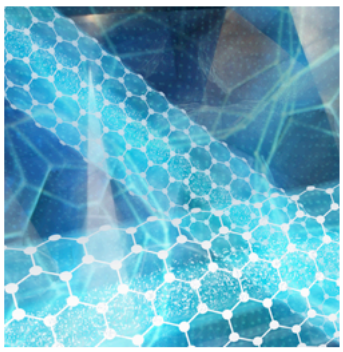
Prerequisite Knowledge and Skills

- Ability to research topics independently (for optional activity).

Related Standards

- NSES Science and Technology: 12EST2.2, 12EST2.4
- History and Nature of Science. 12GHNS3.3
- NSES Science as Inquiry: 12ASI2.3

Day	Activity	Time	Materials
Day 1 (35 min)	Show the PowerPoint slides: Applications of Nanoscience, using teacher's notes as talking points. Describe and discuss interactively with students the examples shown of possible applications. Try to stimulate student interest!	20 min	PowerPoint slides: Applications of Nanoscience Computer and projector
	What's New Nanocat? Assign or allow students to choose the nanotechnology topic they want to investigate for the project. Students will work in groups of 3 or 4.	15 min	What's New Nanocat? Teacher Instructions and Rubric Prepare a sign-up sheet for each student group to indicate their chosen topic and the names of all students in their group.
Days 2-4 (full class)	Students conduct independent investigation and prepare a presentation, in groups, on chosen/assigned topic.	3 days	Computers with internet connection, journal articles, library. Materials for making a poster presentation using PowerPoint or posters.
Day 5 (full class)	Students make their presentations to the class. Class members discuss and ask questions.	1 day	Copies of the What's New Nanocat? Poster Session: Peer Feedback Form Scoring rubric will be used to score student presentations. May require computer and projector for those students wishing to present their topic using PowerPoint. You may want to display paper posters or share PowerPoint slide presentations.



Applications of Nanoscience

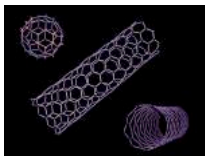
How might nanoscale science and engineering improve our lives?

NanoSense
the basic sense behind nanoscience

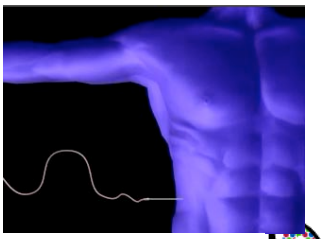
Potential Impacts of Nanotechnology

- **Materials**
  - Stain-resistant clothes
- **Health Care**
  - Chemical and biological sensors, drugs and delivery devices
- **Technology**
  - Better data storage and computation
- **Environment**
  - Clean energy, clean air

Thin layers of gold are used in tiny medical devices



Carbon nanotubes can be used for H fuel storage

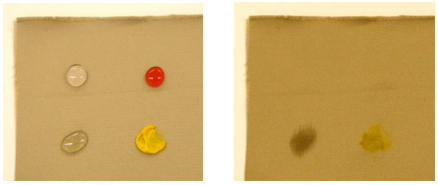


Possible entry point for nanomedical device

Materials: Stain Resistant Clothes

- **Nanofibers create cushion of air around fabric**
  - 10 nm carbon whiskers bond with cotton
  - Acts like peach fuzz; many liquids roll off

Nano pants that refuse to stain; Liquids bead up and roll off



Nano-Care fabrics with water, cranberry juice, vegetable oil, and mustard after 30 minutes (left) and wiped off with wet paper towel (right)

Sources: http://www.sciencentral.com/articles/view.php3?article_id=218391840&cat=3_5
http://mrsec.wisc.edu/Edetc/IPSE/educators/activities/nanoTex.html

Materials: Paint That Doesn't Chip

- **Protective nanopaint for cars**
  - Water and dirt repellent
  - Resistant to chipping and scratches
  - Brighter colors, enhanced gloss
  - In the future, could change color and self-repair?

