From Atom to Organism: Choosing the Best Tool

Overview
This lesson allows students to explore the concept of size and scale as they relate to biological organization levels, as well the necessity of choosing the correct tool when conducting scientific research. Students will create a paper foldable by exploring various visualization tools and techniques, such as light microscopy and scanning electron microscopy, and matching them with biological structures of varying sizes to understand how the tool may be used to “see” structures of interest.

Key Search Words
biology, biological sciences, biomedical sciences, 9-12, high school, size, scale, organization, light microscope, electron microscope, gel electrophoresis, computerized tomography (CT), magnetic resonance imaging (MRI), protein, cell, tissue, organ, organism

Learning Objectives
After completing this lesson, the student will be able to:
- Organize levels of biological organization from smallest to largest.
- Describe tools that may be used to visualize biological structures of varying sizes.
- Explain the importance of selecting the most appropriate tool when conducting scientific research.

Curriculum Alignment
NGSS Standard:
HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

NGSS Science and Engineering Practice:
Planning and Carrying out Investigations: Select appropriate tools to collect, record, analyze, and evaluate data.

Classroom time required
- 135 minutes (approximately three 45-minute class periods)

Materials & Technology
- Computer with access to Google Slides and Google Docs (or comparable software)
- Projector that can be connected to computer
- Printer
- Laminator or plastic document sleeves
- Scissors
- Glue or tape
- Teacher materials
    - Teacher slide set
    - Tools and Techniques card set key
- Student handouts
    - Prior Knowledge card set
    - Foldable template
    - Tools and Techniques card set
    - Scale number line

Safety
This activity uses common, everyday materials typically found in a classroom. Students should be aware of others as they move around the room to join their small groups. They should also be careful when using the scissors to create their foldable and cutting out activity cards.

Teacher Preparation for Activity

1. Print student Prior Knowledge card set and Tools and Techniques card sets (one copy per student)
    a. Teacher may cut these out and paperclip one set for each student, or allow students to cut the cards out themselves)
2. Print student foldable template (one per student)
3. Print size/scale number line (one per student)
4. Set up Teacher slide set to present to students
5. Prepare scissors and glue for students

Student Preparation for Activity

Before completing this lesson, students are expected to have an understanding of biological levels of organization (organisms are made of organs, organs are made of tissues, tissues are made of cells, etc.). A review of the tools and techniques that students have already used in previous life sciences classes may be helpful. Students should also have a basic understanding of metric measurements and prefixes.

Procedure

Lesson Activities	Approximate Time Required

Activating Strategy
 	
The teacher will…
 	
1. Project individual images (produced by scanning electron microscopes) of various biological structures. *(See accompanying slide set.)*
    a. For each image, ask students what they think the structure is. Call on student volunteers to share their ideas.
    b. Continue to answer key slides and share the actual identity of each image.
	10 minutes

Prior Knowledge
 	
The teacher will…
 	
1. Group students into small groups of 3-4.
2. Distribute the activity cards; *each student should receive one set (see teacher preparation instructions).*
3. Instruct students to work with their group to organize their cards in order from **smallest** to **largest**. Allow students time to complete the task.
4. Instruct groups to rotate to another group's cards and check their answers, adjusting the position of the other student's cards as needed.
    a. When they are finished, they should return to their own cards to see if any changes were made.
    b. Instruct students to discuss any changes with their group. If any changes were made, students should decide as a group whether they want to keep those changes or return their cards to their original order.
5. As a whole group, review the correct order.
    a. (atom → DNA → protein → cell → tissue → organ → organism)
6. Distribute class copies of the scale number line. *The teacher may choose to laminate these for longevity.*
    a. Point out to students that the scale is not actually linear, and that the line does not show the true size difference between each value. Also point out the main unit of measure (meters).
7. Instruct students to place each of their cards on the scale in the location where they think the card belongs.
8. Project the actual sizes for students to check their responses (see teacher slide set slide #21).
    a. The students should discuss structures that aren't in the provided image, such as organs and organisms, and decide where they think each structure belongs on their number line.
	40 minutes

Activity

70 minutes

The teacher will…

Part 1: Foldable Preparation

1. Distribute a foldable template to each student.
2. Instruct students to follow the instructions provided on the template to fold and cut their foldable.
3. Instruct students to glue their cards from the Prior Knowledge activity to the outside of their foldable, in order from smallest to largest.

