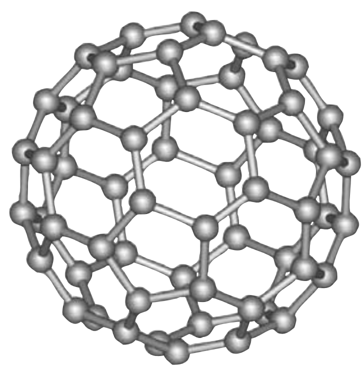
Nanoscale Science



Activities for Grades 6–12

M. Gail Jones ● Michael R. Falvo ● Amy R. Taylor ● Bethany P. Broadwell

NSTA press
NATIONAL SCIENCE TEACHERS ASSOCIATION

NSTApress
NATIONAL SCIENCE TEACHERS ASSOCIATION

Claire Reinburg, Director
Judy Cusick, Senior Editor
Andrew Cocke, Associate Editor
Betty Smith, Associate Editor
Robin Allan, Book Acquisitions Coordinator

ART AND DESIGN
Will Thomas, Director
Joanne Moran, Assistant Art Director, Cover and Inside Design

PRINTING AND PRODUCTION
Catherine Lorrain, Director
Nguyet Tran, Assistant Production Manager
Jack Parker, Electronic Prepress Technician

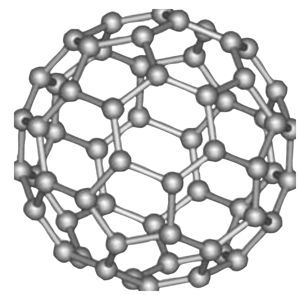
NATIONAL SCIENCE TEACHERS ASSOCIATION
Gerald F. Wheeler, Executive Director
David Beacom, Publisher

10 09 08 07 4 3 2 1

Library of Congress Cataloging-in-Publication Data

Nanoscale science : activities for grades 6-12 / M. Gail Jones ... [et al.].
p. cm.
Includes index.
ISBN 978-1-933531-05-2
1. Nanoscience. 2. Nanostructures. 3. Nanotechnology. 4. Science--Study and teaching (Secondary)--Activity programs. 5. Technology--Study and teaching (Higher)--Activity programs. I. Jones, M. Gail, 1955-
QC176.8.N35N35577 2007
620'.5--dc22
2007006376

Contents



The Authors

M. Gail Jones is a former middle and high school biology teacher and currently is a professor of science education at North Carolina State University. She leads the Nanoscale Science Education Research Group investigating effective ways to teach nanoscale science.

Michael R. Falvo is a research associate professor of physics and materials science at the University of North Carolina at Chapel Hill. Mike conducts research with nanoscale materials and teaches a special course on nanoscale science for undergraduates.

Amy R. Taylor is a former high school biology teacher and is currently a doctoral student in science education at North Carolina State University. Amy is conducting research on how students learn scale and scaling.

Bethany P. Broadwell is a former middle school science teacher and currently serves as a lecturer in science education at North Carolina State University. Bethany has conducted research on nanoscale science education and conducted workshops for teachers in nanotechnology.

Acknowledgements

The authors wish to thank the many people who inspired, reviewed, and helped craft this book. Our special gratitude goes to Adam Hall for his insightful cartoons and beautiful electron micrographs, Tom Oppewal for ideas for an early draft of the Shrinking Cups investigation, Jenn Forrester for reviewing the manuscript with a teacher's eye, and the many nanoscale researchers who shared their research and images. Thanks to Richard Superfine, Russell Taylor, Tim O'Brien, Sean Washburn and the rest of the nanoscience research group at University of North Carolina who have supported and collaborated with the authors in developing nanoscale science education. Thanks also to Robert A. Freitas Jr., senior research fellow at the Institute for Molecular Manufacturing, Thomas P. Pearl, department of physics, North Carolina State University, and Elizabeth Collie, Knotty Oak Middle School, Coventry, Rhode Island for their thoughtful reviews.

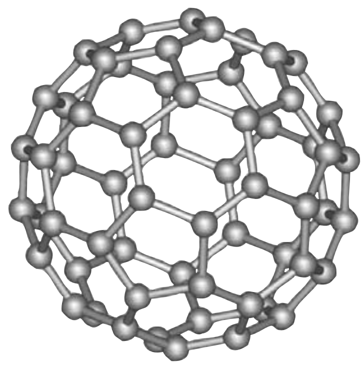
Our special appreciation goes to the National Science Foundation for supporting our nanoscale science research, our research into how students learn nanoscale science, and the development of new courses that focus on nanotechnology for undergraduates.