Mercedes covered with tougher, shinier nanopaint

Sources: http://www.supanet.com/motoring/testdrives/news/40923/

Environment: Paint That Cleans Air

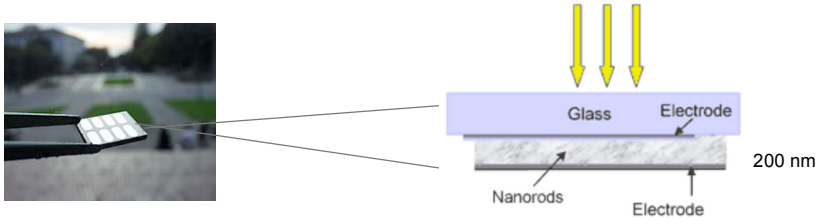
- **Nanopaint on buildings could reduce pollution**
  - When exposed to ultraviolet light, titanium dioxide (TiO2) nanoparticles in paint break down organic and inorganic pollutants that wash off in the rain
  - Decompose air pollution particles like formaldehyde

Buildings as air purifiers?

Sources: http://english.eastday.com/eastday/englishedition/metro/userobject1ai710823.html

Environment: Nano Solar Cells

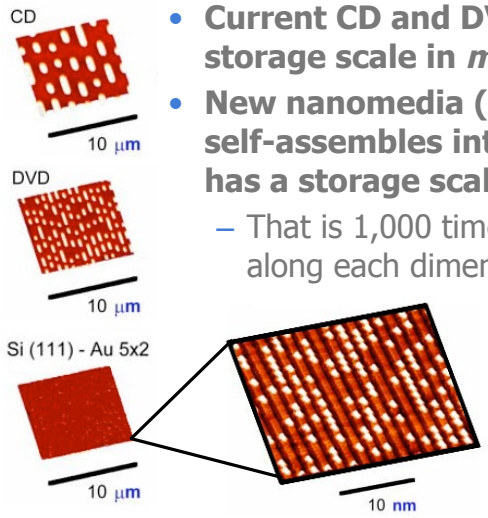
- **Nano solar cells mixed in plastic could be painted on buses, roofs, clothing**
  - Solar becomes a cheap energy alternative!



Nano solar cell: Inorganic nanorods embedded in semiconducting polymer, sandwiched between two electrodes

Source: http://www.berkeley.edu/news/media/releases/2002/03/28_solar.html

Technology: A DVD That Could Hold a Million Movies



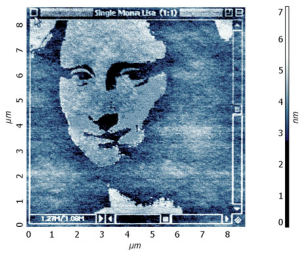
- **Current CD and DVD media have storage scale in *micrometers***
- **New nanomedia (made when gold self-assembles into strips on silicon) has a storage scale in *nanometers***
  - That is 1,000 times more storage along each dimension (length, width)…

…or 1,000,000 times greater storage density in total!

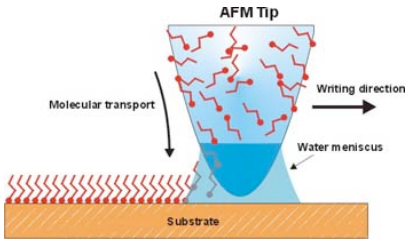
Source: Images adapted from http://uw.physics.wisc.edu/~himpsel/nano.html

Technology: Building Smaller Devices and Chips

- **Nanolithography to create tiny patterns**
  - Lay down "ink" atom by atom



Mona Lisa, 8 microns tall, created by AFM nanolithography

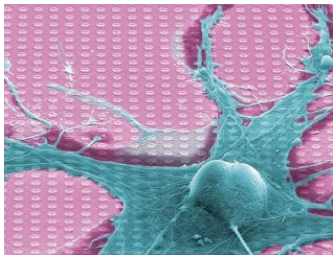


Transporting molecules to a surface by dip-pen nanolithography

Sources: http://www.ntmdt.ru/SPM-Techniques/Principles/Lithographies/AFM_Oxidation_Lithography_mode37.html
http://www.chem.northwestern.edu/~mkngrp/dpn.htm

Health Care: Nerve Tissue Talking to Computers

- **Neuro-electronic networks interface nerve cells with semiconductors**
  - Possible applications in brain research, neurocomputation, prosthetics, biosensors

