WASHINGTON MESA AND
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GENOME SCIENCES EDUCATION OUTREACH

AMAZING Cells

A Cell Biology Unit for Grades 5 through 7

Megan T. Brown, Ph.D., Maureen Munn, Ph.D., Laura Tyler

Amazing Cells—A Cell Biology Unit for Grades 5 through 7

Developed by Washington MESA and University of Washington Genome Sciences Education Outreach

Authors

Megan T. Brown, Ph.D., Maureen Munn, Ph.D., Laura Tyler
Writing and Development Team

Megan T. Brown, Ph.D.
Department of Genome Sciences Education Outreach
University of Washington
Seattle, WA

Maureen Munn, Ph.D.
Department of Genome Sciences Education Outreach
University of Washington
Seattle, WA

Laura Tyler
Washington MESA (Math, Engineering, and Science Achievement)
University of Washington
Seattle, WA

Field Test Teachers

Kim Wagner
North Bend Elementary School
North Bend, WA

Mary Holmberg
Meadows Elementary School
Meadows, WA

Constance Wood
Seattle MESA
University of Washington
Seattle, WA

Document Design and Production:
Jo-Ann Sire, John Linse,and Jessie Schutzenhofer

Illustrations: Diana Lim, Maureen Munn, Megan Brown

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Laura Tyler
University of Washington
Box 352181
Seattle, WA 98195
(206) 543-0562
ltyler@u.washington.edu

Maureen Munn, Ph.D.
University of Washington
Box 355065
Seattle, WA 98195
(206) 616-4538
mmunn@u.washington.edu

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Introduction

Amazing Cells is an instructional module for grades 5-7 developed by Washington MESA and University of Washington Genome Sciences Education Outreach. The seven activities in this module engage students in learning about cells, the building blocks of life. This topic area and the approaches used in this unit, listed below, reflect the recommendations presented in the National Science Education Standards (National Research Council, 1996). The organization of living things into cells is a fundamental concept in biology, and learning about cells provides a natural link between the study of whole organisms and molecular processes, including genetics. The study of cells also provides an ideal context for learning to use an important scientific tool, the microscope. Students of this age are excited to use microscopes to view very small things up close, and they are old enough to use them correctly and successfully. A strength of this curriculum is its integration of math and science concepts throughout the activities. Students will frequently be called upon to measure, estimate, use the metric system, scale up numbers proportionately, and calculate surface area and volume.

In the *Amazing Cells* activities, students will:

- Learn through a variety of approaches, including active investigation, discussion, listening, reading, and writing
- Work with concrete materials
- Make connections between science and mathematics
- Employ higher level thinking skills through observation and analysis of data to develop conclusions about the natural world
- Respond to open-ended questions
- Learn about science careers by modeling the jobs of scientists and by reading and discussing the Career Link features
- Collaborate in small groups
- Work with their families on investigations through the Family Link feature

PEDAGOGY

Throughout the unit, students work on activities in small groups, collaborating and sharing information with each other. Teachers can group students in a variety of ways, for example, socially (with friends), by ability (mixed or same), or randomly. Teachers may use one type of grouping one day and another the next, or use the type of grouping that works best in her/his class.

Each activity follows a science learning cycle that has several phases. Students *encounter* a concept, *investigate* or *explore* it, *reflect* on their learning, and then *extend* their knowledge or *apply* what they have learned to a new situation (Karplus & Thier, 1967; Lawson, 1995; Marek & Cavallo, 1997). In this approach, exploration is central to the students' learning. Their understanding of underlying concepts is developed during the reflection that accompanies and follows the exploration. It derives from their observations and experiences during the exploration. In contrast, a more traditional approach to science teaching involves imparting knowledge to students through instructor lectures and explanations and student confirmation of this knowledge through laboratory activities.