This material is based on work supported by the National Science Foundation under Grants Numbers 0354578, 0634222, 0507151, 0411656, and 0303979.

Dedication

This book is dedicated to Toby and Davis and all children who remind us that the smallest things can be the most important.

Introduction



Imagine you could build something from scratch atom by atom. What would you build? Would you build a robot that would move through your body gobbling up diseased cells or create a new molecule that when sprinkled on an oil spill would break down the oil, eliminating any risk to the environment? For the first time in human history we have the ability to manipulate and build materials from the atom up. New tools such as the atomic force microscope allow us to not only image atoms, but also move atoms into new arrangements that have never been attempted before. What makes all this particularly remarkable is that all this takes place at the nanoscale—one-billionth of the size of a meter. Futurists predict that nanotechnology will be the next major scientific revolution and will have greater impact on our lives than the industrial revolution or the great advances that have been made in genomics.

This book examines nanoscale science with an eye toward understanding nanotechnology. Geared toward middle and high school teachers, these investigations are designed to teach students about the unique properties and behaviors of materials at the nanoscale. The investigations were developed as a result of three National Science Foundation grants given to the authors for research examining effective ways to teach and learn nanoscale science. The investigations are designed as guided inquiry with open-ended exploration where possible. The goal of the book is to introduce the essential concepts that students need to understand nanoscale science while maintaining a broad inquiry approach. The activities of this introductory book may serve to whet the students' appetites to know more. The book is organized around five themes: scale, tools and techniques, unique properties and behaviors, nanotechnology applications, and societal implications (see key concepts listed in Table 1).

Table 1
Key NanoScience and Engineering Concepts.

Size and Scale

Nanoscale	The unique placement of the nanoworld between atomic and micro/macro scales allows exploration of the regime where properties transition from atomic behavior to familiar macro behavior.
Relative Scale	How large objects are in relation to each other. (Which is bigger an atom, molecule, or a virus?)
Powers of Ten	What is a nanometer? How much smaller is a nanometer than a micrometer?

Tools and Techniques

Atomic Force Microscopy	Probing microscopes use a scanning tip to detect physical properties of materials.
Nanoimaging	The ability to detect the arrangement of matter at the nanoscale allows for the design of new materials.
Nanomanipulation	Manipulating matter at the nanoscale opens up whole new possibilities building new objects.

Unique Properties and Behavior

Stickiness	Intermolecular forces dominate familiar forces such as gravity (van der Waals bonding, hydrogen bonding…) at this scale.
Shakiness	Thermal energy produces strong effects (Brownian motion, thermally activated processes).
Bumpiness	Graininess of matter (atoms/molecules) and properties (quantization, quantum confinement) makes working at this scale bumpy.

Nanotechnology Applications

Nanomaterials	The ability to synthesize small materials means new functionality, improved materials properties, and revolutionary technology.
Textiles	Nano construction allows for the creation of new fabrics that resist staining or have antibacterial properties.
Building Materials	The ability to mimic nature at the nanoscale allows the lotus effect to be applied to objects such as windows.
Medicine	Medical applications include nanoshells that target cancers and tumors for detection and treatment.
Water Quality	Nanoparticles that can detect and combine with pollutants may provide more efficient ways to clean water.

Societal Implications

Environmental	What are the unknown dangers of generating new nanoparticles that may be released in the environment?
Ethical	What are the ethics of creating new materials and rearranging matter?
Social	How will society change as a result of using nanolabels to track the movement of people, animals, and materials throughout the globe?

Nanoscale science uniquely ties together all the science domains because it focuses on the raw materials—atoms and molecules—that are the building blocks of physics, chemistry, biology, and Earth and space sciences (Table 2). In unprecedented ways, scientists from different departments are collaborating in nanoscale research to explore science from multiple perspectives. For example, physicists are interested in the unusual properties of gold nanoshells. These tiny nanoparticles begin as glass beads that are then covered with gold. The nanoshell behaves differently depending on the size of the gold shell. Different-sized shells have different melting temperatures, different electrical conductivity behaviors, and are even different colors. These properties make it an ideal tool for use in medical testing and treatment.