Part 2: Choosing the Best Tool

4. Distribute the Tools and Techniques cards; *each student should receive one set (see teacher preparation instructions).*
5. Instruct students to take a moment to read each of their cards.
    a. **Possible questions to ask students**:
        i. Have you heard of any of these terms?
        ii. Do you know what they are or what they are used for?
6. Explain to students that each of the terms is a tool or technique used to *visualize* things, from very small to very big, and that they will be exploring how each of these tools or techniques works.
    a. **Possible questions to ask students**:
        i. Why might it be useful to be able to see an organ? DNA? An atom?
7. Group students into seven small groups.
8. Assign each group one of the seven tools or techniques provided on the activity cards. *If the class is too small to create seven groups, one or more groups may be assigned multiple tools or techniques.*
9. Instruct each group to research their assigned tool or technique. Explain that they will become the "expert" in their assigned tool/technique. On each student's corresponding card, they should describe the following:
    a. A brief description of how the tool or technique works.
    b. The scale at which the tool or technique is typically used to "see" or measure.
10. Redistribute student groups to create new groups with one student "expert" per tool/technique.
11. Instruct students to share their assigned tool/technique with their group members, summarizing how the tool/technique works and the scale at which it is typically used to "see." As students share, the other group members should complete their personal card set for each tool/technique.
12. Return to the whole group and review each of the tools/techniques by having students share the information on their cards.
    a. As students share, correct any misinformation and/or add additional details as students check their own cards.
13. Return students to groups; instruct students to match each of the tools/techniques cards with the Prior Knowledge cards.
    a. For example, which tool do you think would be best used to view *atoms?* What about *tissues?*
14. Instruct students to glue their cards down on the inside of the appropriate flap on the inside of their foldable. ***Each card from the Prior Knowledge card set should have an accompanying tool/technique card underneath.***
    a. Explain to students that each of these tools and techniques has a wide range of sizes that they can visualize. The values on their cards are just typical examples. There is no right or wrong answer for their cards. For example a transmission electron microscope could be used to visualize atoms, DNA, or proteins. Students should understand that scientists may choose different tools for different circumstances.

Part 3: Sample Images (Optional, time permitting)

15. Instruct students to use the internet to find images created by each of the tools or techniques highlighted in their foldable. Students may print the images they find and glue them underneath each biological structure flap. For example, if students decided that a scanning electron microscope (SEM) is the best choice to view tissues, they may find an image created by an SEM of human tissue, print it and glue it underneath the "Tissue" flap, toward the middle of their foldable.

Discussion	15 minutes
The teacher will… 1. Ask discussion and extension questions to facilitate discussion surrounding the topic of **size-and-scale** as it relates to the biomedical sciences, as well the importance of choosing the right tool when conducting scientific research. **Possible questions to ask students:** a. Why is it important to know the approximate size of biological structures? b. Why is it important to know the scale at which these tools and techniques can be used to visualize things? c. How do you think scientists studied very small things before the invention of tools such as electron microscopes? d. What might happen if a scientist chooses the wrong tool for the structure they would like to visualize? e. Gel electrophoresis does not provide a scientist with information about the nucleotide sequence of a sequence. What tool might a scientist use to determine the nucleotide sequence of DNA? Why might that be useful to know?	

