Teacher's Notes

Nanobiotechnology

Overview

Nano is a prefix that means "one-billionth." The nanometer is one-billionth of a meter — much too small to see with the naked eye or even with a conventional light microscope. **Nanotechnology** involves creating and manipulating materials at the nano scale. This is a relatively new area for researchers, with rapidly growing commercial applications. By the end of 2011 there were more than 1,300 consumer products using some form of nanotechnology. Nano**bio**technology is biotechnology at the nano scale, and it has exciting applications in drug delivery systems, diagnostic medical tests and regenerative medicine. North Carolina universities and companies are developing many new nanobiotechnology applications.

The goal of this chapter is to help students understand the science concepts on which nanobiotechnology is based and explore some of the many career possibilities in this exciting field. It also is intended to provide a snapshot of some of the leading nanobiotechology research and manufacturing efforts in North Carolina. However, it is not intended to be a comprehensive summary. For a broader overview of nanobiotechnology efforts throughout the state, please refer to NCNanotechnology.com, a website created and maintained by the North Carolina Board of Science and Technology.

Alignment with Standards

Biology Objectives from the Essential Standards

Bio.1.1: Understand the relationship between the structures and functions of cells and their organelles.

- **Bio.1.1.1:** Summarize the structure and function of organelles in eukaryotic cells (including the nucleus, plasma membrane, cell wall, mitochondria, vacuoles, chloroplasts and ribosomes) and ways these organelles interact with each other to perform the function of the cell.

(Relate to nanobiotechnology through understanding of how nanoparticles may be used as drug delivery devices targeting particular cells.)

Bio.3.3: Understand the application of DNA technology.

- **Bio.3.3.1:** Interpret how DNA is used for comparison and identification of organisms.

(Relate to nanobiotechnology through understanding of how nanoparticles may be used as drug delivery devices targeting particular cells.)

Nanobiotechnology (continued)

AP Biology Themes and Topics

Themes	Topics
Relationship of Structure to Function	Cells • Subcellular organization
Science as a Process	Molecular Genetics • Nucleic acid technology and applications
Science, Technology and Society	Structure and Function of Plants and Animals • Reproduction, growth and development

Biomedical Technology Objectives from 2004 Course Blueprint

BT01.00: Interpret biomedical prefixes, suffixes, root words and abbreviations.
- **BT01.01:** Identify biomedical word roots, prefixes, suffixes and abbreviations.
- **BT01.02:** Combine word elements to form words commonly used in biomedical technology.

BT02.00: Analyze biomedical ethics and legal principles.
- **BT02.02:** Analyze the ethical principles of biomedical technology.

BT04.00: Analyze mathematical concepts in health care.
- **BT04.01:** Calculate weights, heights and volume in metric units of measure.
- **BT04.02:** Convert among metric measures and standard measures.

BT09.00: Evaluate careers and techniques that use biomedical technology.
- **BT09.01:** Investigate laboratory careers.
- **BT09.02:** Discuss imaging careers and technology.
- **BT09.04:** Outline biotechnology careers and genetics.
- **BT09.05:** Evaluate the importance of biomedical technology in a chosen health career.

Teacher's Notes

Nanobiotechnology (continued)

BT10.00: Analyze biomedical research.

- **BT10.01:** Discuss biomedical research.
- **BT10.02:** Outline biomedical research methods.
- **BT10.03:** Analyze the benefits of biomedical research.

BT11.00: Analyze challenges to biomedical research.

- **BT11.01:** Interpret personal beliefs about biomedical research.
- **BT11.03:** Evaluate therapeutic versus reproductive cloning.
- **BT11.04:** Debate pros and cons of animal research and animal rights.

BT12.00: Analyze current issues in biomedical technology.

Key Vocabulary

- **Nano** is a prefix meaning "one-billionth", or 10^{-9}.
- **Nanobiotechnology** is biotechnology at the nanoscale. It includes the application of the tools and processes of nanotechnology to study and manipulate biological systems.
- **Physical properties** are properties of a material that can be measured without changing the composition of the material. Examples of physical properties are color, density and boiling temperature.
- **Chemical properties** are the properties that describe how a substance will interact with other substances. Examples of chemical properties are flammability and solubility.
- **Materials characterization** is analyzing the structure and properties of a material.
- **Bioaccumulation** is the buildup of a chemical in the tissue of organisms because they take it in faster than they can get rid of it.
- **Biomagnification** is the process in which the concentration of a contaminant increases as it passes up the food chain.
- **Photolithography** is a process to transfer patterns and make layered materials using photosensitive substances and selective light exposure.
- A **cleanroom** is a space designed specifically to keep all airborne particles out.

Nanobiotechnology

Overview of Emerging Nanobiotechnology Field

Imagine cancer drugs that travel through the body attacking only cancer cells. Imagine bandages that release special particles to stop bleeding and infection. Imagine safer cheaper vaccines and faster, cheaper, more sensitive blood tests for common diseases. Imagine hospital bed sheets that prevent bedsores. Researchers working in the emerging field of nanobiotechnology are currently developing all of these and more. But, what exactly is nanobiotechnology? What does it mean for North Carolina? What implications does it have for your future? In this chapter, we will explore these questions and look at some exciting new applications of nanobiotechnology.

In their 2003 book *The Next Big Thing is Really Small*, Deb Newberry and Jack Uldrich define nanotechnology as “the willful manipulation of matter at the atomic level to create better and entirely new materials, devices, and systems.” (p. 12) The National Nanotechnology Initiative (United States National Nanotechnology Initiative, n.d.) defines nanotechnology as “the understanding and control of matter at dimensions between approximately 1 and 100 nanometers (nm), where unique phenomena enable novel applications not feasible when working with bulk materials or even with single atoms or molecules.”

What these definitions have in common is the “nano” — a metric system prefix meaning one-billionth — and new technologies that allow people to manipulate materials at the level of atoms and molecules. These technologies are being used in new and exciting applications in many different fields, including medicine, textiles, computer chip manufacturing and environmental remediation. Nanobiotechnology applies the tools and processes of nanotechnology to build devices for studying and manipulating biosystems. This has applications in many fields but is particularly relevant to the field of medicine. Three areas in medicine already being transformed by nanobiotechnology are: (1) drug delivery systems, (2) diagnostic tests and (3) biocompatible coatings for implants, such as replacement joints.

Nanobiotechnology (continued)

Nanobiotechnology in North Carolina

North Carolina is a global leader in nanobiotechnology, with universities and industry focused on nanoscience research and applications. A recent report (Klaus, Faulconer, & Adams, 2011) lists 35 nanobiotechnology companies, 70 nanotechnology companies and 35 university research centers focused on nanobiotechnology in North Carolina. Universities increasingly collaborate with industry to do innovative research in developing products and technologies and are leading the way in investigating environmental and public health concerns associated with nanomaterials. North Carolina has educational programs at all levels, from informal education at museums and science centers to community college, masters degree and Ph.D. programs. In addition, courses and programs in many other disciplines are incorporating nanotechnology skills to prepare students to work in the many fields that will use this emerging technology. These disciplines include engineering, textiles, biology and chemistry.

Background Science

Nanomaterials and Properties of Matter

"Nano" is a prefix that means "one-billionth." The nanometer is one-billionth of a meter, or 10^{-9} meters. It is abbreviated "nm." A red blood cell is between 6,000 and 10,000 nanometers in diameter. A ribosome is approximately 30 nanometers long. The width of a DNA molecule is about 3 nanometers. Nanoscale scientists are interested in studying and manipulating materials and systems at this scale.