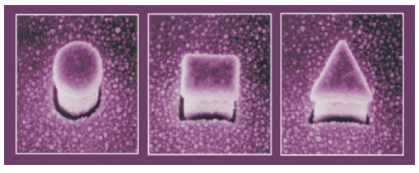


Snail neuron grown on a chip that records the neuron's activity

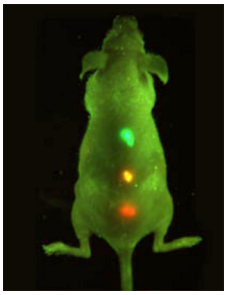
Source: http://www.biochem.mpg.de/mnphys/publications/05voefro/abstract.html

Health Care: Detecting Diseases Earlier

- **Quantum dots glow in UV light**
  - Injected in mice, collect in tumors
  - Could locate as few as 10 to 100 cancer cells



Quantum Dots: Nanometer-sized crystals that contain free electrons and emit photons when submitted to UV light

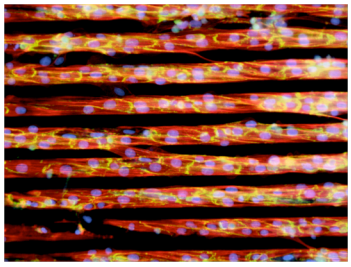


Early tumor detection, studied in mice

Sources: http://vortex.tn.tudelft.nl/grkouwen/qdotsite.html
http://www.whitaker.org/news/nie2.html

Health Care: Growing Tissue to Repair Hearts

- **Nanofibers help heart muscle grow in the lab**
  - Filaments 'instruct' muscle to grow in orderly way
  - Before that, fibers grew in random directions

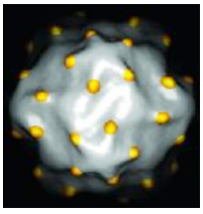


Cardiac tissue grown with the help of nanofiber filaments

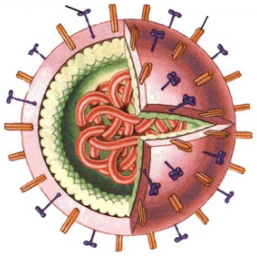
Source: http://www.washington.edu/admin/finmgmt/annrpt/mcdevitt.htm

Health Care: Preventing Viruses from Infecting Us

- **Nanocoatings over proteins on viruses**
  - Could stop viruses from binding to cells
  - Never get another cold or flu?



Gold tethered to the protein shell of a virus

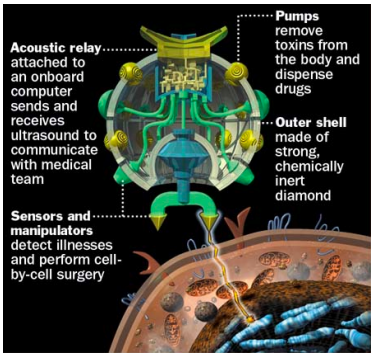


Influenza virus: Note proteins on outside that bind to cells

Sources: http://www.zephyr.dti.ne.jp/~john8tam/main/Library/influenza_site/influenza_virus.jpg
http://pubs.acs.org/cen/topstory/8005/8005notw2.html

Health Care: Making Repairs to the Body

- **Nanorobots are imaginary, but nanosized delivery systems could…**
  - Break apart kidney stones, clear plaque from blood vessels, ferry drugs to tumor cells



Source: http://www.genomenewsnetwork.org/articles/2004/08/19/nanorobots.php

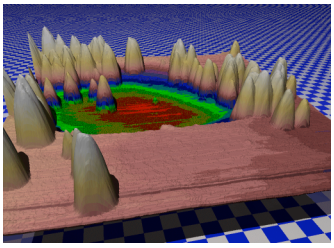
Pause to Consider

How delicate are nanoscale-sized objects?

How well do we understand the environmental and health impacts of nanosized clusters of particles?

Nanodevices Are Sensitive!