Table 2
Nano Investigations and the Science Domains.

Investigations	Biology	Physics	Chemistry	Mathematics	Environment
Introduction					
Fact or Fiction? Exploring the Myths and Realities of Nanotechnology	●	●	●	●	●
Size and Scale					
That's Huge!				●	
One in a Billion			●	●	
Nano Shapes: Tiny Geometry		●	●	●	
Biological Nanomachines: Viruses	●	●		●	
Tools and Techniques					
What's in Your Bag? Investigating the Unknown		●			
NanoMagnets: Fun With Ferrofluid		●	●		
Scanning Probe Microscopy		●			
Unique Properties of Nano Materials					
It's a Small World After All: Nanofabric		●	●		
Biomimicry: The Mystery of the Lotus Effect	●	●	●		
How Nature Builds Itself: Self-Assembly		●	●		
Physics Changes With Scale		●		●	
Shrinking Cups: Changes in the Behavior of Materials at the Nanoscale		●	●	●	
Limits to Size: Could King Kong Exist?	●			●	
Nanotechnology Applications					
NanoMaterials: Memory Wire		●	●		
Nanotech, Inc.	●	●	●		
NanoMedicine	●	●	●		
Building Small: Nano Inventions	●	●			●
Societal Implications					
Too Little Privacy: Ethics of Nanotechnology					●
Promise or Peril: Nanotechnology and the Environment	●	●	●		●

The gold that coats the nanoshell is an inert metal that easily absorbs light and the rate of absorption and reflection depends on the thickness of the gold layer. This differential rate of absorption means the nanoshell can be used for locating and treating cancer. When nanoshells are coated with antibodies and injected into the body, they are delivered by the body to a specific cancer where antibodies on the nanoshell attach to antigens on cancer cells. When a laser is shown on the cancerous area, the gold nanoshells heat up—essentially cooking the cancer while the surrounding healthy cells are unharmed. In addition to treating the cancer, a similar process is used to attach florescent dyes to nanoshells. When the florescent dyes are injected into the body the nanoshells glow in areas where there are cancer cells, which makes the nanoshells a remarkable tool that allows doctors to very specifically locate cancers and target specific areas for treatment. Not only is nanotechnology being innovatively used in medicine but also in environmental science. Scientists are exploring the use of nanoshells as a way to target and filter specific pollutants in water. The goal is to have a highly efficient way to provide clean water to countries around the Earth. As this example shows, a single application such as a nanoshell can be used in chemistry, physics, biology, and Earth and space sciences. By exploring science at the tiniest of scales, students can begin to understand the building blocks of materials and the properties of atoms and molecules that make up our world.

This book begins the study of nanotechnology for students by getting them to think about the very small size of a nanometer. Understanding size and scale at this very tiny level is difficult because we cannot easily experience things this small. Most students have trouble understanding the small sizes of things like cells or bacteria, and even more difficulty understanding the size of atoms, molecules, or viruses. The investigation of scale begins with a focus on relative size (understanding which is bigger, a virus or a cell) and moves to investigating the powers of ten, which are the foundation of the metric system. Students explore just how tiny one part in a billion really is through a series of investigations with dilutions (One in a Billion). Students explore the size and geometry of nanomaterials such as buckyballs, carbon nanotubes, and even viruses (Nano Shapes: Tiny Geometry). Next students take a look at viruses as self-assembling nanomachines (Biological Nanomachines: Viruses). These activities lay the foundation for later concepts that focus on molecular self-assembly and the introduction of unique properties of nanotubes.

Tools and Techniques

Just as the microscope and the telescope opened up new worlds that had never been seen before, the atomic force microscope and other new nanoscale tools have enabled significant advancements in nanoscale science. But unlike the telescope and microscope, the nanoscale world is too small to be seen and can only be detected through other more indirect means. Students explore what it is like to try to detect unknown materials bound inside a black bag (What's in Your Bag: Investigating the Unknown). They must think like scientists to detect the properties and shape of their unknown materials. Next, students explore how an atomic force microscope (AFM) works to probe these tiny materials. Using a pen flashlight they model how an AFM scans back and forth to detect shape (Scanning Probe Microscopy). Next, students use magnets to shape ferrofluid into new forms and explore how magnetism can be a tool for detection and manipulation (NanoMagnets: Fun With Ferrofluid).

