Teacher's Preparatory Guide

How Small Is That?

Overview: One of the biggest challenges facing nanotechnology scientists and engineers is how to keep samples clean and free from debris. Because nanoparticles are so small, objects like dust, stray skin cells, or germs can completely ruin a sample. A common analogy is that a dust particle to a nanoscale object is like an elephant on your dinner plate. High school biology students have spent the year learning that cells are the smallest unit of life. In this lab, students will explore relative size, and the idea that cells are quite big when compared to nanomaterials.

Purpose: This lab is designed to help students understand the size of nanoparticles compared to the size of other known quantities, such as a human being or a skin cell. After the size of nanoparticles is understood, the students will be challenged to come up with a way to "save" nanoparticles from being polluted by larger objects. Their design will be presented in the form of a comic strip.

Time Required: Three 50-minute class periods (plus time outside of class for students to complete their comics)

Level: Middle school general science; high school life science

Big Idea: Size and Scale

Teacher Background: Due to several prominent misconceptions, even older students struggle to understand the size of different scientific objects and organisms. These lessons are aimed to address the following student misconceptions:

1. Not realizing the connection between relative and absolute sizes of two objects[1]
2. The idea that cells are the smallest objects in existence.

A nano is a measurement that is 1×10^{-9} or one billionth of a length. Nanoscale science is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers where unique phenomena enable novel applications. In relation to nanotechnology specifically, the small scale means that scientists have to work hard to keep larger particles, like skin cells, off of their samples. This is why a clean suit is required in a nanofabrication laboratory[2].

A nanofabrication laboratory is a lab equipped with an extensive set of tools for nano and micro fabrication, synthesis, characterization, modeling and design. This work is usually conducted in a cleanroom. A clean room is an environment with a low level of environmental pollutants such as dust, airborne microbes, and chemical vapors. It has a controlled level of contamination.

To help keep out contaminants users of the cleanroom wear a cleanroom suite which is made up of hoods, face masks, glove, boots and coveralls.

Sources:

1. National Nanotechnology Infrastructure Network. "Shrink Me." (accessed July, 2013)

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http://www.nnin.org/education-training/k-12-teachers/nanotechnology-curriculum-materials/shrink-me
2. NISE Network, "Tiny Particles, Big Trouble!" (accessed July, 2013) http://www.nisenet.org/catalog/programs/tiny_particles_big_trouble

Parts of this lesson are adapted from NNIN lessons *Shrink Me* and *Noodling Around* found at: http://www.nnin.org/education-training/k-12-teachers/nanotechnology-curriculum-materials

Materials per student

- Student Handouts
- Calculator

Materials per lab group of 2-4 students

- Microscope with 4X, 10X, 40X
- Microscope slides (clear glass)
- 1 drop Aniline Blue dye
- Long tooth pick or skewer (for dipping into blue dye)
- Wet paper towel
- Tape - clear adhesive
- Tweezers
- Transparency grid (teacher made)
- A few grains of rice, beads, or small beans
- Small metric ruler
- Pre-made "milli-teacher" Shrinky Dinks®
- Pool noodle with length of 1 meter
- Pool noodle with length of 1 decimeter

Materials per class

- Meter sticks
- Access to the internet and a projector, to play NiseNet's *Intro to Nano* video http://www.youtube.com/watch?v=GmUeCf_bI-s
- Box to collect used slides during cleanup

Advance Preparation: Purchase the materials in the table below:

Source/Website	Material
Michaels Craft Store or Shrinky Dinks Website: http://www.goestores.com/catalog.aspx?storename=shrinkydinks&DeptID=34365&ItemID=9692327&detail=1 and other online suppliers	Shrinky Dinks Crystal Clear Plastic Pack
Local General Store	Pool Noodles
Sigma Aldrich http://www.sigmaaldrich.com	Aniline Blue Dye (Sigma Cat#B8563)

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Day one preparation: Be sure to purchase pool noodles prior to the lab, and cut them into 1 meter and 1 decimenter lengths as shown to the right. Have enough so there is one set per group. Also, set up meter sticks around the room as measuring stations, one on top of the other, so that students can measure their height, as shown in the images below.

One meter and one decimeter pool noodles.