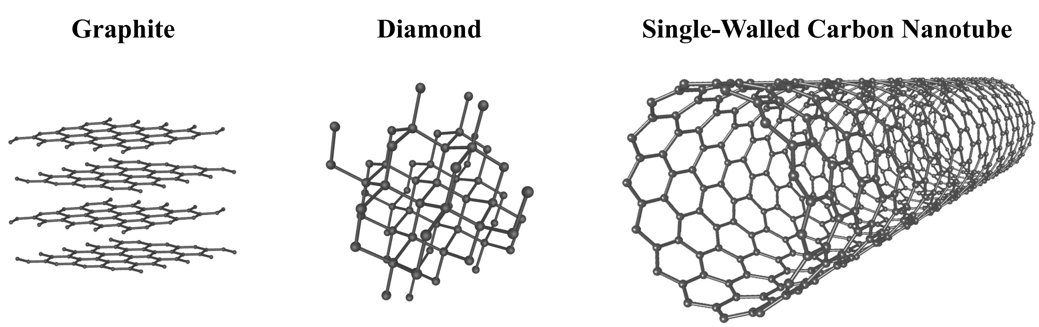
In earlier science courses, you may have learned that matter is made up of atoms and molecules with physical and chemical properties. These properties are determined by the type and arrangement of atoms and molecules. **Physical properties** can be measured without changing the composition of the material. The boiling and freezing temperatures of water are physical properties. This means you can measure these temperatures without changing the water into a different chemical. **Chemical properties** refer to how the material will interact with other materials. Many of the chemical and physical properties of water are determined by its polar structure — the oxygen end has a slight negative charge, while the two hydrogen ends are slightly positive. This polar structure

Nanobiotechnology (continued)

gives water many special properties, including the ability to dissolve many other substances.

Materials composed of the same atoms and molecules may have different properties depending on their arrangement at the nanoscale. Many factors can affect these properties. Snowflakes are a familiar example with structure determined at the nanoscale. Snowflakes are a type of ice formation whose nearly infinite variety of individual shapes can be categorized as needles, hollow columns, prisms or plates. These shapes are determined by the shape of the dust mote the flake forms on, temperature, the water vapor in the air and the amount and orientation of the water molecules added to each flake during its assembly. Even though each water molecule is the same, the many individual shapes are formed by nanoscale interactions of the water molecules as the snowflake forms.

In the case of snowflakes, the chemical structure of the water molecules remains the same even as different flake shapes are formed. However, other materials may have the same chemical formula but a different chemical bonding structure. Consider the differences between graphite, diamonds and carbon nanotubes. All are composed solely of carbon atoms, but their different chemical bonding structures lead to very different chemical and physical properties. This, in turn, leads to very different uses for these materials



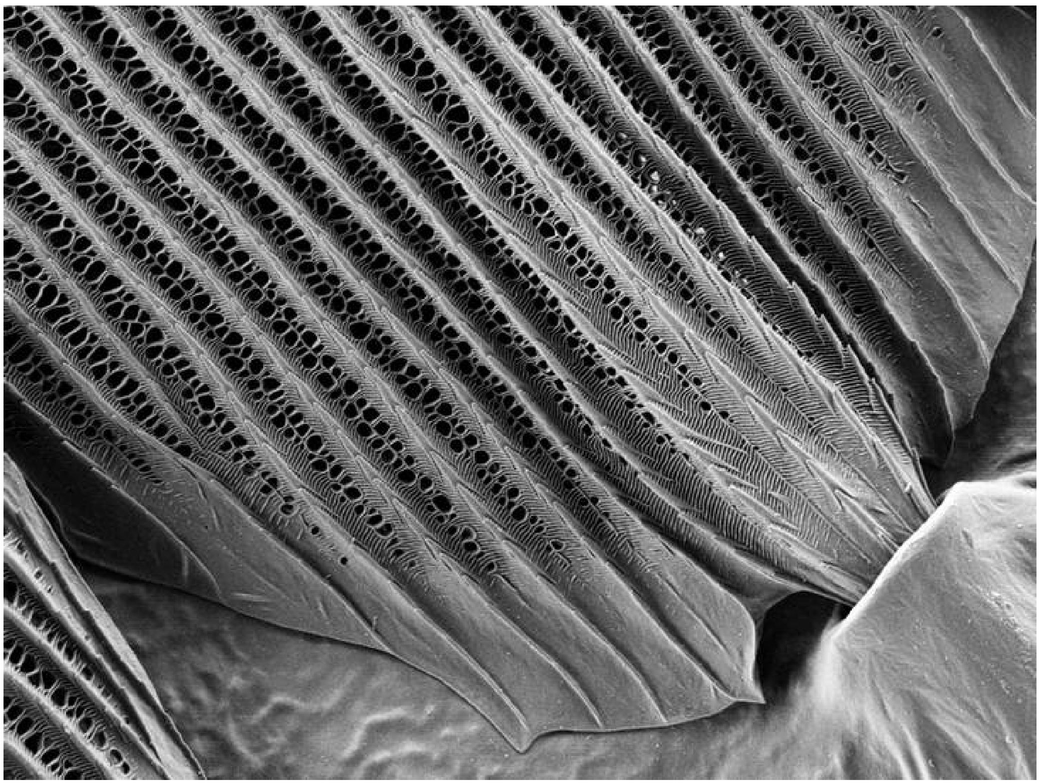
Examples of different molecular configurations that carbon atoms can form.

Image Credit: Michael Ströck / Wikipedia

Glucose, the main fuel for most cellular respiration, also comes in several different forms. The molecules of each form are made of the same atoms: $C_6H_{12}0_6$ (6 carbon atoms, 12 hydrogen atoms, 6 oxygen atoms). However, the atoms are oriented differently in the different forms, changing their biological

Nanobiotechnology (continued)

properties. The main form used by your body and most other organisms is D-glucose, also known as dextrose. It has a stereoisomer called L-glucose. Stereoisomers have the same atoms, bonded in the same order, but forming structures that are mirror images. Just as your right hand is different and not interchangeable with your left hand, the right-handed form of glucose is not interchangeable with the left-handed form. Enzymes in the digestive system can only catalyze the breakdown of the right-handed form. This is an example of structure determining function at the molecular level.



Scales on the wings of some butterflies are examples of structural colors found in nature. As opposed to chemical colors, such as pigments, structural colors are formed through the diffraction of light off small features — such as those between the ridges on the scales of a butterfly wing. (This image has been magnified 2,550 times.)

Image Credit: Adam Boseman / University of North Carolina at Greensboro

Nanobiotechnology (continued)

Characterizing Materials

An important task of nanoscale scientists and technicians is to characterize materials at the nanoscale. This task involves analyzing the structure and properties of the material to understand how the material will work in various applications. **Characterization** is important for the fundamental understanding of materials as well as improving the quality of manufactured goods. In a manufacturing setting such as a factory, characterization is used to check the quality of incoming raw materials and the results of each step of the manufacturing process to detect and eliminate problems. Characterization starts with looking at the material. However, nanoscale structures are much too small to be seen with the naked eye or even with a light microscope. Instead, nanotech researchers use specialized tools such as scanning probe microscopes, atomic force microscopes and helium-ion microscopes. Each tool has advantages and disadvantages. *(See the Tools and Techniques section below.)*

Fabricating Materials

In addition to characterizing materials, an important goal of nanotechnology is to make new materials with special properties. Approaches to fabrication at the nanoscale are categorized as "top-down" or "bottom-up." **Top-down** methods start with existing materials and shape them at the nanoscale. This technique is similar to many current macro production techniques in the assembly line factory.

An example of a top-down nano technique is **photolithography**, where a photosensitive substance is painted onto an underlying substrate such as a silicon wafer (in the case of a computer chip production). Selective light exposure then is used to transfer a pattern to the material. Next, either the negative or the positive part of the pattern can be etched away by a developer solution and replaced with another material. This process can be repeated multiple times to make layered materials. This is how integrated circuits, which are found inside computers, are built into silicon wafers.