- **Radiation particles can cause fatal defects**
  - Development requires very clean environments
  - Redundant copies compensate for high defect rate



Pit created by nuclear radiation (an alpha particle) hitting a mica surface

Sources: http://www.nanopicoftheday.org/2004Pics/February2004/AlphaRecoil.htm
http://www.trnmag.com/Stories/2004/090804/Nano_memory_scheme_handles_defects_Brief_090804.html

Potential Risks of Nanotechnology

- **Health issues**
  - Nanoparticles could be inhaled, swallowed, absorbed through skin, or deliberately injected
  - Could they trigger inflammation and weaken the immune system? Could they interfere with regulatory mechanisms of enzymes and proteins?
- **Environmental issues**
  - Nanoparticles could accumulate in soil, water, plants; traditional filters are too big to catch them
- **New risk assessment methods are needed**
  - National and international agencies are beginning to study the risk; results will lead to new regulations

Summary: Science at the Nanoscale

- **An emerging, interdisciplinary science**
  - Integrates chemistry, physics, biology, materials engineering, earth science, and computer science
- **The power to collect data and manipulate particles at such a tiny scale will lead to**
  - New areas of research and technology design
  - Better understanding of matter and interactions
  - New ways to tackle important problems in healthcare, energy, the environment, and technology
  - A few practical applications now, but most are years or decades away

Applications of Nanoscience Slides: Teacher Notes

Overview

This series of slides introduces students to some of the areas thought to have great potential for impact on our lives through nanotechnology innovations. Example applications and references for further information are provided. *Don't feel that you need to show all of these slides*. Show the ones that you think will most interest and reach your particular students.

Slide 1: Applications of Nanoscience

Explain to students that you're going to present several examples of how new innovations in nanotechnology might impact our lives.

Slide 2: Potential Impact of Nanotechnology

Point out that tools for manipulating materials are becoming more sophisticated and improving our understanding of how atoms and molecules can be controlled. This will lead to significant improvements in materials, and, in turn, to new products, applications, and markets that could have revolutionary impact on our lives.

This presentation will focus on innovations related to nano materials, the environment, technology, and healthcare. A few of these products being commercialized now, but most are in research labs or are envisioned for the distant future.

References:

- Nanotechnology now – Current uses: http://www.nanotech-now.com/current-uses.htm
- Nanoscale Science and Engineering Center: http://www.mos.org/cst/section/2.html
- Book: "The Next Big Thing Is Really Small: How Nanotechnology Will Change The Future Of Your Business" by Jack Uldrich and Deb Newberry (2003)

Slide 3: Materials: Stain Resistant Clothes

Manufacturers are embedding fine-spun fibers into fabric to confer stain resistance on khaki pants and other products. These "nanowhiskers" act like peach fuzz and create a cushion of air around the fabric so that liquids bead up and roll off. Each nanowhisker is only ten nanometers long, made of a few atoms of carbon. To attach these whiskers to cotton, the cotton is immersed in a tank of water full of billions of nanowhiskers. Next, as the fabric is heated and water evaporates, the nanowhiskers form a chemical bond with cotton fibers, attaching themselves permanently. The whiskers are so tiny that if the cotton fiber were the size of a tree trunk, the whiskers would look like fuzz on its bark.

Nano-resistant fabric created by NanoTex is already available in clothing available in stores like Eddie Bauer, The Gap, and Old Navy. This innovation will impact not only khaki wearers, but also dry cleaners who will find their business declining, and detergent makers who will find less of their project moving off the shelf.

References:

- Fancy pants: http://www.sciencentral.com/articles/view.php3?article_id=218391840&cat=3_5
- NanoTex lab activity: http://mrsec.wisc.edu/Edetc/IPSE/educators/activities/nanoTex.html

Slide 4: Materials: Paint That Doesn't Chip

Nanopaints are ceramic based coatings that make the paint a lot more durable and resistant to rock chips and scratches. In addition to holding up better to weathering, nanopaints have richer and brighter colors than traditional pigments. In the future, nanopaints may also even change color

References:

- Mercedes-Benz Nano Paint (3 page article on benefits, material, and paint process): http://www.auto123.com/en/info/news/news,view.spy?artid=21942&pg=1

Slide 5: Environment: Paint That Cleans Air

Chinese scientists have announced that they have invented nanotech-based coating material that acts as a permanent air purifier. If the coating proves to be effective at air cleaning, it will be gradually used on buildings to improve air quality. The core of the material is a titanium-dioxide-based compound developed using advanced nanotechnology. Exposed under sunlight, the substance can automatically decompose ingredients like formaldehyde that cause air pollution.