Table 3
Interdisciplinary NanoScience:

Links to the Science and Mathematics Education Standards.

Physical Sciences
Motions and forces
Interactions of energy and matter
Entropy and conservation of energy
Life Science
The cell
Molecular basis of heredity
Matter, energy, organization in living systems
Earth Science
Properties of Earth materials
Geochemical cycles
Science and Technology
Abilities of technological design
Understandings about science and technology
Mathematics
Measurement
Proportionality
Mathematical modeling and representations
Problem solving
Unifying Concepts and Processes
Constancy, change, and measurement
Systems, order, and organization
Science in Personal and Social Perspectives
Health
Risks and benefits

Unique Properties and Behaviors

The section on unique properties and behaviors of nanoscale materials introduces students to the structure of these materials. They begin their investigations exploring how nanofabrics are able to repel a range of stains and liquids (It's a Small World After All: Nanofabric). This effect is explored further with living materials as students explore biomimicry of the lotus effect using plant leaves. This remarkable activity shows how the structure of some leaves makes them highly resistant to dirt, giving them a self-cleaning mechanism. Using magnifying glasses, students can see water bead up on leaves like cabbage and then watch as water droplets pick up other solid materials and as it rolls off the leaf (Biomimicry: The Mystery of the Lotus Effect). This macroscale investigation models the behavior of new self-cleaning glass that is used in skyscraper windows.

Materials behave very differently at the nanoscale than they do at the macroscale that we usually experience. The investigations Physics Changes With Scale, How Nature Builds Itself, and Shrinking Cups are designed to explore the shaky, bumpy, and sticky nanoworld. At this tiny scale materials are very bumpy and are highly influenced by changes in thermal energy. Students model this behavior through a self-assembly activity using Legos and magnets. After placing pieces of magnets and Legos into a box and shaking the box repeatedly, uniform structures form. This investigation models self-assembly that occurs with structures such as virus capsids at the nanoscale. The magnets in this activity model the intermolecular forces that dominate other forces such as gravity. Students explore how different scales influence each other by looking at the relationships of surface area to volume (Limits to Size: Could King Kong Exist?). By measuring different sized cubes and examining how the volume differs when surface area decreases, students are encouraged to think about why friction and heat play major roles in nanoscale manipulation.

Nanotechnology Applications

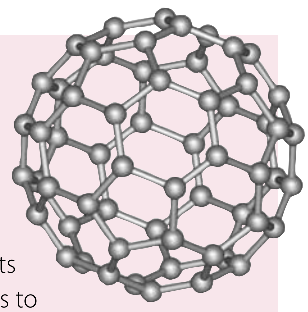
An examination of new applications in nanotechnology challenges students to think about the tremendous potential nanoscale engineering may offer to our society. Students conduct investigations with memory wire (NanoMaterials: Memory Wire) and nanofabricated socks that are antibacterial (Nanotech, Inc.). Using gelatin and gel, students explore how gold nanocapsids are able to kill tumors without damaging the surrounding healthy tissue (Nano Medicine). This section ends by challenging students to think of their own inventions that could be created with nanotechnology. Students imagine a world where nanobots can reshape their eyes so they don't need glasses or a world where nanomachines move around their mouths mopping up bacteria. This futuristic writing activity places them in the shoes of modern engineers who apply nanoscale science to human problems (Building Small: Nano Inventions).

Societal Implications

One of the greatest changes that nanotechnology may bring is the use of tiny labels and tracking devices that will allow us to monitor the movement of most materials around the globe. The changes in our privacy may be dramatic, from diamond rings that can have nanosized names and addresses tagged in them, to explosive materials that are embedded with distinctive markers (Too Little Privacy). What are the ethical implications of engineering new and totally different materials that are released into the environment? Should we build self-assembling robots just because the technology is available? Furthermore, what are the potential problems that can occur from this type of invisible engineering (Promise or Peril)? The last section of this book examines the ethical and societal implications of nanotechnology. Students consider how this remarkable technology could alter the way we live and imagine a new world where we can build nearly anything from the bottom up.