Bottom-up methods of nanofabrication use the natural properties of molecules and their tendency to organize themselves according to their charge and other features. These approaches often involve self-assembly of materials, as in the snowflake example. In nature, molecules are always moving. Building on an extensive knowledge base in chemical synthesis, nanoscale structures are built by creating the right conditions for these moving molecules to self-assemble into the desired structure.

Nanobiotechnology (continued)

Tools and Techniques

One challenge of working at the nanoscale is how to prevent contamination of the materials being characterized or fabricated. Because the scale is so small, even the tiniest particles present a threat. **Cleanrooms** are special facilities designed to keep airborne particles out. They can be small laboratories or large manufacturing facilities. Air entering and circulating within a cleanroom is constantly filtered to remove particles. People wear special clothing to keep particles from their skin and clothes from contaminating the air. They must enter the cleanroom through special airlocks that keep particles out. Special cleaning procedures, training for all staff and ongoing vigilance are required to maintain each cleanroom at its designated low level of airborne particulates.

Special instruments are needed for characterizing and manipulating materials at the nanoscale. Ordinary light microscopes are limited by the wavelength of light and cannot resolve objects smaller than about 200 nm. Therefore, nanoscience depends on new, more powerful imaging techniques including scanning probe microscopes and helium ion microscopes. There are many types of scanning probe microscopes in use, including scanning tunneling microscopes and atomic force microscopes. Atomic force microscopes scan the surface of an object with a probe that comes to a sharp point and respond to changes in the forces exerted by the surface being scanned. Their resolution allows imaging of features smaller than a nanometer in size. Some of these microscopes can be used to view samples in air or water, which makes them useful for biological material, including living organisms. The helium ion microscope is similar to a scanning electron microscope except that it aims a sharp beam of helium ions rather than electrons at a surface. This causes emission and scattering of electrons from the surface. These secondary electrons are then used to create an image of the surface. Because all these instruments are measuring tiny forces, they are very sensitive to vibrations. Specially constructed rooms are used to provide a stable environment, and the sample scanning is controlled by a computer.

Concerns About Nano

One of the concerns people have about nanotechnology is the possibility of producing new kinds of particles that were not previously found in nature, with negative biological effects. Nanoparticles are so small and potentially

Nanobiotechnology (continued)

so reactive that they may be able to enter and react with cells in ways that larger particles of the same substance would not. Furthermore, nanoparticles are being manufactured into more consumer products, which eventually break down and release the nanoparticles. These particles will then accumulate in the environment and may **bioaccumulate** in organisms. Then, as the particles enter various food webs, they may **biomagnify** and potentially build up to toxic levels as they move up the food chain. One example of a potential problem is the release of silver nanoparticles. Silver nanoparticles frequently are used to make antibacterial products such as clothing and food containers. The particles are gradually released into the environment as the products are used, washed and eventually discarded. Researchers are finding that silver nanoparticles can cause dangerous changes in soil bacteria populations, reducing the population of bacteria that fix atmospheric nitrogen. These bacteria convert atmospheric nitrogen into ammonia and other nitrogen compounds that can be used by plants. Without these bacteria, the soil becomes infertile.

Another potential problem is the titanium dioxide nanoparticles found in sunscreen. When these products gradually wash off swimmers and bathers, the nanoparticles accumulate in the water supply, where they may affect aquatic food chains. Titanium dioxide nanoparticles have been shown to cause nerve cell damage in fish. Other researchers are studying the effects of manufactured nanoparticles on lung health.

A growing number of universities and government agencies are developing research programs to assess these threats to human and ecosystem health. The Center for the Environmental Implications of Nano Technology at Duke University, in Durham, N.C., is studying all types of nanomaterials, how they are released and spread in the environment, and their impact on ecosystems. The National Institute of Environmental Health Sciences (NIEHS), located in Research Triangle Park, N.C., has a range of programs to support research into the effects of nanoscale materials on human health. The National Institute for Occupational Safety and Health (NIOSH) is investigating nanosafety issues, particularly with regard to the workplace, and publishes guidelines and recommendations based on the latest research in this area. The Food and Drug Administration (FDA) regulates the use of nanoparticles in food and medicine.

Nanobiotechnology (continued)

Nanobiotechnology: Innovations in Medicine

An exciting, new, top-down nanobiomanufacturing process is PRINT, which stands for Particle Replication in Non-wetting Templates. The PRINT process was developed by Dr. Joe DeSimone's research group at the University of North Carolina at Chapel Hill (Liquidia Technologies, 2012). The process uses top-down lithography to make tiny, precisely shaped molds, which in turn can be used to make precisely shaped nanoparticles. *(See the Nanomanufacturing activity in this chapter to learn more about lithography.)* Researchers use particles manufactured to specified sizes and shapes to investigate the effects of size, shape and other particle characteristics on cellular processes and on uptake and distribution in organisms. This will lead to a better understanding of how to use nanoparticles as delivery systems for medications.

Another use of the PRINT technology is developing new vaccines that are cheaper, safer and more effective. The first of these new vaccines is aimed at preventing influenza and already is in the early phases of clinical trials in people. A vaccination exposes the recipient's body to an antigen (part of the disease-causing agent) in a weakened or killed form. The antigen stimulates the immune system and protects the recipient if they are exposed to the same disease in the future. The new vaccine manufacturing process uses the PRINT technology to produce a dissolvable nanoparticle to deliver the vaccine antigens in the body. This makes the vaccine more effective with less antigen. Liquidia Technologies, a spin-off company from Dr. DeSimone's research group, also is developing a new vaccine to combat one of the types of bacteria that causes pneumonia. This particular bacteria species has an outer coat made of polysaccharides, and the new vaccine will use nanoparticles made from these polysaccharides. This will be a new type of vaccine antigen. If successful, this technique may be useful in developing other vaccines against diseases for which it has been very difficult to develop vaccines.

Pharmaceutical researchers working to develop new medications also are excited about nanoparticles because the properties of some nanoparticles allow them to penetrate the blood-brain barrier. The blood-brain barrier is the separation of blood from central nervous system tissue by tightly packed endothelial cells. These tightly packed cells prevent many materials in the blood from entering brain tissue. While this helps protect the brain from infections, it sometimes causes problems because some medications as well as dyes needed for diagnostic imaging cannot reach the brain. Nanoparticles present the

Nanobiotechnology (continued)

possibility of a solution to this problem. Researchers are working on various nanoparticles to help deliver medications to the brain.

In a related area, researchers at the University of California, Los Angeles recently published the results of their work developing proteins that self-assemble into tiny nano cages, much smaller than cells. They plan to develop techniques to attach molecules to the outside that would enable the cages to recognize and enter cancer cells. A toxin to destroy the cancer cells would be contained within the cage and released after the cage enters the cancerous cells. Further work is needed to design cages that will not leak the toxins nor be destroyed by the immune system before they reach the cancer cells.

Another novel nano technique might be used in both the diagnosis and treatment of cancer. Tumor cells and the blood vessels that supply them are abnormal in several ways and tend to accumulate small particles, while healthy cells do not. This is called the enhanced permeability and retention effect. The novel nano technique, which is being assessed in clinical trials, makes use of gold nanoshells. These nanoshells are tiny balls of silica surrounded by a thin shell of gold. The nanoshells also can be coated with molecules specifically designed to stick to tumor cell markers or antigens. Once the gold nanoshells have accumulated in the tumor tissue, they can be heated with lasers, killing the tumor cells while having little effect on healthy tissue.

Careers in Nanobiotechnology

Nanotechnology, including nanobiotechnology, is a rapidly emerging, multidisciplinary field. As new research leads to new applications, new career paths are opening up with positions ranging from technician to research scientist. Students need a strong basic background in chemistry, physics and biology, as well as engineering and design skills. Beyond that, they should seek to develop expertise in one area and be prepared to share that expertise with an interdisciplinary team.