References:

- Paint to help clean and purify the air: http://english.eastday.com/eastday/englishedition/metro/userobject1ai710823.html

Slide 6: Environment: Nano Solar Cells

Enough energy from the sun hits the earth every day to completely meet all energy needs on the planet, if only it could be harnessed. Doing so could wean us off of fossil fuels like oil and provide a clean energy alternative. But currently, solar-power technologies cost as much as 10 times the price of fossil fuel generation. Chemists at U.C. Berkeley are developing nanotechnology to produce a photovoltaic material that can be spread like plastic wrap or paint. These nano solar cells could be integrated with other building materials, and offer the promise of cheap production costs that could finally make solar power a widely used electricity alternative.

Current approaches embed nanorods (bar-shaped semiconducting inorganic crystals) in a thin sheet (200 nanometers deep) of electrically conductive polymer. Thin layers of an electrode sandwich these nanorod-polymer composite sheets. When sunlight hits the sheets, they absorb photons, exciting electrons in the polymer and the nanorods, which make up 90 percent of the composite. The result is a useful current that is carried away by

the electrodes. Eventually, nanorod solar cells could be rolled out, ink-jet printed, or even painted onto surfaces, so that even a billboard on a bus could be a solar collector.

References:

- Painting on solar cells: http://www.californiasolarcenter.org/solareclips/2003.01/20030128-6.html
- Cheap, plastic solar cells may be on the horizon: http://www.berkeley.edu/news/media/releases/2002/03/28_solar.html
- New nano solar cells to power portable electronics: http://www.californiasolarcenter.org/solareclips/2002.04/20020416-7.html

Slide 7: Technology: A DVD That Could Hold a Million Movies

In 1959, Richard Feynman asked if we could ever shrink devices down to the atomic level. He couldn't find any laws of physics against it. He calculated that we could fit all printed information collected over the past several centuries in a 3-dimensional cube smaller than the head of a pin. How far have we come? A 2-dimensional version of Feynman's vision is in research labs. The picture on this slide illustrates the potential of nano-devices for data storage. On the left are images of two familiar data storage media: the CD-ROM and the DVD. On the right is a self-assembled memory on a silicon surface, formed by depositing a small amount of gold on it. It looks like CD media, except that the length scale is in nanometers, not micrometers. So the corresponding storage density is a million times higher! The surface automatically formats itself into atomically-perfect stripes (red) with extra atoms on top (white). These atoms are neatly lined up at well-defined sites along the stripes, but occupy only about half of them. It is possible to use the presence of an atom to store a 1, and the absence to store a 0. The ultimate goal would be to build a data storage medium that needs only a single atom per bit. The big question is how to write and read such bits efficiently.

References:

- Franz J. Himpsel's web site: http://uw.physics.wisc.edu/~himpsel/nano.html
- R. Bennewitz et al., "Atomic scale memory at a silicon surface" Nanotechnology 13, 499 (2002)

Slide 8: Technology: Building Smaller Devices and Chips

A technique called nanolithography lets us create much smaller devices than current approaches. For example, the Atomic Force Microscope (AFM) nanolithography image of the Mona Lisa was created by a probe oxidation technique. This technique can be used to further miniaturize the electrical components of microchips. Dip pen nanolithography is a 'direct write' technique that uses an AFM to create patterns and to duplicate images. "Ink" is laid down atom by atom on a surface, through a solvent—often water.