As students are engaged in the activities, teachers should circulate around the room to ensure that all students are on task and to encourage them to delve deeper. Here are some useful strategies:

- Giving students the opportunity to think out loud, discuss their thinking with their peers, and reflect on their ideas by writing in their laboratory notebooks
- Employing group learning strategies (for example, “Think-Pair-Share,” Lymna, 1981)
- Encouraging students to focus on the process of solving the problem and developing their critical thinking skills, not just on obtaining the “correct” answer
- Asking students open-ended questions that are clearly stated and that help guide student discovery and learning. Teachers should be sensitive to their students’ cultural perspectives on questioning.

Tangible assessments, such as answering questions in writing, filling out data tables, and drawing objects observed in the microscope, are integrated throughout the Amazing Cells activities. In addition, teachers should continually carry out formative assessments of student learning as they circulate around the room when students are carrying out the activities. Formative Assessment suggestions for each activity are included in the activity chapters. Teachers can ask themselves the questions below as they observe any of the student activities:

Formative Assessment of Student Learning

- Are students actively engaged?
- Are the student sheets filled out or blank?
- Do students articulate their ideas?
- Are students discussing with each other, listening to each other, justifying their ideas about what they think, and refining their ideas based on group discussions?
- Do students propose experiments for additional testing?
- Can students justify their conclusions using what they have learned?
- Are students able to apply their learning to a new situation?

NOTEBOOKS

When students are engaged in a hands-on activity, they often focus on doing the activity but neglect to fully record their findings or consider implications of their discoveries. We encourage teachers to use science notebooks in conjunction with the student sheets included in this unit. Every scientist uses a laboratory notebook to record the details of each experiment, including purpose, hypothesis, method, results (observations, data tables, graphs), and conclusions, as well as insights, contradictions, and ideas for further experimentation. Students can use laboratory notebooks (and student sheets) in much the same way, modeling authentic science practice. The student sheets are designed to help students record their observations in a logical manner, and they include questions that challenge students to analyze results. If desired, the student sheets can be taped into the science notebooks after they have been completed and graded. Students should also be encouraged to record in their notebooks additional observations and reflections that have not been specifically elicited by the student sheets. The science notebook provides a permanent record of experiments that can be referenced well after completion. The process of organizing data and observations in a notebook leads students to organize their thoughts coherently, which helps them to recognize patterns in their data and make inferences about what they are studying.

Overview

The *Amazing Cells* curriculum consists of seven linked activities (Table I) covering eight major concepts in cell biology (Table II). Many of these concepts overlap with state and national science standards for grades 5-8.

TABLE I. AMAZING CELLS ACTIVITIES

Activity	Description
1. Living and Non-Living	By sorting objects into living and non-living categories, students develop a definition of life.
2. Introduction to Microscopes	Students learn how to use compound microscopes and gain experience viewing and drawing microscopic objects.
3. Field of View	Students learn about a microscope's field of view and how to use it to measure the size of microscopic objects.
4. Plant and Animal Cells	Students observe plant and animal cells in the microscope, measure their size, and identify cell parts.
5. Modeling Cells	Students build a simple cell model and discover the relationship between cells, tissues, and organs.
6. Drawing to Scale	Students draw microscopic objects to scale to demonstrate their knowledge of the small size of the objects and their ability to calculate how small to draw each object.
7. Sizing Up Cells	Students learn that cells are small so that nutrients and wastes can easily move in and out of them.

TABLE II. MAJOR CONCEPTS

CONCEPT	ACTIVITY 1	2	3	4	5	6	7
1. Living things have characteristics that distinguish them from non-living things: growing, reproducing, consuming/eating, getting rid of waste, reacting to the environment, and dying.	•			•			•
2. Cells are the building blocks of living things.				•	•		•
3. Cells have parts with specific functions: the nucleus, DNA, cytoplasm, cell membrane, and cell wall.				•	•		•
4. Microscopes are tools that allow the observation and study of very small objects such as cells.		•	•	•		•	
5. Cells are extremely small.				•		•	•
6. Cells are very small so that materials such as nutrients and wastes can be exchanged efficiently between the inside and outside of the cell.							•
7. Models help us understand complex biological structures such as the cell.					•		•
8. Cells make up a tissue, and tissues make up an organ.					•		