There are a small but growing number of degree programs in nanotechnology. North Carolina's nanotechnology degree programs include masters and Ph.D. programs at the Joint School of Nanoscience and Nanoengineering, in Greensboro (a collaboration between North Carolina A&T State University

Nanobiotechnology (continued)

and the University of North Carolina at Greensboro). The University of North Carolina at Charlotte offers a Ph.D. program in Nanoscale Science. Forsyth Technical Community College offers an AAS degree in Nanotechnology as well as certificate and diploma programs. And North Carolina State University is developing an M.S. degree in Nanoengineering.

Special Thanks To...

Dr. James Ryan, Dr. Daniel Herr and Jacqueline Oates, of the University of North Carolina at Greensboro, for their invaluable help in developing this chapter.

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- Liquidia Technologies. (2012). *Liquidia utilizes a proprietary PRINT Technology Platform*. Retreived from http://liquidia.com/ProductPlatform.html

- Newberry, D., & Uldrich, J. (2003). *The Next Big Thing is Really Small: How Nanotechnology will Change the Future of Your Business*. New York: Crown Business.

- United States National Nanotechnology Initiative. (n.d.). *Nanotechnology* 101. Retreived from http://www.nano.gov/nanotech-101/nanotechnology-facts

- University of Wisconsin–Madison Materials Research Science and Engineering Center. (2008). *Exploring the Nano World: Probe Microscopes*. Retreived from http://education.mrsec.wisc.edu/Edetc/background/STM/index.html

Nanobiotechnology (continued)

Resources

Nanoscale Science

- Jones, G., Falvo, M., Taylor, A., & Broadwell, B. (2007). *Nanoscale Science: Activities for Grades 6-12*: NSTA Press.

Optical Properties of Nanoparticles

- Tutorial on the optical properties of nanoparticles from nanoComposix, a company that specializes in fabrication, characterization and integration of nanomaterials into products and systems. http://nanocomposix.com/kb/general/plasmonics

Size and Scale Resources

- Eames Office (2010) *Powers of Ten*. http://www.powersof10.com/film. This is the classic film exploring scale in the universe.

- Size and Scale resources from University of Wisconsin Exploring the Nanoworld. http://mrsec.wisc.edu/Edetc/nanoscale/index.html

- Prizewinning size and scale website developed by Cary and Michael Huang, two high school students. http://htwins.net/scale2

- Genetic Science Learning Center (1969, December 31) Cell Size and Scale. *Learn.Genetics*. Retrieved September 30, 2012, from http://learn.genetics.utah.edu/content/begin/cells/scale

More Scientific Information on Snowflake Formation

- Nanoscale Informal Science Education (NISE) Network *Snowflakes: Nano at its Coolest*. Website with PowerPoint, lesson plans, teacher resources, etc. Available at: http://www.nisenet.org/catalog/programs/snowflakes-nano-its-coolest

- Libbrecht, K. (1999) SnowCrystals.com Available at: http://www.its.caltech.edu/~atomic/snowcrystals/primer/primer.htm

- Scientific Paper on Snowflake formation http://www.its.caltech.edu/~atomic/publist/rpp5_4_R03.pdf

Nanobiotechnology (continued)

- NOAA on Snowflake formation http://www.noaa.gov/features/02_monitoring/snowflakes.html

Online Self-Assembly Activities

- http://pbskids.org/dragonflytv/web_assets/pdf/dftv_nanoedguide_selfassembly.pdf#page=2. This includes two classroom activities suitable for early high school students.

- http://concord.org/activities/molecular-self-assembly. Discussion of this activity: http://mw.concord.org/modeler/articles/self-assembly.pdf. This is a higher-level interactive online activity suitable for chemistry or more advanced biology students.

- http://cnsi.ctrl.ucla.edu/nanoscience/pages/selfAssembly-expProc. A hands-on self-assembly activity using simple inexpensive materials.

- http://www.unl.edu/ncmn/sites/unl.edu.ncmn/files/outreach/images2/Enders.Lego_Self_Assembly_Pamphlet_Final.pdf. This activity, developed by Michael Falvo and Gail Jones, models molecular self-assembly.

Resources for *The Ethics of Nanotechnology* Activity

- http://www.nanotechproject.org/process/assets/files/7060/nano_pen16_final.pdf

- http://nnin.org/nnin_ethicstraining.html. Short presentation from National Nanotechnology Infrastructure Network. This presentation is designed for researchers but discusses ethical issues to consider when planning research. Available as a PowerPoint or video version.

Resources for *Nanotechnology Reading* Activity

For AP Courses:

- *Nanoengineering Ion Channels for Optical Control*
  http://www.ncabr.org/downloads/supplemental/rxManual/nanotechnology/ap_opticalControl.pdf

Nanobiotechnology (continued)

- *NanoPen: Dynamic, Low-Power, and Light-Actuated Patterning of Nanoparticles*
  http://www.ncabr.org/downloads/supplemental/rxManual/nanotechnology/ap_nanoPen.pdf
- *Nuclear Neighborhoods and Gene Expression*
  http://www.ncabr.org/downloads/supplemental/rxManual/nanotechnology/ap_nuclearNeighborhoods.pdf
- *Understanding and Re-engineering Nucleoprotein Machines to Cure Human Disease*
  http://www.ncabr.org/downloads/supplemental/rxManual/nanotechnology/ap_nucleoproteinMachines.pdf

For Biology Courses:

- *The convergence of bio, nano, and information technology: When Worlds Collide*
  http://www.ncabr.org/downloads/supplemental/rxManual/nanotechnology/biology_convergence.pdf
- *Next-generation quantum dots*
  http://www.ncabr.org/downloads/supplemental/rxManual/nanotechnology/biology_quantumDots.pdf
- *Second window for* in vivo *imaging*
  http://www.ncabr.org/downloads/supplemental/rxManual/nanotechnology/biology_inVivoImaging.pdf

How Big or is it How Small?

Size and scale items from the following document:
http://www.nnin.org/doc/sizeandscalerevised.pdf

Learning Outcomes

- Students will compare the size of common objects.
- Students will explore the metric system.
- Students will estimate the size of an object in nanometers.
- Students will measure the object and convert the measurement into nanometers.

Key Vocabulary

- Metric system
- Nano-
- Nanometer
- Dimensional analysis
- Unit factor method

Time Required

- Approximately 5 minutes of prep time
- Approximately 60 minutes of class time for activity and discussion

Materials for Each Group

- Metric ruler
- 1 set of object strips in an envelope/baggie
- Pencil

Background Information

1 quart equals 2 pints. 1 pint equals 2 cups. How many ounces are in 1 cup? According to the apparent pattern of measurements, a person might think that 1 cup equals 2 ounces — but it actually equals 8 ounces. The English system of measurement is confusing. It does not follow logical progressions between sizes. The metric system, on the other hand, provides a logical progression between sizes — in increments of 10 — from very large to very small

How Big or is it How Small? (continued)

measurements. In this lesson, students will review the scale of objects and the metric system of prefixes and focus on what "nano" means and the length or width of objects in terms of nanometers.

Teaching Notes

Before teaching the activity, it will be helpful to assess some math skills. Assess how comfortable students are with converting measurements from one unit to another. Also check how comfortable students are with multiplying fractions. Review powers of 10, negative exponents and scientific notation. Teachers also may need to review dimensional analysis.

To prepare materials for this lesson, make copies of the Object Strips for each student group. Laminate the strips, separate the strips and place one set of strips in an envelope/baggie for each group.

Safety

Students should use proper laboratory techniques for measuring length.

Procedure

There are several great web resources to engage students in thinking about size and scale.

- *Powers of Ten* (http://www.powersof10.com/film)
  This nine-minute documentary begins by zooming out to the universe from a 1-meter square and then all the way back to the 1-meter square down into the subatomic level.