Day two preparation: Set microscopes out (see picture.) Prepare a "tool box" on each lab table to help the students determine the size of their skin cells. Some recommended items: transparency paper with a grid on it (can be purchased or made), a grain of rice or a bead, tweezers, a small ruler, and a calculator.

Make sure microscopes are charged and ready before day two.

Day three preparation: Purchase the Shrinky Dink sheets, which can either be ordered online directly through the Shrinky Dink website or other inline suppliers, or in any Michael's craft supply store. Shrinky Dinks shrink to about 1/9 their original size. Divide your height (in meters) by 1,000 to determine how tall your "milli-teacher" should be. Use this information to draw a stick figure version of yourself on the plastic that is **9 times bigger** than your milli-teacher would be. Then, cut it out and shrink it. You will need one "milli-teacher" per lab group.

Safety Information Aniline blue will stain skin and clothes. Make sure to warn students of this. Also, be sure students are handling the glass slides carefully, as they are sharp.

You don't want the student's hands to look like that →

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Suggested Instructional Procedure:

Time	Activity
Day 1	**Day Before Student Lab**
10 min	Show nanotech video and introduce nanotechnology (http://www.youtube.com/watch?v=GmUeCf_bI-s). While video is playing, pass out Day 1 student worksheets and calculators.
5 min	Introduce the pre-fix table
5 min	Have students answer question 1 while you pass out pool noodles
5 min	Have students answer questions 2-5
5 min	Go over the answers for questions 2-5
10 min	Have students measure their lab partner and go through questions 6-10
10 min	Go over questions 6-10
Day 2	**Day of Student Lab**
5 min	Review what you learned yesterday while a TA or student helper passes out Day 2 student worksheets
2 min	Ask groups to estimate the size of a skin cell
15 min	Give groups time to find skin cells under the microscope
15 min	Give groups a chance to estimate the cell's size
10 min	Allow students to write up their findings
3 min	Reveal the approximate size of skin cells
Day 3	**The day after the student lab**
5 min	Review what the students learned yesterday while a TA or student helper passes out Day 3 student worksheets
5 min	Give students time to discuss questions 1-3 in groups
5 min	Go over questions 1-3 and pass out "milli-teachers"
15 min	Give students time to look at the "milli-teacher" and answer questions 4 and 5
20 min	Introduce the comic project, pass out 1 comic template to each student, allow student to begin project

Teaching Strategies: This lab should be done in groups of two to four, depending on your class size. The comic strip portion on Day 3 is best done individually. Give students time in class to start their comic, and then assign the rest of the project as homework to be turned in a few days later. Some students may have a hard time coming up with ways to approximate the size of the skin cell. Give verbal encouragement and let them know there is more than one "right" answer.

Guided Dialog: *Before* beginning the lab, review the meaning of these terms:

Meter - *The unit of measurement for length used in science and engineering.*

Cell - *The smallest unit of life.*

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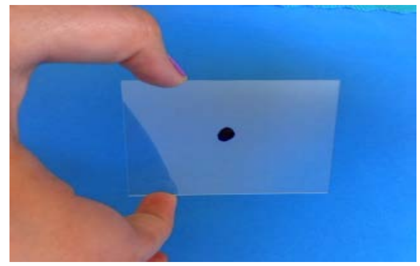
Ask students questions to provoke thought and review what they already know:

1. What tools do we use to determine something's size*? Common answers will be rulers, a weighing scale, measuring tape, etc.*
2. Name one type of cell in the human body. *Answers may include: blood cell, skin cells, sperm cells, egg cells, nerve cells, etc.*

Procedure: During Day 2 of the lab, have the students follow the procedure found in their student worksheet. The section below describes some helpful suggestions.



1. Carefully have the students dip their toothpick into the aniline blue dye and deposit one ***tiny*** drop of the dye onto the middle of their glass slides.

2. The students should gently but thoroughly clean off the back of their hand with a wet paper towel and dry it off.

3. The students should take 4 cm of clear adhesive tape and press it onto the back of their hands with their fingertips (remind them to try to avoid getting fingerprints on the sticky side of the tape). Have the students pull the tape off their hands with tweezers and mount it on the microscope slide, sticky side down, over the dot of blue dye. ***Tweezers are useful for doing this to avoid getting your fingerprint on the tape***. If too much dye is used you get the mess shown on the right. Have the students retry with another slide if this occurs.