Organization

Each activity is organized into the following sections:

- Overview (including required materials and tips for getting ready)
- Background Information for Teachers
- Presenting the Activity
- Formative Assessment of Student Learning
- Overhead Masters
- Student Sheets
- Interest Links (extra readings and mini-activities)

National Science Standards and the Amazing Cells Activities

Amazing Cells fulfills many of the learning objectives established by the National Science Education Standards for grades 5–8 (National Academy of Sciences, 1996). The content standards relevant to ***Amazing Cells*** are excerpted below and include standards related to science as inquiry, subject-specific standards in life science and physical science, standards related to science in personal and social perspectives, and standards that address the history and nature of science.

CONTENT STANDARD A → Science As Inquiry

Abilities Necessary to do Scientific Inquiry

- Use Appropriate Tools and Techniques to Gather, Analyze, and Interpret Data
- Develop Descriptions, Explanations, Predictions, and Models Using Evidence
- Think Critically and Logically to Make the Relationships between Evidence and Explanations
- Use Mathematics in all Aspects of Scientific Inquiry

CONTENT STANDARD B → Physical Science

Transfer of Energy

- Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection).

CONTENT STANDARD C → Life Science

Structure and Function in Living Systems

- Living systems at all levels of organization demonstrate the complementary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms, and ecosystems.
- All organisms are composed of cells—the fundamental unit of life. Most organisms are single cells; other organisms, including humans, are multicellular.
- Cells carry on the many functions needed to sustain life. They grow and divide, thereby producing more cells. This requires that they take in nutrients, which they use to provide energy for the work that cells do and to make the materials that a cell or an organism needs.
- Specialized cells perform specialized functions in multicellular organisms. Groups of specialized cells cooperate to form a tissue, such as a muscle. Different tissues are in turn grouped together to form larger functional units, called organs. Each type of cell, tissue, and organ has a distinct structure and set of functions that serve the organism as a whole.

Reproduction and Heredity

- Reproduction is a characteristic of all living systems; because no individual organism lives forever, reproduction is essential to the continuation of every species.

Regulation and Behavior

- All organisms must be able to obtain and use resources, grow, reproduce, and maintain stable internal conditions while living in a constantly changing external environment.

CONTENT STANDARD F → Science in Personal and Social Perspectives

Science and Technology in Society

- Science and technology have advanced through contributions of many different people, in different cultures, at different times in history.
- Scientists and engineers work in many different settings, including colleges and universities, businesses and industries, specific research institutes, and government agencies.

CONTENT STANDARD G → History and Nature of Science

Science as a Human Endeavor

- Women and men of various social and ethnic backgrounds–and with diverse interests, talents, qualities, and motivations–engage in the activities of science, engineering, and related fields such as the health professions. Some scientists work in teams, and some work alone, but all communicate extensively with others.
- Science requires different abilities, depending on such factors as the field of study and type of inquiry.

Nature of Science

- Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.

Resources

The resources below provide additional age appropriate information, background, and activities that are related to the Amazing Cells activities.

WEBSITES

Cells Alive. How big?

http://www.cellsalive.com/howbig.htm

Interactive animation illustrating the size of various cells and micro-organisms compared to a pinhead. Can be viewed online or downloaded.

Molecular Expressions

I. Perspectives: Powers of 10

http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10

From outer space to electrons and protons, view the universe in this animation that gets steadily smaller by leaps of powers of ten.

II. Microscope Magnification

http://micro.magnet.fsu.edu/primer/java/scienceopticsu/virtual/magnifying

Look at onion cells as well as other items at magnifications ranging from 25X to 1000X.

Size Machine

http://www.msu.edu/~russellr/portfolio/size_machine/size_machine.html

Compares the size of objects from a mouse to the polio virus in a clever way that helps students understand the scale of what they see in a microscope. May help students visualize what they are trying to do in Activity 6, *Drawing to Scale*.