- Scale of the Universe 2 (http://htwins.net/scale2)
  Two high school students, Cary and Michael Huang, developed an interactive website which allows the user to control the jumps between different sizes of objects. The user may also click on the object to find out background information on the object.

How Big or is it How Small? (continued)

- Cell Size and Scale (http://learn.genetics.utah.edu/content/begin/cells/scale) The University of Utah's Learn Genetics website focuses on the size and scale of cells.

After watching a web resource, ask students to list the units which measure length and write the answers on the board. If students give only a few answers, ask students to name units used to measure smaller items or much larger items, such as the distance from Earth to Alpha Centauri or the radius of a hydrogen atom. Students should sort the measurements into three categories on the handout: metric units, English units and other units.

Depending on the students' background knowledge, you may want to spend some time discussing the merits of the metric system. Explain that the metric system defines base units on carefully defined and measured physical constants. The metric system builds on the base units by attaching prefixes indicating multiplication by various powers of 10. Explain how powers of 10 can be represented with scientific notation. Remind students that a negative exponent means the reciprocal of the number. Review a few examples to be sure students understand this key concept. If students have not previously worked with negative exponents, they will need more instruction. Explain to the students that this lesson focuses on the metric system and on a particular prefix: "nano." Students may want to discuss why the United States doesn't use the metric system in daily life.

$$2^{-3} = \frac{1}{2^3} = \frac{1}{8} = .125$$

and

$$10^{-3} = \frac{1}{10^3} = \frac{1}{1000} = .001$$

The basic unit of length is the meter. By combining the meter with metric prefixes, we can obtain much larger and much smaller units. If the prefix is associated with a positive exponent, the resulting unit will be larger than a meter. If the prefix is associated with a negative exponent, the unit will be

How Big or is it How Small? (continued)

smaller than a meter. Ask students to complete the metric chart of prefixes and scientific notation in the handout.

Divide the class into groups and give each group a set of object strips. The task is to sort the strips so the objects are listed from largest to smallest. Ask the students to work without talking for one minute. After one minute, allow the students to discuss any changes they think are needed. Groups are allowed to move objects during this five-minute discussion. At the end of this discussion, project the object measurements for the class to see. Give the students five additional minutes to make adjustments to their lists using the object measurements. Finally, project the ordered object answer sheet for the students to check their order.

Ask the students to estimate the length of their pencil in nanometers. Next, give each pair a metric ruler to measure the length of the pencil in centimeters. Finally, convert the centimeter measurement to nanometers using dimensional analysis. Provide examples of dimensional analysis as needed.

Example:
A 14 cm pencil:

$$14 \text{ cm} \times \frac{1 \text{ m}}{10^2 \text{ cm}} \times \frac{10^9 \text{ nm}}{1 \text{ m}} = 14 \times 10^7 \text{ nm} = 140,000,000 \text{ nm}$$

Ask the students how accurate they think this measurement is. Depending on the level of the students, this is a good place to discuss the limitations of various measurement instruments and the uncertainty of measurement. Explain that scientists are now making products and machines that are only a few nanometers in size. For accurate measurement, special instruments such as scanning tunneling microscopes and helium ion microscopes are needed.

Assessment

Students should complete the *How Big or is it How Small?* Handout. Students should create their own pictorial scale chart including pictures and lengths of objects using metric prefixes, from “kilo-” to “nano-.” Students must remember to cite the source for each picture taken from an online or print source.

How Big or is it How Small? (continued)

Extension

The activity may be extended by asking students to research some of the instruments that allow scientists to measure objects at the nanoscale. Other research topics include the history of the metric system and the uses of more obscure metric prefixes, such as “peta-” or “atto-”.

How Big or is it How Small? (continued)

Object Strips

Airport runway	Airport runway
Anthrax bacteria	Anthrax bacteria
Apple	Apple
Atom (He; 3 across)	Atom (He; 3 across)
Boeing 767 400ER jet	Boeing 767 400ER jet
Cat (average length)	Cat (average length)
Dalmatian (average length)	Dalmatian (average length)
Dime thickness	Dime thickness
DNA width	DNA width
Flea	Flea
Field mouse (average length)	Field mouse (average length)
Football field length	Football field length
Grain of sand	Grain of sand
Hair diameter	Hair diameter
Head of a pin	Head of a pin
Hummer H1	Hummer H1
Influenza virus (diameter)	Influenza virus (diameter)
iPod length	iPod length
Pollen grain	Pollen grain
Queen Mary II cruise ship	Queen Mary II cruise ship
Red blood cell	Red blood cell
Soccer ball	Soccer ball
Yellow jacket	Yellow jacket

How Big or is it How Small? (continued)

Objects (ordered alphabetically)

Object	Approximate Size
Airport runway	3.35 km
Anthrax bacteria	1 µm
Apple	76 mm
Atom (He; 3 across)	1 nm
Boeing 767 400ER jet	64 m
Cat (average length)	0.45 m
Dalmatian (average length)	1 m
Dime thickness	1 mm
DNA width	2.5 nm
Flea	2.5 mm
Field mouse (average length)	152 mm
Football field length	110 m
Grain of sand	0.5 mm
Hair diameter	60–80 µm
Head of a pin	2 mm
Hummer H1	4.7 m
Influenza virus (diameter)	20 nm
iPod length	90 mm
Pollen grain	30 µm
Queen Mary II cruise ship	345 m
Red blood cell	7 µm
Soccer ball	254 mm
Yellow jacket	12.7 mm

Size information of objects adapted from:
http://www.nnin.org/doc/sizeandscalerevised.pdf

How Big or is it How Small? (continued)

Objects (ordered by size)

Object	Approximate Size
Airport runway	3.35 km
Queen Mary II cruise ship	345 m
Football field length	110 m
Boeing 767 400ER jet	64 m
Hummer H1	4.7 m
Dalmatian (average length)	1 m
Cat (average length)	0.45 m
Soccer ball	254 mm
Field mouse (average length)	152 mm
iPod length	90 mm
Apple	76 mm
Yellow jacket	12.7 mm
Flea	2.5 mm
Head of a pin	2 mm
Dime thickness	1 mm
Grain of sand	0.5 mm
Hair diameter	60 – 80 µm
Pollen grain	30 µm
Red blood cell	7 µm
Anthrax bacteria	1 µm
Influenza virus (diameter)	20 nm
DNA width	2.5 nm
Atom (He; 3 across)	1 nm

Size information of objects adapted from:
http://www.nnin.org/doc/sizeandscalerevised.pdf

How Big or is it How Small?

Metric or English system — what should you use and why? This activity will explain some differences between the two systems and why the nanometer is a useful unit for very small objects.

Procedure and Observations

1. List Metric, English and other measurement system units in the table below.

Metric System	English System	Other Measurement Systems

2. Complete the metric system prefix chart.

Prefix	Multiplier in Scientific Notation	Multiplier in Expanded Notation
giga-	10^9	
mega- (M-)	10^6	
kilo- (k-)	10^3	
hecto- (h-)	10^2	
deka-	10	
STANDARD UNIT (meter)	1	
deci- (d-)	10^{-1}	
centi- (c-)	10^{-2}	
milli- (m-)	10^{-3}	
micro- (μ-)	10^{-6}	
nano- (nm-)	10^{-9}	

How Big or is it How Small? (continued)

3. What was the biggest surprise for you in organizing the objects by size?

4. Estimate the length of your pencil in nanometers. ________________nm

5. Measure the length of your pencil in centimeters. ________________cm

6. Convert the length of your pencil in centimeters to nanometers. Use dimensional analysis and show your work.

7. Estimate the width of your science book in nanometers. ______________nm

8. Measure the width of your science book in centimeters. ______________nm

How Big or is it How Small? (continued)

9. How did your measurement compare to your estimate? Why was there such a difference?

Discussion Questions

1. How are the metric and English measurement systems different?

2. What is the difference between nanometer and meter?

3. Give three examples of items which are a few nanometers in length.

4. What challenges do you think scientists have working at the nanolevel?

Tools and Techniques for the Nanoworld

Learning Outcomes
- Students will explain how tools for observing the earth have changed through history.
- Students will explore the surface features of samples using a variety of tools.
- Students will brainstorm how technology could change over time to explore the nanoworld.