Differentiation

This lesson is intended for standard and honors biology students, as well as students in AP and upper level science elective courses, such as AP Biology of PLTW Medical Interventions. There are a variety of ways this lesson could be adapted to learners at different levels. Possible differentiation strategies include:

For students who need additional support:

- The teacher may choose to stop at various points throughout the lesson. For example, the Prior Knowledge activity may be completed as a stand-alone activity, either as review or to introduce the concept of organization levels.
- The teacher may choose to reduce the number of Prior Knowledge cards and Tools/Techniques cards, focusing only on tools/techniques that the students use or will use throughout the course.

For students who are prepared for independent practice or extension:

- The teacher may choose to have students create the entire foldable at one time. For example, students could be given a list of organization levels and a list of tools and tasked with ordering the levels, researching the tools, matching them and gluing them into their foldable.
- The teacher may choose to have students complete an extension activity. For example, following the discussion questions at the end of the lesson, students may be tasked with researching the process of Sanger sequencing or next generation sequencing and producing an infographic to illustrate how the process provides information about the nucleotide sequence of a DNA segment.

For virtual delivery formats:

- An alternative to paper foldables may be used. For example, the teacher may use a single-page graphic organizer that students may complete electronically, including using draggable “cards” and inserting images where appropriate.
- Whole group discussion may be facilitated using online tools such as Padlet.
- Small group discussion may be facilitated using breakout rooms.

Assessment/Check for Understanding

Provide additional examples of biological structures and challenge the students to determine which of the tools or techniques on their foldable would be the most appropriate choice to view each structure. Students may first be tasked with determining the size of the structure, and how it compares to the structures on the outside of their foldable, before choosing a tool/technique

Throughout the remainder of the school year, challenge students to determine which tool or tools would be best suited to the task they are working on. For example, if students will be analyzing patient DNA to determine the identity of a crime perpetrator, ask students to return to their foldable and decide which, if any, tool or technique they think they will be using to do so.

Required resources

Student card sets
Student foldable template
Student size/ scale number line
Teacher slide set

Sources

Image sources:

Slide Set Title Page Microscope Image:
"Microscope" by BWJones is licensed under CC BY-NC-ND 2.0. To view a copy of this license, visit https://creativecommons.org/licenses/by-nd-nc/2.0/jp/?ref=openverse.

Activating Strategy Mystery Images:
Bell, A. (n.d.). *Bio-EM Images*. NCSU Analytical Instrumentation Facility. https://www.aif.ncsu.edu/bio-em-images/

Prior Knowledge Card Set, Muscle Tissue:
"File:414 Skeletal Smooth Cardiac.jpg" by OpenStax College is licensed under CC BY 4.0. To view a copy of this license, visit https://creativecommons.org/licenses/by/4.0?ref=openverse.

All other card images from Canva. www.canva.com

Lesson Activity Slide #21
Image from Wikipedia Commons. Licensed under the Creative Commons Attribution-Share Alike 2.5 Generic license. Authors: Guillaume Paumier, Philip Ronan, NIH, Artur Jan Fijałkowski, Jerome Walker, Michael David Jones, Tyler Heal, Mariana Ruiz, Science Primer (National Center for Biotechnology Information), Liquid_2003, Arne Nordmann & The Tango! Desktop Project

Appendices

Teacher Materials
1. Teacher Slide Set
2. Tools and Techniques card set key

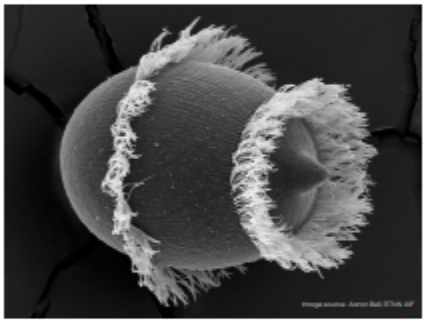
Student Materials
1. Prior Knowledge card set
2. Foldable template
3. Tools and Techniques card set
4. Scale number line