NANOMEDICINE

OVERVIEW



Nanotechnology has opened the door for medical applications that work at the molecular level to diagnose, treat, and prevent disease. This investigation models one approach to treating cancer that uses gold nanoshells to locate and destroy cancer. Students will also learn about different experimental approaches to medical treatments using nanoscale techniques.

NANOTECHNOLOGY TACKLES CANCER

Nanoscale medicine draws on many science domains through a focus on the raw materials—atoms and molecules, which are the building blocks of physics, chemistry, biology, and Earth science. In unprecedented ways scientists from different disciplines are collaborating in nanoscale research to explore science from multiple perspectives. Applications of nanotechnology in the biomedical arena fall into several broadly defined categories:

- **Diagnostics/Sensing.** Over the past 20 years or so, great advances in the ability to fabricate tiny mechanical devices and fluid-handling devices, as well as advances in materials synthesis have opened up a whole new arena of potential sensing technologies. Tiny fluidics devices containing even tinier mechanical and chemical sensors are able to detect very, very low levels of viruses, proteins, or drugs with very small sample sizes. In fact, in the laboratory, the ability to detect individual viruses (one virus landing on a sensor) has been demonstrated. Not only does this improve the overall capability of diagnostic sensing, it has improved the portability of state-of-the-art biochemical analysis for remote regions far from modern hospitals. In other words, simply shrinking current conventional diagnostic kits (for HIV testing, for example) to handheld fluidics devices would have dramatic impact on human health worldwide, especially in areas without modern biomedical infrastructure.
- **Drug Delivery.** Two of the most vexing problems in the administration of drugs and therapies are the problems of specifically targeting the problem areas in the body and regulating the concentration of drug levels in the bloodstream. When a person takes a drug, the side effects are typically caused by the fact that the drug acts on much more than the targeted problem and that the drug level in the bloodstream spikes immediately after taking the drug and then falls (the time-release problem). Scientists are now using clever engineering of nanoparticles as carriers for drugs that address both the specificity and time-release issue.
- **Tissue Engineering.** Another area of intense research focuses on nanomaterials techniques aimed at artificially synthesizing tissue. Researchers are intensively studying how biological systems make materials and attempting to apply what they learn to develop new materials for use in bone and muscle repair as well as improving biocompatibility of implanted devices and prostheses. In biological systems, materials such as shell and bone are made through very complex and still somewhat mysterious processes. Ultimately, these materials are built from the nanoscale up, and therefore efforts in the tissue-engineering area focus very heavily on nanomaterials research.

OBJECTIVES

- To be able to describe nanoscale approaches to diagnosing and treating disease.
- To think critically about new potential treatments for cancer.

Process Skills

- Observing
- Prediction
- Measuring
- Collecting Data
- Analyzing Data
- Using Models

Activity Duration

60 minutes

- **Nanoshells.** In the area of cancer treatment, there has been a lot of recent interest in the use of small nano-engineered particles called "nanoshells." Advances in nanomaterials synthesis procedures now provide scientists with the ability to make nanoparticles of tailored size and chemical functionality. Physicists are interested in the unusual electrical and optical properties of gold nanoshells. These tiny nanoparticles begin as tiny glass beads that are then covered with gold. The properties of the particle can be tuned by the choice of diameter and thickness of the gold shell.

  Different-sized shells have different melting temperatures, different electrical conductivity behaviors, and even different colors. These properties make nanoshells an ideal tool for use in medical testing and treatment. The gold that coats the nanoshell is an inert metal that easily absorbs light, and the rate of absorption and reflection depends on the thickness of the gold layer. This means that the nanomaterials scientists making the shells can tune their optical properties such that they scatter light very effectively for use as a high contrast "dye" to see the cancerous cells with optical microscopy as well as for high absorbance of light energy from a laser to "burn up" cancer cells. Furthermore, the metal shell can be easily functionalized (chemically treated) with biologically active molecules (such as antibodies) that stick specifically to target cells. The antibodies stick only to a specific kind of cancer cell. When nanoshells are coated with antibodies and injected into the body, they are delivered by the bloodstream to the targeted cancer cells where antibodies on the nanoshell attach to antigens on cancer cells. The nanoshells now coat the cancerous cells and do not reside to a high degree on healthy cells. The optical tuning of the nanoshells is such that they scatter light very effectively in the near infrared (NIR) region of the electromagnetic spectrum. This is light that has wavelengths slightly longer than visible light. This is important because biological tissue is transparent to NIR light. Therefore, when NIR is shown on the suspected tissue in a microscope, only the nanoshells show up in the microscope and can be seen below the surface. Furthermore, when very intense NIR light (much stronger than for imaging) is shown on the cancerous area, the gold nanoshells heat up—essentially cooking the cancer while the surrounding healthy cells are unharmed because they do not absorb the NIR light. In this way, the cancer cells are located and destroyed without harming surrounding tissue. Keep in mind that most cancer treatments such as chemotherapy are very nonspecific in their targeting and damage healthy tissue, which in turn leads to harsh side effects. This is the motivation for therapies that are much more specific in their targeting of cancerous cells.