Key Vocabulary
- Surface feature
- Structure
- SPM (scanning probe microscope)

Time Required
- Approximately 15 minutes of prep time
- Approximately 60 minutes of class time for activity and discussion

Materials for Each Group
- 1 piece of sandpaper (60 grit)
- 1 piece of sandpaper (100 grit)
- 1 piece of sandpaper (320 grit)
- 1 toothpick
- 1 magnifying glass
- 1 microscope
- Colored pencils

Background Information
The earth has many different surface features, such as mountains, rivers, canyons and deserts. In order to explore these features, scientists traverse the terrain and study satellite images. On the opposite end of the spectrum, nanoparticles also have surface features and structures which scientists need to explore. However, scientists are not able to traverse the terrain of nanoparticles with traditional tools or techniques. Magnifying glasses and traditional

Tools and Techniques for the Nanoworld (continued)

microscopes do not begin to focus on the surface structures. Scientists have developed tools such as scanning probe microscopes (SPM) and atomic force microscopes (AFM) to explore the surface of nanoparticles. Scanning probe microscopes use physical properties to explore the surface of particles.

Teaching Notes

Before teaching the activity, cut the sandpaper sheets into the number of groups in the class. Write the grit on each sample.

Safety

Students should use proper laboratory techniques. The students should be careful with sandpaper to avoid damage to themselves or the furniture.

Procedure

Begin the discussion by asking students how cartographers developed maps 200 years ago. Allow the students to discuss exploration of the terrain and surveying. Follow up by asking the students to list different kinds of maps and discuss how the data to create these maps is gathered. Most students, having watched the weather and news, are familiar with the wide variety of maps used in meteorology and the instruments used to generate these maps. Ask probing questions to extend their thinking to geological maps, economic maps and population maps. Next, ask students which tools could be used to explore the surfaces of molecules. Discuss the detection of various forces that might provide information about the surface shape and properties.

To get a feel for how the magnetic force microscope works, set up a metal sheet with various materials stuck to it. A refrigerator door with various magnetic stickers, photos and artwork is a perfect example. Then, hold a magnet a few millimeters over the surface and move it back and forth, feeling the magnetic force change as you pass over the different materials.

Divide the class into groups and provide each group with a set of sandpaper samples. Explain that this activity will explore how the terrain of nanoparticles is mapped. Ask the students to explore the surface structure of each sample

Tools and Techniques for the Nanoworld (continued)

and draw a sketch of the surface. It may be helpful to use colored pencils for these sketches. Next, provide the groups with a magnifying glass and allow the students to sketch the surface of each sample. Then, allow each group to take the sample to the microscope and sketch the surface of each sample. Finally, students will explore the surface blind — only using touch — first with their fingertip, then with a toothpick for each group. Ask the students to close their eyes or use a blindfold. This will help students understand that scientists must discover the nanoworld without being able to view it.

Assessment

Students should complete the student handout.

Extension

The activity may be extended by allowing the student to research Scanning Probe Microscopes. Students may build a LEGO model of an SPM, such as the model presented in Exploring the Nanoworld, with LEGO Bricks.

Tools and Techniques for the Nanoworld

How can surface features of the earth be explored? Is it different from how the surface features of sandpaper or an atom are explored? In this activity, surface features will be explored with several different tools.

Procedure and Observations

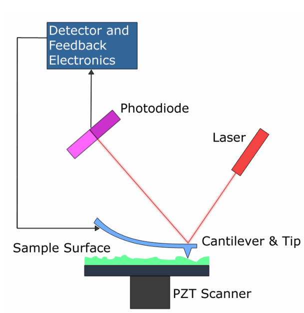
Important note: Use the table that starts on the next page to record your observations.

1. Observe the surface features on the sandpaper samples. Describe what strategies you used to observe the surface features of the sandpaper.

2. Observe the surface features on the sandpaper samples with a magnifying glass. Describe how the surface features of the sandpaper apparently changed with the magnifying glass.

3. Observe the surface features on the sandpaper samples with a microscope. How did the sketch evolve from the observations in questions 1 to 3?

4. Nanoscientists use scanning probe microscopes to explore the surface of nanoparticles. The scanning probe microscope (SPM) scans the surface of the particle in a given pattern. One specific type of SFM is an Atomic Force Microscope, which uses forces such as electrostatic, magnetic, chemical bonds and others.



Atomic Force Microscope

Image Credit: Sciencenter

Tools and Techniques for the Nanoworld (continued)

Explore the surface of the sandpaper using touch — first with your finger tip, then by feeling a toothpick vibrate as you drag it slowly across the surface. What features could you identify?

Sandpaper Sample (grit)	Sketch of the Surface Features and Structures
Question 1	
Question 2	

Tools and Techniques for the Nanoworld (continued)

Sandpaper Sample (grit)	Sketch of the Surface Features and Structures
Question 3	
Question 4	

Tools and Techniques for the Nanoworld (continued)

Discussion Questions

1. How did your confidence in the description of the surface change as your tools improved?

2. How does the scanning probe microscope compare to reading Braille?

3. What current tool can you imagine being re-engineered to explore the nanoparticles?

Nanomanufacturing

Oven mitt activity from:
http://www.mrsec.wisc.edu/Edetc/IPSE/educators/activities/mittenChall.html

Sunprint activity adapted from:
http://mathinscience.info/public/0%20Activities/nano/photolithographic/Photolithographic_Lab-on-a-Chip_Lesson.pdf

Ribbon activity adapted from:
http://pbskids.org/dragonflytv/pdf/DragonflyTV_SelfAssemblyGames.pdf

Learning Outcomes

- Students will explain how macro production techniques are insufficient for the nanoworld unless they are adapted.
- Students will investigate how creating a sunprint can mimic the lithographic production of nanoparticles.

Key Vocabulary

- Bottom-up
- Top-down
- Self-assembly
- Photolithography

Time Required

- Approximately 10 minutes of prep time
- Approximately 45 minutes of class time for activity and discussion

Materials for Each Group

- Roll of blue ribbon
- Roll of red ribbon
- 2 tube socks
- Small bowl of seed beads
- Tweezers/forceps
- 1 foot of beading string
- Magnifying glass
- Sunprint paper
- Transparency
- Paintbrush
- Black tempera paint

Nanomanufacturing (continued)

Background Information
There are three main production techniques used in nanotechnology. First, nanoparticles may be picked up and connected together by outside tools. This is considered a top-down approach. This technique is similar to many current macro production techniques in the assembly line factory. Second, lithography or pattern printing also may be used to create patterns at the nanoscale. In this technique, thin layers of material are printed on a substrate to create patterns at the nanoscale. A variety of techniques are used to add and subtract material in each layer to create the desired pattern. Lithography techniques also are considered top-down approaches. Third, nano materials are made by creating the conditions for self-assembly. The particles assemble into the desired pattern because of natural forces acting on their inherent properties.

Teaching Notes
In this activity, students will explore the three main production techniques. Before teaching the activity, the materials should be sorted for groups. Each group needs a tube sock, a small bowl of seed beads, 1 foot of beading string and tweezers or forceps for the pick-up and connect technique. For the second lithography technique, each group needs sunprint paper, transparency, paintbrush and black tempera paint.

Safety
Before opening the sunpaper, make sure that all light in the room is minimized. Especially close all window shades. Do not look at the sun when exposing the sunprint.