MicrobeWorld

http://www.microbeworld.org

This student-friendly site has interesting, graphics-rich information that is appropriate for upper elementary and middle school students. Check out the microbe discovery timeline, the Meet the Microbes visual catalog, or the microbiology career information. Download the activities from the print publication *Meet the Microbes through the Microbeworld Activities*.

Microscopy Society of America – Project Micro

http://www.microscopy.org/ProjectMicro

Project Micro is the educational site of the Microscopy Society of America. Find great microscopy advice for teachers here as well as K-12 classroom activities, and student-targeted features such as “Ask-a-microscopist.”

American Society for Microbiology – K-12 Education page

http://www.asm.org/Education/index.asp?bid=1191

Curriculum and career resources for K-12 teachers and students.

BOOKS

Enjoy Your Cells.

Fran Balkwill and Mic Rolph. Cold Spring Harbor Laboratory Press. 2002. Recommended for ages 8–12.

Microscopic Explorations.

Susan Brady and Carolyn Willard. Lawrence Hall of Science. 1998. Recommended for grades 4–8.

Small Things and Microscopes.

A Delta Science Module. 1994. Order from http://www.delta-education.com. Intended for grades 3-5, but seems more appropriate for grades 5-8.

Hidden Worlds: Looking Through a Scientist's Microscope.

Stephen Kramer and Dennis Kunkel. 2001. Career-oriented book for grades 4-8 with magnificent EM color photos of various microscopic creatures and objects.

Science Experiments with a Microscope.

Shar Levine and Leslie Johnstone. 2002. Introductory book of engaging microscope activities for ages 9-12. Contains informative pictures and photographs.

ACTIVITY 1.

Living and Non-living

TIME One 50 minute session.

CONCEPTS

- Living organisms are defined by most or all of the following characteristics. They require nutrients, water, and a source of energy; eliminate wastes; respond to stimuli; reproduce; and die.
- There may be ambiguity in whether certain items are living or non-living.
- Scientific results are sometimes ambiguous, and scientists do not always agree about interpretation of results.

SKILLS

- Categorizing objects based on their characteristics.
- Recognizing the characteristics common to all living things.
- Converting a list of characteristics to a definition.
- Writing persuasively to justify why an object is living or non-living.

Overview

Students develop a definition of life by sorting a variety of objects into living and non-living categories and discussing the characteristics of living things.

MATERIALS

for each student

- Student Sheet 1.1, *Living and Non-living*

for each group of four students

- Corks
- Shells
- Live crickets, pill bugs, earthworms, etc. (optional)
- Seeds
- Plants or flowers (growing in pot of soil)
- Plants or flowers (recently cut or picked)
- Bark
- Bone
- Various pictures of plants, animals, running water, crystals, yeast, bacteria, viruses, molds, the sun, fire, etc.

for the teacher

- Transparencies of Student Sheet 1.1, *Living and Non-living* and Overhead Master 1.1, Writing Prompt: *Definition of a Living Thing*
- Carrot or head of lettuce

GETTING READY

1. Photocopy Student Sheet 1.1, enough for one per student.
2. Gather materials.
3. Prepare overheads.

Background Information for Teachers

What does it mean to be alive? We may think this is an easy question for students, but in fact it is very complicated. Even scientists have not come up with a universally accepted definition of life. In this activity, students explore this question by sorting objects into two categories: living and non-living. They will discover just how difficult it is to define life. Shells and bones were once parts of animals. Are they alive? What about a seed? Seeds *can* grow into a living plant if provided with the right environmental conditions. What about a flower that has just been picked?

Students enjoy debating this difficult topic. By thinking of ways that all living things are alike, students can begin to formulate a definition of life.

Here are some examples of what your students may say that all living organisms can do:

- Eat (they require food for energy)
- Drink (they require water)
- Breathe air
- Make waste
- Move (Animals may actively move; plants may move by responding to stimuli, e.g. by orienting themselves towards the sun.)
- Are composed of cells
- Grow
- Reproduce
- Die

Why does a unit on cells begin with an activity on what it means to be alive? As students progress through this unit's activities, they will learn that cells are the structural building blocks of living things. They will learn that plants, animals, and microorganisms all are made up of cells, and that these cells share certain features and have common parts. In subsequent activities, teachers should relate what students learn about cells back to the idea that there are some characteristics that are universal among living organisms and that many of the features they defined as common to all living things are carried out at the cellular level, such as respiration (breathing) and eating.