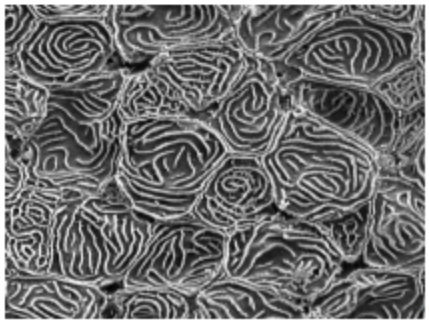
Teacher Materials

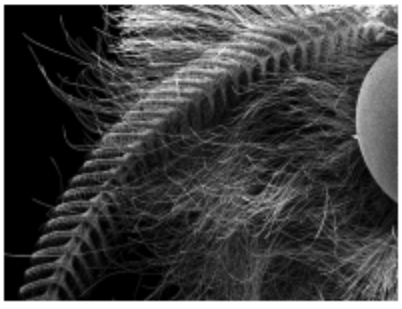

FROM ATOM TO
ORGANISM:
Choosing the Best Tool
A size-and-scale lesson to for use in the biological sciences classroom.

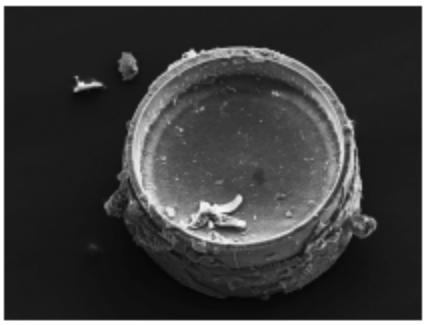

Activating
Strategy

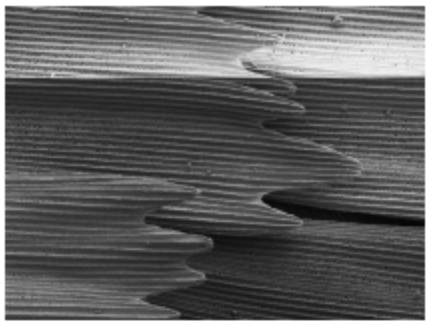

What is it?