References:

- AFM Oxidation nanolithography http://www.ntmdt.ru/SPM-Techniques/Principles/Lithographies/AFM_Oxidation_Lithography_mode37.html
- Dip pen nanolithography: http://www.chem.northwestern.edu/~mkngrp/dpn.htm

Slide 9: Health Care: Nerve Tissue Talking to Computers

Researchers are studying the electrical interfacing of semiconductors with living cells—in particular, neurons—to build hybrid neuro-electronic networks. Cellular processes are coupled to microelectronic devices through the direct contact of cell membranes and semiconductor chips. For example, electrical interfacing of individual nerve cells and semiconductor microstructures allow nerve tissue to directly communicate their impulses to computer chips. Pictured is a snail neuron grown on a CMOS chip with 128x128 transistors. The electrical activity of the neuron is recorded by the chip, which is fabricated by Infineon Technologies. This research is directed (1) to reveal the structure and dynamics of the cell-semiconductor interface and (2) to build up hybrid neuro-electronic networks. Such research explores the new world at the interface of the electronics in inorganic solids and the ionics in living cells, providing the basis for future applications in medical prosthetics, biosensorics, brain research and neurocomputation.

References:

- Nanopicture of the day from Peter Fromherz: http://www.nanopicoftheday.org/2003Pics/Neuroelectronic%20Interface.htm
- Max Planck research: http://www.biochem.mpg.de/mnphys/

Slide 10: Health Care: Detecting Diseases Earlier

Quantum dots are small devices that contain a tiny droplet of free electrons, and emit photons when submitted to ultraviolet (UV) light. Quantum dots are considered to have greater flexibility than other fluorescent materials, which makes them suited for use in building nano-scale applications where light is used to process information. Quantum dots can, for example, be made from semiconductor crystals of cadmium selenide encased in a zinc sulfide shell as small as 1 nanometer (one-billionth of a meter). In UV light, each dot radiates a brilliant color.

Because exposure to cadmium could be hazardous, quantum dots have not found their way into clinical use. But they have been used as markers to tag particles of interest in the laboratory. Scientists at Georgia Institute of Technology have developed a new design that protects the body from exposure to the cadmium by sealing quantum dots in a polymer capsule. The surface of each capsule can attach to different molecules. In this case, they attached monoclonal antibodies directed against prostate-specific surface antigen, which is found on prostate cancer cells. The researchers injected these quantum dots into live mice that had human prostate cancers. The dots collected in the tumors in numbers large enough to be visible in ultraviolet light under a microscope. Because the dots are so small, they can be used to locate individual molecules, making them extremely sensitive as detectors. Quantum dots could improve tumor imaging sensitivity tenfold with the ability to locate as few as 10 to 100 cancer cells. Using this technology, we could detect cancer much earlier, which means more successful, easier treatment.

References:

- Quantum dots introduction: http://vortex.tn.tudelft.nl/grkouwen/qdotsite.html
- Lawrence Livermore Labs work in quantum dots: http://www.llnl.gov/str/Lee.html

- Quantum dots light up prostate cancer: http://www.whitaker.org/news/nie2.html

Slide 11: Health Care: Growing Tissue to Repair Hearts

Cardiac muscle tissue can be grown in the lab, but the fibers grow in random directions. Researchers at the University of Washington are investigating what type of spatial cues they might give heart-muscle cells so that they order themselves into something like the original heart-muscle tissue. Working with one type of heart muscle cell, they have been able to build a two-dimensional structure that resembles native tissue. They use nanofibers to "instruct" muscle cells to orient themselves in a certain way. They have even able to build a tissue-like structure in which cells pulse or 'beat' similar to a living heart.

This image on this slide shows cardiac tissue grown with the aid of nanofiber filaments. It displays well-organized growth that is potentially usable to replace worn out or damaged heart tissue. The ultimate goal of building new heart-muscle tissue to repair and restore a damaged human heart is a long way off, but there have been big advances in tissue engineering in recent years.

References:

- University of Washington cardiac muscle work: http://www.washington.edu/admin/finmgmt/annrpt/mcdevitt.htm

Slide 12: Health Care: Preventing Viruses from Infecting Us

If we could cover the proteins that exist on the influenza virus, we could prevent the virus from recognizing and binding to our body cells. We would never get the flu! A protein recognition system has already been developed. More generally, this work suggests that assembled virus particles can be treated as chemically reactive surfaces that are potentially available to a broad range of organic and inorganic modification.