4. Have the students use the microscopes to observe the skin cells they isolated and complete the activity as described in their worksheet.

Cleanup: Because the microscope slides will have blue stain on them, ask students to place them in a box. These can be cleaned for re-use. Wear gloves during cleaning to prevent staining of the hands.

Enhancing Understanding: Cover this section *after* the activity.
Review the findings with students:

> Just because an object is small compared to a human being, does not mean it is remarkably small. We calculated that a skin cell, which is invisible to the human eye, is still 1,000 times bigger than a silver nanoparticle
>
> There are different prefixes used to describe size, and it is possible to convert between them. We calculated the human height in meters, centimeters, and millimeters. We learned what a nanometer is.

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Going Further: Students who have a good grasp of the content of the lab can be further challenged with these questions:

1. What other challenges do the small size of nanoparticles present? *Not only is it hard to keep them clean, it is hard to develop tools delicate enough to work with them, and microscopes powerful enough to view them. Nanoscale objects (typically 1-100nm) are below the range of visible light (390-700nm).*
2. How could you calculate the size of a human being in nanometers? *Multiply the height of a human in meters by 1,000,000,000.*
3. What are other prefixes you've heard of in relation to size? *Kilo, macro, mega, etc.*

A great extension to this lesson would be to talk about the size of germs. Germs (bacteria and viruses) are also larger than nanoparticles, and it is important to protect samples from germs as well. Many students will recommend that scientists wash their hands before handling nanoparticles, to get rid of excess skin cells and germs. Using a product called "Glo Germ," which glows under UV light, you can show the students how standard hand washing does not remove all germs. This explains why it is necessary for nanoscientists to wear gloves at all times. See "resources" for potential "Glo Germ" demonstrations.

Assessment: At the end of this lesson, students should be able to convert between meters and centimeters, and meters to millimeters. Students should be able to understand the relative sizes of two objects, given the prefix used for measurement. Students should understand that cells are not the smallest known material. These understandings will be graded based on their responses to the lab questions, and their comics.

Resources:

- AAAS. "Observing Skin Cells Lab Sheet." (accessed June, 2013) http://sciencenetlinks.com/student-teacher-sheets/observing-skin-cells-lab-sheet/
- Glo Germ. "Using Glo Germ." (accessed June, 2013) http://www.glogerm.com/using.html
- Sigma-Aldrich. "Properties of Silver Nanoparticles." (accessed July, 2013) http://www.sigmaaldrich.com/materials-science/nanomaterials/silver-nanoparticles.html
- National Nanotechnology Infrastructure Network. "Shrink Me." (accessed July, 2013) http://www.nnin.org/education-training/k-12-teachers/nanotechnology-curriculum-materials/shrink-me.
- National Nanotechnology Infrastructure Network. "Noodling Around." (accessed July, 2013) http://www.nnin.org/education-training/k-12-teachers/nanotechnology-curriculum-materials/noodling-around

National Science Education Standards (Grades 9-12)

Content Standard E: Science and Technology

- Abilities of technological design
  - identify a problem or design an opportunity
  - propose designs and choose between alternative solutions

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Next Generation Science Standards
MS-LS1-1 Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.

HS-LS2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

Rubric for evaluating comic:

Category	Exemplary 4	Accomplished 3	Developing 2	Beginning 1	Points
Content	Covers topic accurately with details and/or example(s). Idea is plausible. Clearly explains method chosen.	Covers essential knowledge about the idea. Subject knowledge appears to be good. Adequately explains method chosen.	Includes information about the topic but there are 1-2 factual errors. Does not fully explain the method chosen.	Content is minimal OR there are several factual errors. Does not explain the method chosen.	
Illustrations	Uses well labeled illustrations to describe method and application.	Uses illustrations to describe method but lacks details of method and application.	Poorly illustrated images used to describe method and application.	No images used to explain method and application.	
Examples	Provides clear and understandable example(s) of how the method is used and the connection to nanotechnology.	Provides good example(s) of how the method is used and the connection to nanotechnology.	Provides poorly defined example(s) of how the method is used and the connection to nanotechnology.	Does not provide example(s) of how the method is used nor the connection to nanotechnology.	
Organization	Content is well organized and clearly described.	The overall organization is logically organized for the most part.	Content is not clearly organized for the most part.	There is no clear or logical organization.	