Procedure
Divide the class into groups and provide each group with a chart paper/whiteboard and markers. Give each group one of the following questions:
1. How is a car produced?
2. How is a page printed with an inkjet printer?
3. How are snowflakes formed?

Allow the students to look up information on their topic online or in reference books. Walk around and provide suggestions to help the students formulate their presentation as needed. The snowflake group may need to be pointed to the physical properties of the water molecules. After 10 to 20 minutes, allow the groups to present their findings to the class. Once all the groups have presented,

Nanomanufacturing (continued)

explain that these three techniques are used in manufacturing nanoparticles but with adaptations to nanoworld. The car assembly is an example of top-down manufacturing, the inkjet printer is an example of a lithographic manufacturing process and the snowflake is an example of bottom-up or self-assembly, where the right materials under the right conditions will form the desired product.

Nanoparticles may be assembled by being picked up and placed together like an assembly line. In the group, have one student wear a tube sock on each hand. This student should attempt to place as many seed beads on the beading string as possible in one minute. Allow the student to remove the tube socks and use the tweezers to help place as many beads as possible on the string in one minute. Discuss within the group how changing the tools used aided in the production of the beaded string.

Provide each group with a magnifying glass and a comic strip frame. Ask students to observe the image. Ask students to define lithography. It is a method of printing in which the image is transferred to a smooth surface using a medium to which ink will adhere. Ask students what the prefix “photo” means. “Photo” means light. Photolithography uses light to print an image. Look for explanations of lithography online and discuss with the students. Photolithography is the focus of this project. Lithography at the nanoscale is used to manufacture semiconductor chips. Explain to students they will be creating a picture in which the sunlight prints a picture of the black tempera image on the light-sensitive paper. Create a black tempera paint image on the transparency using the paintbrush. Place the transparency over the sunprint paper and follow the manufacturer’s instructions for exposing and developing the sunprint. (You likely will need to expose it to sunlight for approximately two to five minutes.)

Self-assembly of nanoproduct is engineered through the physical properties of the nanoparticles. The nanoparticles have areas of attractions or repulsion. As these individual nanoparticles come into contact with each other, the particles begin to form a structure which becomes the backbone of the nanoproduct. You can get students to mimic this process by giving each student a piece of red ribbon and a piece of blue ribbon. Students should tie a red ribbon to the right foot and tie the blue ribbon to the left foot. Divide the class into three teams with an even number of students. Give each team a set of rules to follow:

1. All feet must have two partners (your other foot and someone else).
2. A red ribbon must touch a blue ribbon.

If the teams follow the rules, the students will form a circle and will alternate facing toward the inside and outside of the circle. Different rules may produce a different pattern. As a challenge, have students experiment with the

Nanomanufacturing (continued)

self-assembly patterns at http://pbskids.org/dragonflytv/pdf/DragonflyTV_SelfAssemblyGames.pdf.

Assessment

Students should complete the student handout. Students may create a chart comparing and contrasting the forms of nanoproduction. Look for understanding of the three main methods.

Extension

The activity may be extended by researching examples of how the different forms of manufacturing are used in current production of nanotechnology products. Create a list of the products and the production technology used.

Nanomanufacturing

Because of the size and scale, nanoparticles must adapt macro techniques for the nanoworld. In these activities, examples of nanoproduction will be explored.

Procedure and Observations

1. Production through moving objects to be assembled:
   One student should wear a tube sock on each hand. This student should attempt to place as many seed beads on the beading string as possible in one minute. How many beads were placed in the string?

2. Allow the student to remove the tube socks and use the tweezers to help place as many beads as possible on the string in one minute. How many beads were placed in the string?

   How did changing the tools aid in producing a better beaded string?

3. Lithography:
   Observe a comic strip frame with a magnifying glass. Describe the features of the comic strip frame. How do you think the image was printed?

4. In nanotechnology, engineers must create machines and tools using a nanoscale. What is lithography?

Nanomanufacturing (continued)

5. Layering thin dots of materials on a substrate is one way that production occurs for nanoproducts. This process will be mimicked by creating a sunprint using layering. Create an image on the transparency using the black tempera paint. Place the transparency over the sunprint paper. Follow the developing instructions for the sunprint paper manufacturer. How does the shape of the sunprint image relate to the image on the transparency?

6. Self assembly:
   Because of the physical properties of some particles, they are attracted to particular spots on the particle. This is similar to how snow crystallizes to form different snowflake shapes. Research crystalline structure of ice. Describe how water crystallizes to form snowflakes.

Discussion Questions

1. How can adapting the tools improve the production of nanoparticles?

2. How do the two definitions of lithography relate to nanoproduction?

3. What molecular properties could create points of attraction or repulsion which may be used in nanoproduction?

The Ethics of Nanotechnology

This activity contains content from An Ethics Primer: Lesson ideas and ethics background*, published in 2008 by the Northwest Association for Biomedical Research. Available at:*
http://www.nwabr.org/sites/default/files/learn/ethicsprimer/TOC_Guide.pdf

Ethical questions in the student handout for this activity are from:
http://science.education.nih.gov/supplements/nih9/bioethics/guide/pdf/Teachers_Guide.pdf

Learning Outcomes

- Students will explore the foundational principles of ethics.
- Students will apply general ethical principles to nanotechnology problems.
- Students will write a reasoned argument supporting an ethical position related to the use of nanotechnology.

Key Vocabulary

- Ethics

Time Required

- Approximately 15 minutes of prep time
- Approximately 45 minutes for research of a nanotechnology
- Approximately 45 minutes for group discussion
- Approximately 45 minutes for presentations

Materials for Each Group

- Examples of nanotechnology from the Internet

Background Information

> "Ethics is a field of study that examines the moral basis of human behavior and attempts to determine the best course of action in the face of conflicting choices. *Ethics is central to our human experience and provides an organizing dimension to human interaction.* Because it invokes questions that consider morals, values, and principles, and because it seeks to consider and respect alternate viewpoints, it is a key component to living within a society in a civilized way."
>
> **— *from* An Ethics Primer: Lesson ideas and ethics background**

The Ethics of Nanotechnology (continued)

As society embarks on doing research and production in the nanoworld, we must make well-reasoned judgments while respecting the opinions of others. Typically, ethical questions use words such as “ought” or “should” and have more than one reasonable answer. In this activity, students will research a current topic in nanotechnology, explore the ethical questions raised by the new technology and its applications, take a position concerning one of these questions and write a reasoned argument supporting that position.

Teaching Notes

Before teaching the activity, it is important to create a proper environment for discussing emotional and complex dilemmas. Allow students to create a list of rules all discussion participants will follow. Remind the students that each person has personal experiences which affect their view of science and technology and may influence their views of nanotechnology. Ask students to be respectful as they make and listen to comments.

Consider showing a news clip or reading a news story about nanotechnology to get students’ attention about the nanoworld. Choose nanotechnology topics for your class to study. Suggestions are given in the procedure. You may choose to create a webpage with bookmarks to sources for chosen nanotechnology topics to ensure your students use reputable sources.

Procedure

Grab the students’ attention by reading a nanotechnology news story or showing a news clip featuring nanotechnology. Ask the students what questions they have about the story. List those questions on the board. Explain that students will become experts on a nanotechnology and explore the ethical implications of that technology. This is a short list of suggestions for nanotechnology research. Many others topics may be used:

- Nanoparticles in sunscreen
- Nanoparticles in food
- Nanoparticles in medicine delivery
- Nanoparticles in embryonic stem cell research
- Nanoparticles in nanosurgery
- Nanobots
- Nanoparticles in medical diagnostics
- Nanoweaponry

The Ethics of Nanotechnology (continued)

Point out the ethical questions about the initial story. Ethical questions could range from environmental consequences of nanowaste to security implications of novel weaponry. Explain that they will create an ethical question about the topic they are given and form suggestions/conclusions for the question.