Presenting the Activity

IS IT ALIVE?

Engage the students' interest by placing a head of lettuce or a carrot in front of the class. Working in groups of four, have students consider whether this "organism" is alive or not. If students say the lettuce or carrot is not alive now, ask them when it first stopped being alive. Was it alive yesterday or last week before it was picked from the garden? Was it alive right after it was picked? Alternatively, you can show the class a living lettuce or carrot plant—one that is planted in a pot—and ask them whether this vegetable is alive. Then show them a picked head of lettuce or carrot and ask them the same question.

LIVING AND NON-LIVING

Pass out Student Sheet 1.1 and a variety of objects and pictures to each group. Each group need not receive the same objects. Be sure that each group receives seeds, as well as some items that were formerly alive, e.g. bark, bones, cork; some items that were never alive, e.g. rocks; and some items that are alive, e.g. a plant or an animal. Working in groups of four, students sort the objects into living and non-living categories and record their results on the chart on Student Sheet 1.1. (Note that the non-living category should contain both objects that have never been alive and objects that were formerly alive.) Did they find it difficult to categorize any of the objects? What about objects that were once part of a living organism, such as bones or cork? Are these things still alive?

Are seeds alive? Seeds present a fascinating case that may not easily fit into students' conception of a living organism. Seeds don't move, breathe, eat, or drink, yet they can grow into a plant if given the right environmental conditions. Here are a few sample responses to the question 'are seeds alive?' from fifth grade students.

Seeds are ready to be alive; they just need nutrients.
Seeds have two lifestyles, living and non-living.
Seeds are not living or non-living; they are in a neutral zone.

You might encourage students to suggest an experiment to test whether seeds are alive. Students will recognize that something that is living must be able to die. How could they treat seeds so that they are no longer able to sprout when provided with water? Does the fact that seeds can be treated so that they no longer sprout ("killed"), prove that they were formerly alive?

If student groups reach an impasse and cannot decide whether to place a particular object in the living or non-living category, you can use this as a teaching opportunity to explain that scientists often encounter ambiguity when they do experiments. As the scientific knowledge base grows and more experiments are done, questions that initially could not be answered with certainty may now be able to be answered. Reassure students that it is a valid option to place an object in the "not sure" category on their charts.

After sorting the objects, students should create a list of characteristics shared by all living things. They can refer to their lists of living and non-living objects to help them come up with a list that applies to all objects in the living category. To "test" whether a characteristic on their list is really common to all living things, they can try to think of exceptions to the rule, i.e. a living thing that does not have that particular characteristic. In this way, they can refine their list by "trying out" each characteristic.

Using their list of characteristics, students should now write a definition of a living thing. They should use their list of characteristics to help them write their definition. For example, if their list includes breathing, eating, drinking, and growing, their definition might look like this:

"A living thing breathes, drinks, eats, and grows. Things that do not have all four of these characteristics are not alive. For example, although crystals can grow in size, they cannot breathe, drink, or eat, so they are not alive."

Students sometimes have difficulty developing a definition of a living thing from their list of characteristics. If this is a problem for your students, you may wish to use Overhead Master 1.1 to provide them with a template for writing their definition.

DISCUSSION QUESTIONS

Lead the students in a discussion using the questions below or some they have generated themselves.

1. Did your definition of a living organism change as you worked your way through this activity? How?
2. Share your definition with the class. Does your definition differ from other groups?
3. Which items could not easily be classified as living or non-living? Share your results for these items with other groups and see if you classified these items the same way.
4. Why do you think scientists are interested in defining what it means to be alive?