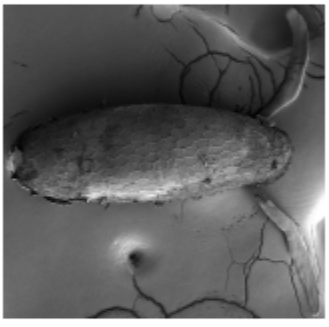


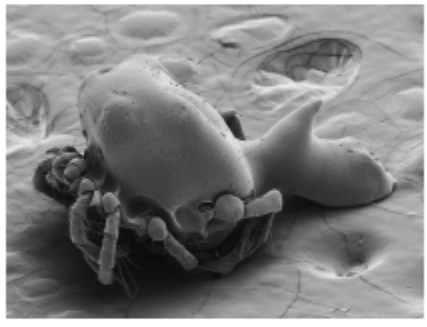


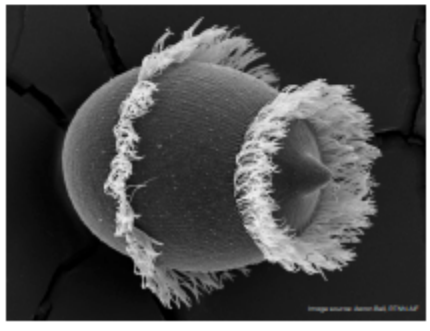




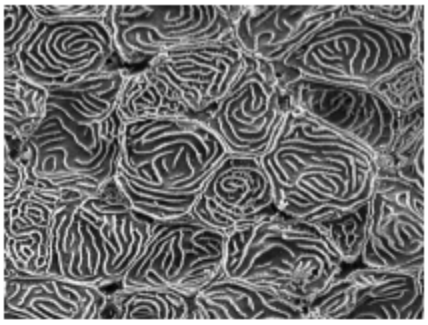






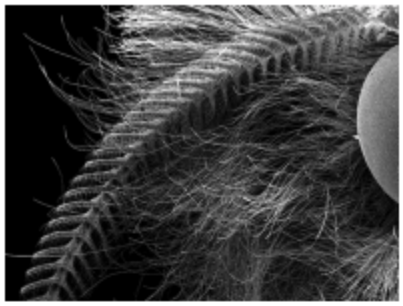


Didinium nasutum, a single-celled aquatic eukaryotic organism



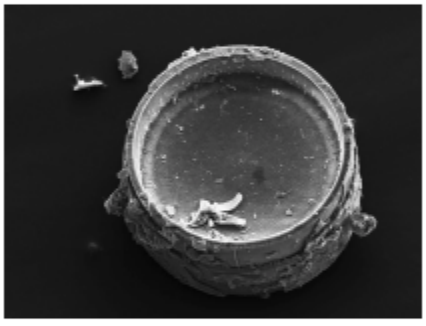
Goldfish gill cells

Image source: Axion Bad, ETH Zürich



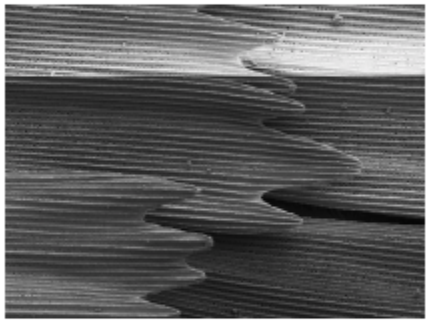
Moth antennae

Image source: Axion Bad, ETH Zürich



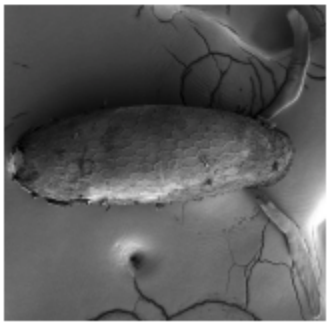
Diatom

Image source: Axion Bad, ETH Zürich



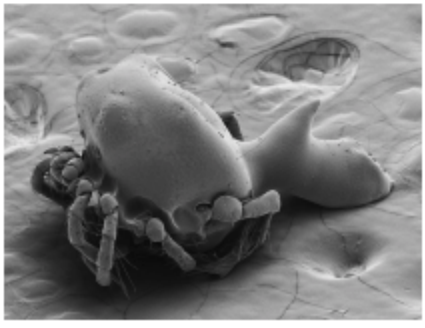
Butterfly wing scale

Image source: Axion Bad, ETH Zürich



Fly egg

Image source: Axion Bad, ETH Zürich



Water mite

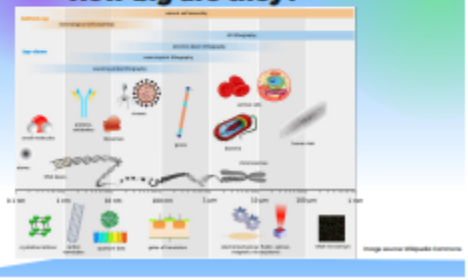
Image source: Axion Bad, ETH Zürich

Prior Knowledge Activity

Your Task:

Place your cards in order from *smallest* to LARGEST.

How big are they?



FROM ATOM TO ORGANISM: CHOOSING THE BEST TOOL

Lesson Activity Part 2 Card Set

Teacher Instructions: Print one copy per student. Cut out the card set and paperclip or place in a bag. Distribute one card set to each student. Alternatively, have students cut out the cards (cards are printed out of order).

Note; A blank card is provided to add additional cards, if desired.

Scanning Electron Microscope

How it Works:

Uses electrons to visualize the surface of things

Typical size of structures:

~10 nm

Gel Electrophoresis

How it Works:

Separates DNA fragments by size and shows them as bands on an agarose gel

Typical size of structures:

~500 nm

Computerized Tomography

How it Works:

Uses many x-rays from various angles to form detailed images of body structures

Typical size of structures:

~1 cm

Atomic Force Microscope

How it Works:

Uses a very small tip to scan the surface of an object, creating a 3-D view of its surface.