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Name:______________________________Date:_____________Class:______________

Student Worksheet

How small is that? Day 1 (with Answers in Red)

You just watched a video introducing nanotechnology. Nanotechnology is the science of working with materials at a very, very small scale (the scale of 1 to 100 nanometers.) Scientists have found that when known elements, like gold and silver, are divided into very small particles, they have unique and often useful properties that they don't possess in bulk form. These unique properties are why nanoscientists work with such small particles. Nanotechnology techniques are already being employed in many electrical devices, such as the ones in your cell phones, and in medicine as well. To understand nanotechnology, we first need to understand how small a nanometer is.

What is a nanometer? The prefix "nano" refers to an object's size, and comes from the Greek word for "dwarf." The meter is the unit for measuring length used in science. See the table below for other size prefixes.

Prefix	Deci-	Centi-	Milli-	Micro-	Nano-
Fraction	1/10	1/100	1/1000	1/1,000,000	1/1,000,000,000
Decimal	0.1	0.01	0.001	0.000001	0.000000001
Scientific notation	1×10^{-1}	1×10^{-2}	1×10^{-3}	1×10^{-6}	1×10^{-9}
Phrase	One tenth	One hundredth	One thousandth	One millionth	One billionth

1. Which prefix in the table represents the smallest number? ______*Nano*____________________

The prefixes are only helpful if you know what they look like. Look at the large pool noodle on your desk. This is one meter. The smaller pool noodle on your desk is a decimeter.

2. How many decimeters does it take to make one meter?________________________________

A meter can be divided up into smaller and smaller pieces, and as the pieces get smaller, the name changes. As we said, one tenth of a meter is called a decimeter. One hundredth of a meter is called a centimeter.

3. Look at the table. What do you think one thousandth of a meter is called? ____*millimeter*____

4. What do you think one millionth of a meter is called?_________*micrometer*_______________

5. What do you think one billionth of a meter is called? _________*nanometer*________________

Look at the walls around the room. At each measuring station, there are two meter-sticks stacked on top of one another. Please use those to measure the height of one of your group members.

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6. Our group member is ___________*~1.6 meters tall*___________________________________

Let's convert their height into centimeters. A centimeter is 1/100th of a meter, meaning that there are 100 centimeters in one meter. To convert their height into centimeters, all you need to do is multiple their height by 100.

7. What is your group member's height in centimeters? __________*~160 centimeters*__________

8. Look at the table. If you wanted to find your group member's height in **millimeters,** how much would you multiply their original height by?_________*1,000*__________________________

9. What is your group member's height in millimeters? ____*~1,600 millimeters*_______________

10. Look at the table. If you wanted to find your group member's height in nanometers, how much would you multiply their original height by?__________*1,000,000,000*__________________

11. What is your group member's height in nanometers? ___*~1,600,000,000 nanometers*______

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Name:________________________________Date:________________Class:_________________

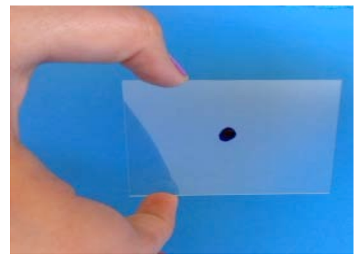
Student Worksheet

How small is that? Day 2 (with Answers in Red)

Measuring your height was pretty easy, because you had meter sticks to help you. Now we are going to try to measure something much smaller. We are going to figure out how to measure the size of one of your skin cells!

1. Before we do that, please write down how big you *think* one skin cell is: *answers will vary*___

Follow these steps to observe your skin cell under the microscope.



a. Carefully dip your toothpick into the aniline blue dye. Deposit one *tiny* drop of the dye onto the middle of your glass slide.

b. Gently but thoroughly clean the back of your hand with a wet paper towel. Dry it off.

c. Take a few centimeters of clear adhesive tape and press it onto the back of your hand with your fingertip (to avoid getting a fingerprint on the sticky side of the tape) Pull the tape off your hand with tweezers and mount it on the microscope slide, sticky side down,over your dot of blue dye. *Tweezers are useful for doing this to avoid getting your fingerprint on the tape.*

d. Make sure the 4x lens (the shortest lens) is in place over the stage. Place the slide onto the stage of the microscope.

e. Look through the eyepiece and turn the coarse focus knob (the largest knob) until an image comes into focus. It should look like scattered blobs.

f. Move the slide around until a nice cluster of blobs moves into the center of your image. Use the fine focus knob (the smallest knob) to make the image as focused as possible.

g. Observe the slide using the 10x objective.