USING THE FAMILY LINK

Have students take the Family Writing Link home and complete it there. They should share the link with family members, discuss their classroom definition of life, and ask their family whether or not they think fire is living or non-living. Students should return to class with their written paragraphs and be prepared to discuss them with the class.

Formative Assessment of Student Learning

During this activity, the students rely on their own knowledge of living organisms to develop a definition of a living thing. Although they do not actively perform an experiment, they apply the inquiry process as they consider each item, categorize it, and write their definitions. As the students carry out this activity, assess whether they are learning by asking yourself the following questions.

- Are students actively engaged in sorting objects and recording them as living or non-living in the table? (Is the chart filled out or blank?)
- Are students discussing which category objects should go in, listening to each other, persuading others about what they believe is the correct category?
- Do students articulate why certain items are difficult to sort?
- Do students propose experiments to test whether something is alive?
- Are students creating and refining their lists based on discussion within their groups?
- Can students make a list of common characteristics of living things by considering the objects in their "living" list?
- Can students write a definition of life based on their list of characteristics?
- Are students able to apply their definition to a new "object" and decide whether it is living or non-living (e.g. the flame in the Family Writing Link)? Are they able to justify their conclusion using their list and definition and by referring to objects previously categorized?

STUDENT SHEET 1.1. **NAME** ______________________

Living and Non-living

Examine the objects and pictures that have been given to your group. Classify each object as Living, Non-living, or Not sure, and record in the chart below.

LIVING	NON-LIVING	NOT SURE

Think about why you put objects in the living column. List the characteristics shared by those living things and *all* living things. (Hint: if you aren't sure if *all* living things have a certain characteristic, try to think of a living organism that does not. If you can't think of an organism without that characteristic, then *all* organisms must have it.)

Using the list above, define a living thing. Make sure your definition can be used to describe both plants and animals.

Writing Prompt: Definition of a Living Thing

A living thing has most or all of the following characteristics: ______________________________

____

____

____

____.

In addition, some living things may____

____

____

____

____.

FAMILY LINK: IS FIRE ALIVE?

Take home your definition of what it means to be living and share it with your family. Discuss the definition with them and decide if there is anything you would like to add or change. Once you and your family are happy with your definition of a living thing, ask an adult family member to light a candle. Observe the candle's flame for a moment, while thinking about this question.

Is fire a living or a non-living thing?

Write a paragraph or two describing whether you think fire is living or non-living. Use your observations of the flame, the list of characteristics that you created in class, and the definition that you refined with your family to help support your answer. Make sure you include similarities and differences of fire to living objects.

Bring your paragraph back to school to share with your classmates.

ACTIVITY 2.

Introduction to Microscopes

TIME Two 50 minute sessions or one longer session.

CONCEPTS

- Microscopes are scientific instruments used to examine objects too small to observe with the naked eye.
- A microscope's lenses determine the magnification of an object viewed in the microscope.
- A microscope's lenses may invert or reverse an image.

SKILLS

- Using a compound microscope.
- Preparing dry mount slides.
- Calculating the magnification of objects viewed in the microscope.
- Drawing objects viewed in the microscope accurately, keeping them in scale with the field of view.

Overview

Students learn how to use compound microscopes and gain experience viewing and drawing microscopic objects.

In this activity, students will learn the parts of a microscope and what each part does, identify the parts on their own microscopes, calculate the magnification of their microscope, and learn how to use and care for a microscope. Through firsthand use of the microscope, they will become familiar with how much objects are magnified and learn that the image of an object observed in the microscope is reversed or inverted by the microscope's lenses. They will also gain experience drawing objects they observe with the microscope. This lesson lays the foundation for Activities 3 and 4, which also require the use of a microscope. Together, the microscope lessons develop the technical and observational skills that students will build on when they use more complex microscopes in middle and high school.