New Forms of Medical Treatment With Nanotechnology

With the new materials science and chemical techniques available to researchers, they are thinking very creatively about diagnosing, treating, and preventing disease with nanotechnology. As mentioned, much progress has been made in fabricating sensors with micro and nanoscale parts of mechanical and chemical functionality. These new forms of sensors involve detecting and tracking specific types of molecules. Sensing techniques range from providing tags that glow different colors in the presence of particular types of diseased or dysfunctional cells, to extremely small "lab on a chip" tests that sample minute amounts of tissues or fluids with handheld devices. One group of researchers is exploring the possibility of creating nanotags that could probe DNA and signal when an individual has a defect in their genome. This could be useful in predicting delayed-onset illnesses like Parkinson's disease and Alzheimer's disease. Imagine the day that you go to school and there is a sensor that can immediately detect whether or not you have been exposed to a cold or flu virus and could suggest you stay home and rest. Earlier detection of disease could greatly reduce the spread of infectious agents.

Complementing sensing and diagnostic applications of nanotechnology are techniques using nanotechnology for treatment of disease. Approaches for treatment include highly specific targeting of diseased tissue (like the gold nanoshells that heat up to kill cancer) or delivering very small amounts of chemicals that could destroy diseased areas. Techniques similar to gene therapy are also being explored where tiny viruslike capsules are used to deliver DNA to the defective cells and repair the dysfunctional DNA. This approach could be used to induce a cell to produce more of a hormone or insulin for a diabetic patient. Tiny capsules could also target specific areas that need repair and deliver materials to only that area. For example, if an individual had a small infection on the skin, the nanocapsules could deliver minute amounts of antibiotic that would travel only to the infected site. Other treatments include using nanoscale materials to improve artificial implants by eliminating impurities and building better bonding agents. For people who receive artificial hips or knees, providing materials that are more compatible with existing bones could decrease complications and healing time. Researchers are currently exploring the use of nanoengineered particles that could be inserted into broken bones and could provide better scaffolding for bone growth.

There is also potential to use nanomedicine to help keep healthy people healthy. Sensors could perform routine laboratory tests to monitor your cholesterol levels, kidney functioning, or stress hormone levels. For those with respiratory illness, nanotubes could deliver oxygen directly to tissues, supplementing circulating red blood cells.

The Unknowns

Nanomedicine seems like a wonderful solution to many medical problems but there is a lot that is unknown about nanoscale medicine. Will nanoparticles wander around the body—leaving the area that was targeted for treatment untouched? Will these particles cause harm? How will they be removed from the body? Is it possible that nanoparticles may interact with other medicines, cells, or tissues in harmful or unintended ways? The potential for good outcomes from these developments must be carefully balanced by research on side effects and unintended consequences.

Fry and Die: Modeling Nano Cancer Treatment

This investigation models how lasers are able to selectively heat and destroy cancerous tissues without harming surrounding healthy tissue. Students create a gold nanopacket surrounded by healthy tissue (gel). Using a heat lamp, the gold nanopacket melts, modeling the destruction of the diseased area (cancer) while the surrounding area (tissue) is left unharmed.

Preparation of Model Tissue and Cancer

Prepare one model for each student group.

Materials

For the class:

Part 1: Artificial Tissue

- 10 Kool-Aid Gel cups (1 cup per 3 groups) in light color such as yellow, orange, or red

Note: Gel cups are available in most grocery stores and are used for this activity because they contain the gelling agent carrageenan, rather than gelatin. Carrageenan has a higher melting temperature, important in this activity.