THIS IS WAY TOO MUCH DYE! DON'T DO THIS!!

National Nanotechnology Infrastructure Network *www.nnin.org*

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h. Observe the slide using the 40x objective. Can you see any cells? Draw what you see below.

2. With your group, come up with a way to measure the size of one skin cell. For inspiration, check out the box of items on your desk. Describe your method, using at least three complete sentences, below.

Answers will vary. Students could place the transparency grid over their slide, and see how much space a cell takes up on the grid. Then students could measure the size of the grid and make an estimate. Another possibility: students could measure an object such as a grain of rice, and compare the size of the grain to the relative size of the cell.

3. We estimate that the size of the cell is: ___*answers will vary*______________________________

4. Our teacher told us that the size of one skin cell is about: *50 micrometers in size*____________

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Student Worksheet

How small is that? Day 3 (with Answers in Red)

This week we explored the metric system, and the different prefixes scientist use to measure size. In our exploration, you measured the height of one of your lab group members and analyzed a skin cell. Today, we are going to explore how large and small different objects are compared to one another. Using the table below to help you, please answer the following questions:

Prefix	Deci-	Centi-	Milli-	Micro-	Nano-
Fraction	1/10	1/100	1/1000	1/1,000,000	1/1,000,000,000
Decimal	0.1	0.01	0.001	0.000001	0.000000001
Scientific notation	1×10^{-1}	1×10^{-2}	1×10^{-3}	1×10^{-6}	1×10^{-9}
Phrase	One tenth	One hundredth	One thousandth	One millionth	One billionth

1. Your teacher, a human being, is 1.6 meters tall. A skin cell is about 50 micrometers in size. This means that a skin cell is roughly ___c. 1,000,000_ times smaller than a human being.

a. 1,000 c. 1,000,000
b. 100,000 d. 1,000,000,000

2. A silver nanoparticle is a particle of silver that is about 50 nanometers in size. When silver is that small it has antimicrobial properties that can be used to prevent bacteria from growing. Certain brands of bandages have silver nanoparticles in them, to prevent cuts from being infected.

How many times smaller is a silver nanoparticle than a human being?___d. 1,000,000,000______

a. 10,000 c. 1,000,000
b. 100,000 d. 1,000,000,000

3. A skin cell is 1,000 times bigger than a silver nanoparticle. But what does "1,000 times bigger" really mean?

If you shrunk your teacher down by a factor of 1,000, you would measure them in ____________
________c. millimeters____

a. decimeters c. millimeters
b. centimeters d. nanometers

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4. Your teacher decided to make a model of herself/himself 1,000 smaller than her actual size. (Each table will get one). You may have to use a microscope to see her! Please write down one observation about milli-teacher:

Answers may vary. Many students will write about how you can't see the detail without using a microscope. ____

____.

For reference, your teacher is 1,000 times bigger than the milli-teacher you have on your table, just like a skin cell is 1,000 times bigger than a nanoparticle.

5. If you were trying to look at a silver nanoparticle under a microscope, and one of your skin cells fell onto your sample, what would happen? **Remember that nanoparticles are smaller than visible light so you cannot use an optical microscope to see them. You must use special microscopes such as a Scanning Electron Microscope or an Atomic Force Microscope to see them. These microscopes use electrons and atomic forces to visualize nanoscale objects.**

Answers may vary, but should include the idea that the skin cell would block the view of the nanoparticle because it is much larger. ____

____

Comic Project: The only way scientists can work with silver nanoparticles is if there are no big, evil skin cells around to block their view. **What can scientists do to make sure none of their skin cells get on the silver nanoparticles they're trying to work with?** Create a five-scene comic that explains your idea. You will be given a piece of white paper broken into five boxes to help you do this. Each box should have a picture and one full sentence of description. This is due one week from today, and must be in color.

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Title of your Comic:

____

Created By: ____________________

Date: _________________________

Period: ________________________

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