Teacher's Preparatory Guide

Scale Models

Overview: This activity gives students a sense of size and scale using objects that cannot be seen with the naked eye. This activity focuses on measuring length, for this is the most common feature when presenting nanoscale structures or nanoscale science. Understanding size and scale is fundamental to learning about nanotechnology as size defines the nanoscale (1-100nm in one dimension). Size is often divided into scales – macro, micro, nano and atomic. Helping students understand these "worlds" is an important part of their science knowledge and will help them to understand the relatively small size of the nanoscale. It can be introduced into the K–12 curriculum by discussing scientific measurement. This activity connects well to the introduction of atoms and cell structures as well as advancements in technology.

Purpose: This activity is designed to help students understand the size and scale of objects.

Time Required: ~15 minutes

Level: Elementary, middle school, and high school; general science, life science, mathematics

Big Idea: Size and Scale

Teacher Background: Students often have trouble understanding size and scale in science, due to the different measurement units taught (metric and English), the different types of units used for length and volume, and the lack of consistent practice through their educational career. These lessons present size and scale to students from kindergarten to high school. Common student misconceptions[1] include:

- mixing units such as centimeters and inches
- not realizing the connection between relative and absolute sizes of two objects
- the inability to use measurement tools accurately
- believing that objects that cannot be seen with the naked eye are approximately the same size

This lesson introduces scale by demonstrating scales as factors of ten. This facilitates the introduction and reinforcement of the metric scale and paves the way to the discussion of lengths that are smaller than what can be seen with the naked eye. The lesson also introduces the concept of using different tools to address different length scales. A commonly used ruler gives way to the microscope, which eventually gives way to the scanning electron microscope (SEM) and the atomic force microscope (AFM) when observing lengths that shrink to the nanoscale.

Source:

1. Stevens, S., Sutherland, L., Krajcik, J., *The Big Ideas of Nanoscale Science and Engineering*. NSTA Press, 2009.

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Materials per class

- drawing of a cell or an ant that is 1 meter in diameter on butcher paper or project an image onto a screen
- masking tape (to hang the drawing on the wall)
- meter stick

Materials per student

- clay or Play-Doh, at least 1 cubic inch
- metric rulers
- colored pencils

Advance Preparation: Acquire butcher paper and colored pencils at a craft supply store. Alternatively, you can find a picture of a cell online, and either print as transparency and use with an overhead, or print and use with a document camera. Purchase play dough or clay, which may be found at a craft store. Play-Doh sells mini canisters of their product in packs of ten. This product may facilitate material logistics. Alternatively, you can make your own play dough by using a recipe at this link: http://www.playdoughrecipe.com

Advance Preparation for Kindergarten–2nd grade

1. Draw an ant that is 1 meter long on butcher paper. An average ant is about 3 mm long, so the scale you will use is 3 mm:1 m.
2. Calculate your height (or any other object) to give the children a new frame of reference by using this formula:

   length of the object in meters $\times$ *1000* $\div$ *3 = scaled length in meters*

   The result will be the scaled length of the object in meters (as compared to your meter-long ant).

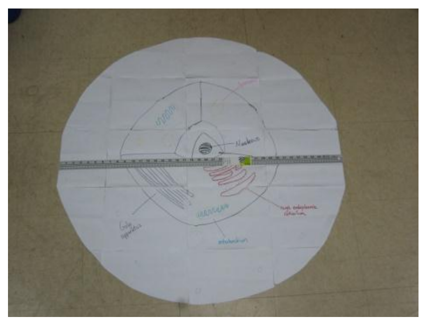
Example: A student is 1.1 meters tall. To calculate her scaled height as compared to the meter long ant:

Step 1: 1.1 meters × 1000 mm/m= 1100 mm
Step 2: 1100 mm ÷ 3 = 366.7 scaled meters

So if an ant were enlarged to a length of 1 meter, and the student increased by the same amount as the ant, the student would stand approximately 367 meters tall.

Advance Preparation for Grades 3–12

1. Draw a cell that is 1 meter in diameter on butcher paper or project an image of a cell onto a screen. The average animal cell is 10 µm in diameter, so the scale you will use is 10 µm:1 m.



An example of a meter-sized cell.

2. Calculate your height as well as other items within this scale for interest.

Example: If a person is 1.5 meters tall:

Step 1: 1.5 m × 1,000,000 µm/m= 1,500,000 µm
Step 2: 1,500,000 µm ÷ 10 = 150,000 scaled meters or 150 km!