Divide the class into groups and provide each group with a topic to research. Monitor student research to make sure reputable sources are being used. Remind students to document the resources used find the facts. Encourage the students to discuss why nanotechnology is so important to this topic and why traditional tools and techniques are not sufficient.

Groups now will create an ethical question. Examples of appropriate questions include: *Should nanoparticles be used in sunscreens without knowing their long terms effects on the human body?* and *Should sunscreen manufacturers be required to identify nanoparticles and their effects on the label?* Students should have their questions approved before continuing. This will allow the teacher to help create a reasonable ethical question based on the technology. Students will list affected people and things and choose an ethical consideration through which to view the nanotechnology. Students then will develop suggestions or conclusions for addressing the concerns from this topic.

Once the students have formulated suggestions, provide an opportunity for each group to share their research and conclusions with the class. Remind students to be respectful of others opinions.

Assessment

Students may complete the student worksheet. Students may present their analysis of nanotechnology to the class using a whiteboard, smartboard or other form of technology.

Extension

The activity may be extended by allowing the student to write to the proper company or government agency to address their concerns about nanotechnology.

The Ethics of Nanotechnology

Nanotechnology is revolutionizing research and production of particles. But the small size of the particle is greatly eclipsed by the questions that arise from nanotechnology and its applications. This activity will provide the opportunity to study a nanotechnology topic and the ethical considerations that frame the dilemma.

Procedure and Observations

1. Research the topic provided by your teacher. Make sure to use .gov, .edu or other reputable online resources for your research. What is the science behind the topic? Be sure to include your source for the information.

   Why is nanotechnology so important to this topic?

   If nanotechnology were not available, how would the topic be affected?

2. Discuss with your group what problems or consequences could arise from this technology. List the problems/consequences that could arise from this technology.

3. Choose one problem and write it in the form of an ethical question. Ethical questions often contain words like “ought” or “should” and have more than one reasonable answer. What is the ethical question?

   BEFORE CONTINUING HAVE YOUR TEACHER APPROVE YOUR QUESTION: __________

The Ethics of Nanotechnology (continued)

Based on your question, what are the relevant scientific facts?

4. As the world is changed by nanotechnology, people and other things will be affected. List the people or things that would be affected once the ethical question is resolved.

5. Based on your question, there are several ethical considerations to remember.
   - **Respect for persons** means never treating someone only as a means to your own goals or ends. Two ways to show respect are enabling people to make their own choices and not undermining or disregarding those choices.
   - **Harms and benefits** can be clarified by stating that benefits are positive consequences, while harms are negative consequences. It is important to consider how one can minimize harms while maximizing benefits.
   - **Fairness** is ensuring that benefits, risks (harms), resources and costs are distributed equitably.
   - **Authenticity** is achieving a goal in a manner consistent with what is valued about the performance and seen as essential (or true) to its nature.

   Discuss as a group which consideration is most important based on the topic and ethical question. List and defend the key ethical consideration.

6. Your research group has been chosen to present their suggestion for the ethical question (Question #3) to the science review board. What suggestions do you have for this nanotechnology?

The Ethics of Nanotechnology (continued)

Discussion Questions

1. What is ethics?

2. How can ethics be used to analyze nanotechnology?

3. What wording often is used in ethical questions?

4. What are the four considerations when looking at ethical questions?

Nanotechnology Reading

Learning Outcomes
- Students will independently read complex nanotechnology articles.
- Students will summarize the central idea of a given text.
- Students will write an informative text on nanotechnology using providing facts and language from the original article.

Key Vocabulary
- Annotation

Time Required
- Approximately 5 minutes of prep time
- Approximately 60 minutes of class time for activity and discussion

Materials for Each Person
- Copy of nanotechnology article

Background Information
Scientists ask questions, do experiments and analyze data. However, the process of scientific research does not stop here. Scientists develop conclusions and share their findings with other scientists. Other scientists read the description of the experiment and the conclusions. They analyze the material, ask questions and offer suggestions for improvement. It is essential for scientists to be able to read, analyze and write scientific texts. This activity will provide an opportunity for students to participate in this process.

Teaching Notes
In this activity, students will independently read a scientific article. While working in groups, students will use several different strategies to analyze the article. Students will use annotation to facilitate this understanding. Students will learn how to read with questions in mind. Students will use the subheadings/keywords to develop questions for each section. After the groups agree on the questions, the students will read the article again to underline details that answer the questions and define key vocabulary. Students will identify the central idea of the article. Students will develop a written summary

Nanotechnology Reading (continued)

of the article to share with the class electronically. The summaries may be shared on Blackboard or a similar site.

See page IV-3.15 for three sample articles for AP courses and three sample articles for biology courses. Use these articles or find other articles that fit the needs of your students.

Safety

Students should use proper laboratory techniques. The students should be careful with sandpaper to avoid damage to themselves or the furniture.

Procedure

> "Research results are more than just accumulated knowledge. Research results make possible new questions, which in turn lead to even more knowledge."
>
> ***— from* Sharing Results Is the Engine of Scientific Progress*, by David Wojick* *(http://www.osti.gov/ostiblog/home/entry/share_results_is_the_engine)***

Share this quote with class. Explain that today the class will read and summarize articles on nanotechnology. Reassure students that although the reading may seem difficult at first, they will learn techniques to help them analyze the articles.

Choose three articles to use. Hand out the one of the three articles and the student page to each student. Ask the students to read the article and answer questions in number 1. Break the students into groups of three to four students who have the same article. There will be several groups working on the same article in the class.

After eight to 10 minutes, break into small groups by articles. Ask the students to reread the article and identify the subheadings or keywords. Rewrite the subheadings in the form of a question using who, what, when, where or why. Provide examples for students at this point, if they are unfamiliar with annotation. Ask the groups to write the questions in the Questions/Details chart.

Nanotechnology Reading (continued)

Encourage the students to evenly divide the questions among the group members. Students should reread the article and highlight or mark details that answer the questions. Students should write their details in the Questions/ Details chart and the details from the other members of the group.

The students should read the article and identify unfamiliar terms. Use the text to write working definitions of the terms. Students should discuss and agree on these definitions from the article.

The groups should use the information from the charts to answer the discussion questions. After completing the discussion questions, the students should work independently to synthesize the information into a written summary of the article. The summary of the articles should then be shared electronically with other students.

Assessment

Students will write a summary of the article to share with other students electronically.

Extension

The activity may be extended by allowing students to identify and read a scientific article on nanotechnology. Students may then write a summary of the article using concepts and proper vocabulary.

Nanotechnology Reading

Scientists must be able to articulate their discoveries. In this activity, you will be able to read, analyze and summarize a scientific article on nanotechnology. You will be able to independently read the article. Then, you will work with other students to analyze the article through annotated reading. Finally, you and your partners will write and publish the summary of the article electronically.

Annotated Reading Process

1. Read the article independently. Answer these questions:

   What do you find interesting in this article?

   What words are unfamiliar? (Reread the article and identify unfamiliar terms. Use the text to write working definitions of the terms.)

Term	Working Definition

Nanotechnology Reading (continued)

2. Break into small groups. While reading the article, identify the subheadings or keywords. Rewrite the subheadings in the form of a question using who, what, when, where or why. Write the questions in the Questions/Details chart on the next page.

3. Evenly divide the questions among the group members. Reread the article and find details that answer the questions. Write the details in the Questions/Details chart on the next page.

4. Share the answers to the questions with other group members and complete the Questions/Details chart on the next page.

Nanotechnology Reading (continued)

Questions	Details

Nanotechnology Reading (continued)

Discussion Questions

1. What are the one or two most important ideas from the text?

List the top 5 to 10 details from the article and show how they are connecting to the details. This may be done in a graphic organizer or bullet points.

Independent Summary

Summarize the important ideas in the article in a clear paragraph. Use details from the article to support the main idea.