MATERIALS

for the teacher

- Overhead 2.1, *The Compound Microscope*

for each student

- Student Sheet 2.1, *Getting to Know* Your Microscope
- Student Sheet 2.2, *Instructions for Viewing and Drawing Microscopic Specimens*
- Student Sheet 2.3, *Observing Specimens in* Your Microscope
- Student Sheet 2.4, *Observing Salt and Sugar*
- Student Sheet 2.5, *Observing More Specimens*

for each group of 2-3 students

- Microscope (A compound microscope having two lenses. For Activity 2, a magnification of only 30-50X is required, although higher magnifications can add detail. For Activities 3 and 4, a magnification of at least 100X will be needed. Dissecting microscopes are not suitable for the activities in this unit)
- External light sources if your microscopes have mirrors instead of built-in bulbs
- Masking tape
- Slides (choose plastic or glass depending on age of students)
- Cover slips (choose plastic or glass depending on age of students)
- Small, blank scraps of newsprint or notebook paper
- Salt
- Sugar
- An assortment of specimens for microscope viewing such as sand, threads, pencil shavings, facial tissues, fabrics, newspaper scraps with words on them, colored comics from the newspaper, etc.facial tissues, fabrics, newspaper scraps with words on them, colored comics from the newspaper, etc.

GETTING READY

1. Photocopy Student Sheet 1.1, enough for one per student.
2. Gather materials.
3. Prepare overheads.

Background Information for Teachers

You may be more comfortable presenting this activity to your students if you have done some background reading on optics. We recommend the following resources.

BOOKS ON OPTICS

Microscopic Explorations. *A GEMS Festival Teacher's Guide. Susan Brady and Carolyn Willard. Lawrence Hall of Science. 1998.* Recommended for grades 4-8.

The "Special Section on Optics" provides excellent background for teachers.

WEBSITES ON OPTICS

Optics: Light, Color and Their Uses

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Optics.Guide.html

Download this excellent NASA educator guide that explains the basics of optics and provides activities for K-12 students. The background section, "Introduction to Mirrors and Lenses," will be especially helpful in preparing teachers for activities 2, 3, and 4.

Optics for Kids

http://www.opticalres.com/kidoptx_f.html

The educational site of Optical Research Associates. See especially the sections on "Light" and "Lenses."

Molecular Expressions: Optical Microscopy Primer

http://micro.magnet.fsu.edu/primer

This site is packed with information and java tutorials on light, lenses, and microscopes. Some of the material goes beyond what teachers need to know, but it contains some good, basic information. A good starting point is "Introduction to Lenses and Geometric Optics," found here:

http://micro.magnet.fsu.edu/primer/lightandcolor/lensesintro.html

A collection of optics activities for elementary students is contained in the "Science, Optics, and You" curriculum, found here:

http://www.magnet.fsu.edu/education/teachers/curricula/scienceopticsyou.html

Microscope Glossary

Compound microscope → A microscope having two lenses for increased magnifying power. One lens is located in the eyepiece, and one right above the stage. Images appear inverted. Illumination is from below the specimen, so samples must be transparent.

Cover slip → A thin, small square or circle of clear plastic or glass that is placed on top of a wet specimen on the microscope slide. The cover slip holds the sample to the slides and helps spread liquid throughout the sample.

Dissecting microscope → A compound microscope with two lenses, but also with an extra lens or a mirror added in order to show images in their correct orientation. Total magnification is lower than in a compound microscope, and the light usually illuminates from above the specimen instead of below. Dissecting microscopes are useful for observing larger objects, for dissecting specimens, and for viewing objects that are not transparent.

Diaphragm → The part of the microscope that restricts the passage of light through the specimen.

Dry mount → A specimen for microscopy prepared without water or liquid.

Eyepiece → The part of the microscope that the eye looks through to view the sample. The eyepiece, also called the ocular, contains a lens that increases the magnifying power of the microscope.

Field of view → The circle of light seen when looking through a microscope's eyepiece, as well as everything within it.

Focus wheel or knob → Small knob on side of microscope that allows you to bring the sample into focus by raising and lowering the lens or the stage. Some microscopes have two focus knobs, one for coarse adjustment and one for fine adjustment.

Lens → A transparent object with at least one curved surface, usually made of glass or plastic. Objects are magnified when they are viewed through a lens.