- Student Sheet 2

Part 2: The Nanoshells and Cancer

- 1 packet of unflavored gelatin
- 1.5 cups of hot water
- Gold or green food coloring (2–3 drops to make a contrast to the tissue gel color)

Part 3: Heating the Tissue

- 1–2 heat lamps

Gel Model of Tissue and Gold Nanoshell

Part 1: Artificial Tissue. Remove gel from container and make 2–3 slices (2 cm) across the gel. Each group gets one slice that represents the healthy tissue. Cut a hole from the center of the gel with a round cookie cutter or tube. The hole should be about 20% of the diameter of the gel.

Part 2: The Nanoshells and Cancer. Prepare the gelatin as directed on the package (reduce water to 1.5 cups per envelope of gelatin). Add 2–3 drops of food coloring to color the gel darker than the color of the Kool-Aid Gel. Pour gelatin into a square pan to a depth of at least 2 cm. Allow gelatin to cool and set. When firm, cut the gelatin with the same tube used to cut holes in the artificial tissue. Insert the column of gelatin into the hole in the Kool-Aid gel. Note: If the gelatin breaks up the investigation will still work. Simply fill the hole in the Kool-Aid Gel to the top of the gel slice.

Procedures

ENGAGE Read the traditional and nanomedical scenarios on the Student Sheet 1. Discuss the problems that are often encountered with traditional cancer treatments. Ask students how nanomedical treatment could be better than traditional treatment. (Be sure to note that at this stage these are experimental treatments and not yet available for people on a routine basis.)

EXPLORE Distribute Student Sheet 2 to the groups. Briefly describe how the model of the tissue and cancer was produced. Be sure to highlight that two different materials were used in the gel and the gelatin. The gel contains carrageenan and the gelatin contains gelatin.

Modeling the Cancer Treatment

Explain that students will investigate through the use of models how nanotechnology is used to treat cancer without harming the surrounding tissue.

Researchers are coating gold nanoshells with antibodies and injecting them into the body. The nanoshells circulate in the blood until they attach to antigens on cancer cells. When a laser is shown on the cancerous area, the gold nanoshells heat up—essentially cooking the cancer while the surrounding healthy cells are unharmed. This investigation uses gel and gelatin to model this process.

Directions: Place the tissue-cancer model approximately 20 cm under a heat lamp and observe. Within approximately 3–5 minutes students should see the gelatin melt while the surrounding gel is intact.

Targeting the "Nanoshell"

Melted "Nanoshell"

EXPLAIN

Ask the students, *What happened to the gelatin and the gel? Why did the gelatin melt while the gel did not? Are they both made of the same ingredients?* (You may want to pass around the packages so students can see the ingredients).

Ask, *How does this process model nanoscale cancer treatment? What represented the laser? Why didn't the gel melt like the gelatin did?*

Explain that the gelatin has a lower melting point than the carrageenan. In nanotreatment, the laser would heat the metal nanoshells faster than the surrounding tissue thus killing the cancerous tissue while leaving the healthy tissue unharmed.

Ask, *Can you think of other ways we could target diseased tissues and eliminate them without surgery?*

EXTEND

Invite students to interview someone who is a cancer survivor about their experiences with cancer treatment. What were the greatest challenges that the person faced?

Place students into groups to brainstorm other creative ways that nanotechnology could be used to diagnose and treat diseases. Have the students share their ideas with the class.

EVALUATE

Check for understanding:

1. Why must the nanoshell be metal in order to work properly?
   Answer: The metal absorbs the energy from the light or laser used in the treatment and heats up dramatically while the tissue and biological material is transparent to the light and therefore does not absorb the light energy.

2. Why isn't the healthy tissue destroyed?
   Answer: In these treatments, a certain wavelength of light is used for which tissue is transparent. This type of light is called *near infrared*. So it passes right through the tissue without being absorbed.

3. Are there environmental problems that could be solved using a similar process?
   Answer: Possibly oil spills could be broken up with nanoshells or toxic wastes incinerated by lasers and nanoshell tags.