References

- Virus nanoblocks: http://pubs.acs.org/cen/topstory/8005/8005notw2.html

Slide 13: Health Care: Making Repairs to the Body

The image on this slide depicts what one nanoscientist from the Foresight Institute imagines might be possible one day in the far future. It shows how a nanorobot could potentially interact with human cells. When people hear of nanotechnology from science fiction, this is often the form that it takes. But we may not know for decades whether such a probe is even possible. But if they are developed someday, they could be used to maintain and protect the human body against pathogens. For example, they could (1) be used to cure skin diseases (embedded in a cream, they could remove dead skin and excess oils, apply missing oils), (2) be added to mouthwash to destroy bacteria and lift plaque from the teeth to be rinsed away, (3) augment the immune system by finding and disabling unwanted bacteria and viruses, or (4) nibble away at plaque deposits in blood vessels, widening them to prevent heart attacks.

References:

- Nanorobots: medicine of the future: http://www.ewh.ieee.org/r10/bombay/news3/page4.html
- Robots in the body: http://www.genomenewsnetwork.org/articles/2004/08/19/nanorobots.php
- Drexler and Smalley make the case for and against molecular assemblers http://pubs.acs.org/cen/coverstory/8148/8148counterpoint.html

Slide 14: Pause to Consider

The next 2 slides focus on the delicate nature of nanosized objects, the potential risks of nanotechnology to humans and the environment, and the need study the risks and regulate the development of products that contain nanoparticles.

Slide 15: Nanodevices Are Sensitive!

Because of their small size, nanodevices are very sensitive and can easily be damaged by the natural environmental radiation all around us. In the picture for this example, we see a pit caused by an alpha particle hitting the surface of mica. An alpha particle is a high-energy helium nucleus that is the lowest-energy form of nuclear radiation. Alpha particles are also the particles that Rutherford used for the gold foil experiment in which he discovered the arrangement of protons within the atom that is now commonly known as the nucleus. The impact of alpha particles on a solid surface can cause physical damage by causing other atoms in the surface to be moved out of place. These types of defects can be potentially fatal in high-density electronics and nanodevices. To compensate, extremely clean manufacturing environments and very high redundancy—perhaps millions of copies of nanodevices for a given application—are required.

References:

- Fei and Fraundorf on Alpha recoil pits: http://www.nanopicoftheday.org/2004Pics/February2004/AlphaRecoil.htm
- Nano memory scheme handles defects: http://www.trnmag.com/Stories/2004/090804/Nano_memory_scheme_handles_defects_Brief_090804.html

Slide 16: Potential Risks of Nanotechnology

Nanotechnology's potential is encouraging, but the health and safety risks of nanoparticles have not been fully explored. We must weigh the opportunities and risks of nanotechnology in products and applications to human health and the environment. Substances that are harmless in bulk could assume hazardous characteristics because when particles decrease in size, they become more reactive. A growing number of workers are exposed to nanoparticles in the workplace, and there is a danger that the growth of nanotechnology could outpace the development of appropriate safety precautions. Consumers have little knowledge of nanotechnology, but worries are already beginning to spread. For example, environmental groups have petitioned the Food and Drug Administration to pull sunscreens from the market that have nano-size titanium dioxide and zinc oxide particles. As nanotechnology continues to emerge, regulatory

agencies must develop standards and guidelines to reduce the health and safety risks of occupational and environmental nanoparticle exposure.

References:

- Risks of nanotechnology: http://en.wikipedia.org/wiki/Nanotechnology
- Overview of nanotechnology: Risks, initiatives, and standardization: http://www.asse.org/nantechArticle.htm

Slide 17: Summary: Science at the Nanoscale

Nanoscience is an emerging science that will change our understanding of matter and help us solve hard problems in many areas, including energy, health care, the environment, and technology. With the power to collect data and to manipulate particles at such a tiny scale, new areas of research and technology design are emerging. Some applications—like stain resistant pants and nanopaint on cars—are here today, but most applications are years or decades away. But nanoscience gives us the potential to understand and manipulate matter more than ever before.

Nanoscience is truly an interdisciplinary science. Progress in nanoscale science and technology results from research involving various combinations of biology, chemistry, physics, materials engineering, earth science, and computer science. Nanoscience also provides a way to revisit the core concepts from these domains and view them through a different lens. Learning about nanoscience can support understanding of the interconnections between the traditional scientific domains and provide compelling, real-world examples of science in action.