For height comparison:

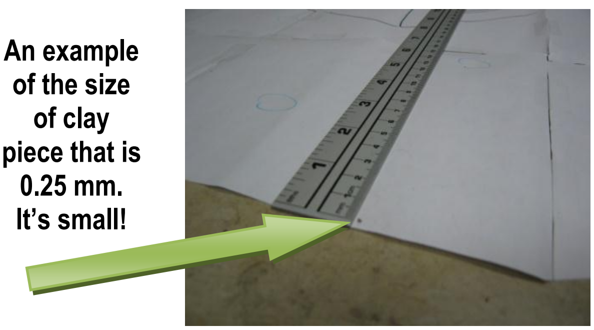
Kindergarten–Grade 2		Grades 3–12	
Height of a basketball hoop	3 m	Mount Everest	~ 9 km
Ten story building	~ 30 m	Space shuttle orbits	320 – 390 km
Statue of Liberty	50 m	Aurora	100 km
Length of a football field	91.44 m		

Other interesting objects to mention may be:

Object	Actual length	Scaled length
Thickness of cell membrane	10 nm	10 mm
Transistor Gate	90 nm	9 mm
Glucose molecule	1 nm	0.1 mm
Width of DNA strand	0.25 nm	0.25 mm

Safety Information: None. Tell students not to eat the clay or play dough.

Teaching Strategies:

Kindergarten–Grade 2	Grades 3–12
1. Ask students to think of objects that are small. Ask students, "How big is a cell of a normal ant?" Students will soon learn that all living things are made of cells, but many students are often confused about how big a cell is and will confuse a cell with organs or tissue. 2. Present the poster of the *scaled ant.* Explain that the ant has now grown to be a meter long. 3. To provide a frame of reference, give an example of how tall you would be if you were to increase in size by the same scale. 4. Distribute play dough to each student. Ask students to show the *size of a cell of this scaled ant*, using the play dough. Give students a fair amount of play dough to fairly assess the student's concept of scale. When all the students are done, have them share their "model" with two other students. Allow students to form their piece of play dough without outside input. Encourage them to share and present their justifications orally and/or on paper. 5. Share results as a class to assess the range of sizes that students came up with and encourage students to justify their answers. 6. Share the scaled length of a cell of a meter-sized ant (3 mm). Have students use their rulers to measure and correct their model.	1. Ask students to think of objects that are small. Present the poster of the scaled cell. Explain that the cell has been increased to be a meter in length. Review where cells are found, the function of the cell, and perhaps the functions of various parts of the cell. 2. To provide a frame of reference, give an example of how tall you would be if you were to increase in size by the same scale. 3. Distribute play dough to each student and ask students to demonstrate *the width of a DNA strand in this scaled cell* using the play dough. Have them share their model with two other students. Share results as a class to assess the range of sizes that students came up with and encourage students to justify their answers. 4. Explain the scaled length of the width of a strand of DNA (0.025 mm/2.5nm). Have students use their rulers to measure and correct their scale model. An example of the size of clay piece that is 0.25 mm. It's small! 

For reinforcement: If possible, keep the large ant or cell poster and a sample play dough piece out and visible in the classroom for the rest of the unit as reinforcement.

Cleanup: Collect play dough in canisters.

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Assessment:
Students should understand the concept of scaled models and how they can be used to more easily comprehend relationships in size. For example, a student should be able to calculate the scaled height of their chair, given the scale model of the ant or cell.

National Science Education Standards (Grades K–4)
Content Standard B: Physical Science

- Properties of objects and materials

Content Standard E: Science and Technology

- Understandings about science and technology
- Abilities to distinguish between natural objects and objects made by humans

National Science Education Standards (Grades 5–8)
Content Standard B: Physical Science

- Properties and changes of properties in matter

Content Standard E: Science and Technology

- Understandings about science and technology

National Science Education Standards (Grades 9–12)
Content Standard B: Physical Science

- Structure and properties of matter

Content Standard E: Science and Technology

- Understandings about science and technology

Principles and Standards for School Mathematics
Measurement

- Understand measurable attributes of objects and the units, systems, and processes of measurement
- Apply appropriate techniques, tools, and formulas to determine measurements

Numbers and Operation

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems
- Compute fluently and make reasonable estimates

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