Name ___________________________________

Medical Treatment, Today and Tomorrow

Today: Traditional Medical Treatment

"Sara" has just gone to the doctor and been told her symptoms suggest that she may have cancer. Sara's doctor orders a series of x-rays to try to detect the cancer. The x-rays have the potential to cause mutations in Sara's genes but she knows this is the first step in cancer diagnosis. The x-ray shows a suspicious mass and the next step is for Sara to have a biopsy. The biopsy involves having a surgeon stick a long needle into the mass and withdrawing small amounts of tissue to be sent to a histology lab. Sara and the physician must wait for the lab to examine the tissue. The lab confirms that Sara has an early stage of cancer and the surgeon recommends having the cancer removed. Sara proceeds and schedules the surgery for three weeks later. The surgery goes well and although the surgeon thinks he may have removed all the cancerous tissue he recommends radiation therapy to make sure there are no cancerous cells surviving. Sara now must endure the side effects of radiation, which include nausea and vomiting, as well as swelling and fluid retention. After the radiation therapy is complete, Sara is left with some damage to the tissue that was irradiated. The good news is that five years after the surgery Sara is still cancer free.

Tomorrow: NanoMedicine

Sara's character is fictional but the events surrounding cancer diagnosis and treatment are typical. New advances in nanotechnology suggest that a very different scenario may be possible in the near future for people who develop cancer. Imagine "Susan" goes to the doctor with suspicious symptoms and the doctor suggests a combination of tests and treatment that do not require surgery. Susan's doctor injects nanometer-sized gold shells into Susan's bloodstream. These minute shells are coated with antibodies that will bind only to antigens on cancer cells and will fluoresce, giving off a brilliant green light when the binding takes place. The nanoshells move through Susan's body and adhere to the cancer cells. The cancer cells are in a mass and when the nanoshells attach to the mass, Susan's doctor can see the spot of bright green light through her skin. The doctor shines a laser on the green area and because the nanoshells are gold metal—they heat up very quickly and in the process kill the cancer cells to which they are attached. The process simply fries the cancer cells. The surrounding cells are not metallic and do not heat up with the laser. The only tissue that is destroyed is the cancerous tissue. The process takes only a few minutes and Susan leaves the doctor's office feeling good knowing that the cancer cells have been eliminated. She has no need for surgery or radiation treatment. The nanoshells that have been injected into Susan will eventually be eliminated from Susan's body as part of the body's immune system.

Susan's nanotechnology medical treatment does not exist at this time but researchers are having success in using gold nanoshells to destroy cancer in experimental conditions. Other researchers have successfully identified tumors with nanoshells that fluoresce. These advances are happening very rapidly and there is widespread hope that nanotechnology will one day eliminate the need for painful surgery and follow-up chemo or radiation therapy.

Name ________________________________

Fry and Die: Modeling Cancer Treatment

In this investigation you will make a model of the gold nanoshell treatment. Using gelatin and a flavored Kool-Aid Gel you will make artificial tissue and then embed a gold model nanoshell inside the tissue. The gelatin "shell" represents the gold nanoshells attached to the cancerous cells.

You will place your tissue model under a heat lamp and observe what happens when the heat lamp heats up the gold capsule.

The process models how lasers are able to selectively heat and destroy cancerous tissues without harming surrounding healthy tissues.

Materials

Each group will need:

Part 1: Artificial Tissue

- Kool-Aid Gel slice in light color such as yellow, orange, or red

Part 2: The Nanoshells and Cancer

- Block of unflavored gelatin with gold food coloring

Part 3: Heating the Tissue

- Heat lamp (1–2 for the class)

Procedures

Researchers are coating gold nanoshells with antibodies and injecting them into the body. The nanoshells circulate in the blood until they attach to antigens on cancer cells. When a laser is shown on the cancerous area, the gold nanoshells heat up—essentially cooking the cancer while the surrounding healthy cells are unharmed. This investigation uses Kool-Aid Gel and gelatin to model this process.

Directions

Predict what you think will happen when you place the tissue under the heat lamp.

____

____

____

____

____

____

____

Place the tissue-cancer model approximately 20 cm under a heat lamp and observe every 30 seconds. Record your observations in the table.

Time	Observations
Starting time: __________	
At 30 seconds	
At 60 seconds	
At 90 seconds	
At 120 seconds	
At 150 seconds	
At 180 seconds	

Conclusions

1. Was your prediction accurate?

2. Explain what happened to the gelatin and Kool-Aid Gel.

3. Can you think of other contexts or applications where this process could be useful?

Index

Page numbers in **boldface** type refer to figures. A following "t" indicates a table.