What's New Nanocat? Poster Session: Teacher Instructions & Rubric

Summary

Students will work in pairs to create a poster that compares a current technology with a related, new nanotechnology application. A list of applications (including references) to choose from will be provided to the students. The list is based on applications that have been mentioned or discussed in class or in associated readings (e.g., nanotubes as stronger tethers, nano solar cells as omnipresent collectors, stain-resistant nanopants).

The student will assume the role of a scientist working on the new nanotechnology application, and explain the proposed usage of the new technology in a poster session. The student will produce a poster showing a current technology and how it is used; a new, related nanotechnology and how it is proposed to be used; how the new nanotechnology works; and how the new nanotechnology will help improve understanding or solve a problem.

The posters will be displayed in class and the students will explain the technology by explaining the poster. This could be done in a science fair type arrangement or in class as a presentation. The presentation must include diagrams along with written descriptions to help someone gain a better understanding of the science. It can also optionally include animations.

Time Frame: 2-3 hours to create posters, 1 hour for poster session

Criteria for Evaluation

The poster will be graded based on a rubric. The student's discussion and answers to questions during the poster session will influence the grade. The students must demonstrate understanding of the technology s/he is explaining.

Relevant Learning Goals

- Nanoscience is an emerging science that could vastly change our understanding of matter and lead to new questions and answers in many areas, including health care, the environment, and technology.
- Nanotechnology focuses on manipulating matter at the nanoscale to create structures that have novel properties or functions.

Required Resources

- List of applications from which students can choose their poster topic.
- Access to the Web to research the technologies, find relevant diagrams, etc.
- Optional use of ChemSense to create diagrams or animations to illustrate how the technologies work
- Optional access to PowerPoint or other slide creation tool for creating poster pages
- If posters are to be displayed in the classroom, access to posterboard, paper, and printer, and glue or tape are required.

Rubric for NanoCat Poster Evaluation

	Novice (1) Absent, inaccurate, or confused	Apprentice (2) Partially developed	Skilled (3) Adequately developed	Masterful (4) Fully developed
Written explan-ations	Shows little understanding or major misunderstanding of ideas or processes. Concepts, data, and arguments are inadequate. Many grammatical errors.	Shows limited understanding or misunderstanding of key ideas. Concepts, data, and arguments are simple or somewhat inadequate. Some grammar errors.	Shows a solid understanding of ideas, no misunderstanding of key ideas. Concepts, data, arguments are appropriate. Grammar is mostly correct.	Shows clear, complete, and sophisticated understanding of ideas, advanced beyond the grasp usually found at this age. Easy to read, with correct grammar.
Graphic explan-ations	Shows little understanding of processes, or inadequate for addressing the application.	Shows limited understanding of ideas. Graphics are crude, simple, or reveal a key misunderstanding.	Shows solid understanding. Graphics show no misunderstanding of key ideas, are not overly simple.	Shows clear, complete, and sophisticated understanding of ideas and processes.
Accuracy and Research	Misunderstanding of nanoscience is evident in inaccurate explanations or science-fiction-like ideas presented as facts. Demonstrates little or no research.	Limited understanding is evident by some inaccurate or simple explanations, or futuristic ideas confused with fact. Demonstrates average research.	Shows solid understanding with clear explanations with sound scientific basis, no clear inaccuracies. Demonstrates solid research.	Shows sophisticated understanding based on current facts and scientific theory, and futuristic ideas presented as such. Demonstrates extensive research.
Attract-iveness	Distractingly messy or bad design.	Somewhat organized, acceptable design, but messy.	Solid organization, with good design, layout, and neatness.	Sophisticated presentation that is well organized and neat, with good design and layout.
Attribu-tion	Diagrams and text do not have any source citations.	More than two diagrams and text do not have source citations.	All but one or two diagrams and text have source citations.	All text and borrowed diagrams have source citations.
Oral Team Present-ation	Most members did not participate, communication was unclear, hard to hear, little eye contact, answered few questions.	Few members participated, communication was somewhat unclear, answered half of audience questions well.	Most members participated, communicated clearly, answered most audience questions reasonably well.	All team members participated, communicated clearly, kept eye contact, and answered audience questions well.