Typical size of structures

~1 nm

Magnetic Resonance Imaging

How it Works:

Uses magnets and radio waves to produce detailed cross-sectional images of body structures

Typical size of structures:

~1 cm

Transmission Electron Microscope

How it Works:

Uses electrons to visualize thin slices of things

Typical size of structures:

~0.1 nm

Light Microscope

How it Works:

Uses visible light and lenses to magnify things

Typical size of structures

~5 µm

How it Works:

Typical size of structures:

Student Materials

FROM ATOM TO ORGANISM: CHOOSING THE BEST TOOL

Prior Knowledge: Card Set

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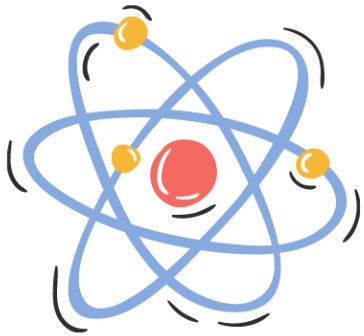
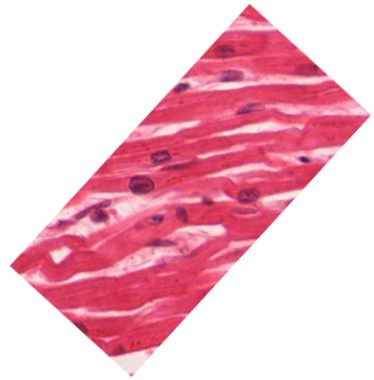
Atom

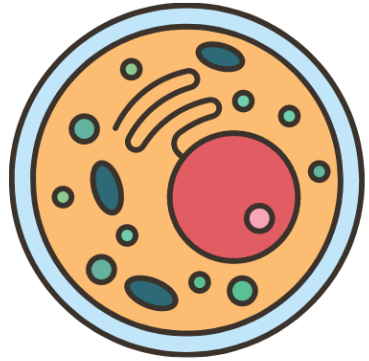


Protein

Tissue

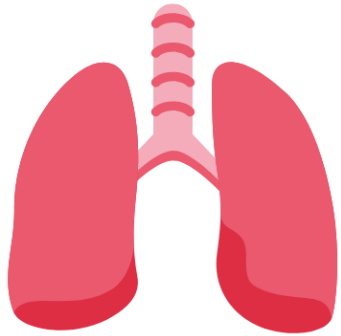


Cell



DNA

Organ



Organism

Largest

Instructions:

1. Fold along the dotted lines.
2. Cut along the solid lines.

Smallest

Size and Scale of Biological Structures

FROM ATOM TO ORGANISM: CHOOSING THE BEST TOOL

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Typical size of structures:

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How it Works:

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Light Microscope

How it Works:

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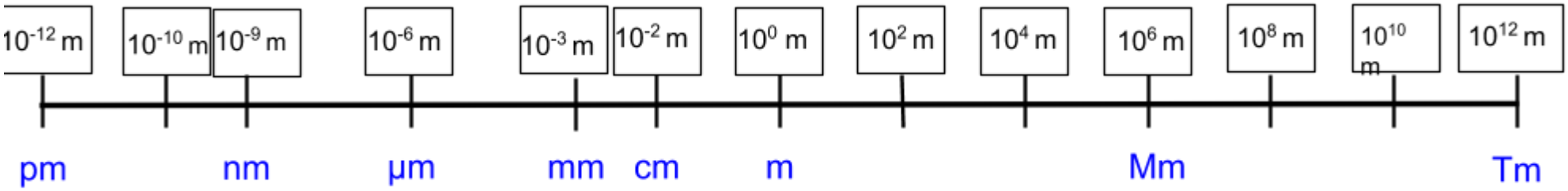
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