Light source → A bulb, mirror, or prism that provides light to illuminate the sample. To allow clear viewing of the sample, light must pass through the sample and lens and into the eye.
A microscope may have its own light bulb, or it may have a mirror or prism to gather the light from the room and reflect it upwards through the sample and lens.

Objective → A lens located directly above the stage. Many compound microscopes have more than one objective to provide a range of viewing magnifications.

Simple microscope → A microscope having only one lens, usually located right above the stage.

Slide → A piece of thin, rectangular glass or plastic that the sample is placed on for microscope viewing.

Specimen → The sample being studied.

Stage → The flat surface that you place the sample slide onto for viewing. The stage may have clamps to hold the slide in place.

Wet mount → A specimen for microscopy prepared with water or a liquid stain. It is usually covered with a cover slip.

CHOOSING MICROSCOPES FOR YOUR CLASSROOM

If you need to choose microscopes for your classroom or school, here are some points to consider:

- The microscopes should be designed for classroom use. Student microscopes are more durable than those not designed for the K-12 market.
- The microscopes should be compound (having two lenses) rather than simple (having only one lens). The short distance between the eye and the sample makes a simple microscope very difficult to use.
- If you want to be able to do the microscope activities in this unit and see really small objects, like cells, you will need a compound microscope with a magnification of at least 100X. This magnification is adequate for observing relatively large cells such as those from onion and human cheek. If you would like to observe opaque, larger objects such as whole nuts, leaves, and insects, then a dissecting microscope is the ideal choice. The remaining points below pertain to compound microscopes.
- Two focus knobs—coarse and fine—are not necessary for grades 5–6. One focus knob can provide good enough resolution and will not be as confusing for young students.
- Consider carefully the microscope's source of illumination. The least expensive models have a mirror located beneath the stage to reflect light from the room up through the sample and into the eye. It is difficult to get enough light reflected to adequately illuminate samples in typical classroom lighting. To collect enough light, mirror-illuminated microscopes will need to be brought near windows or separate lights placed in front of the mirrors (e.g. flashlights or desk lamps). Inadequate light may result in difficulty observing specimens—a major source of student frustration. In addition, young students have a difficult time adjusting the angle of the mirror to reflect light up through the specimen. We recommend choosing microscopes that have either a built-in light bulb or a prism beneath the stage. Prisms are low cost, very efficient at gathering light, and do not need to be adjusted by the student.
- If you choose microscopes equipped with built-in light bulbs, you also have to decide between plug-in or cordless models. Cordless microscopes are more expensive, but many elementary school classrooms are not equipped with multiple, convenient electrical outlets that will allow effective use of plug-in models.
- The microscope does not need to have a stage that moves back and forth and forward and backward. This feature adds to the cost.
- Microscopes with only one eyepiece (monocular) rather than two (binocular) are fine for this age group and much less expensive.
- When you find a model you like, ask the sales representative if you may have the microscope on loan for a trial period (e.g. one week or one month) before deciding to buy a classroom set. If this is not possible, buy only one microscope and test it in your classroom before buying an entire set.
- It is ideal to have one microscope for every 1–2 students. If you cannot afford this many microscopes, buy one for no more than every three students.

Teacher Instructions for Viewing Microscopic Specimens

Use these instructions as you explain to your students how to view a specimen in the microscope. Your students will be given a less detailed instruction sheet (Student Sheet 2.2) but will need your detailed explanation the first time they try to focus on a specimen.

MICROSCOPE INSTRUCTIONS

1. Place a specimen on a microscope slide. If it is a wet mount, add liquid and a cover slip. Set the slide on the stage so the specimen is right under the objective lens and above the hole in the stage. If your microscope has more than one objective, start with the lowest magnification objective in place.
2. As you look from the side of the microscope, turn the focus knob until the objective is just above the specimen, but not touching it. If your microscope has two focus knobs, turn just the coarse focus knob.
3. Turn on the microscope light. If your microscope has a mirror instead of a light, look through the lens and tilt the mirror until there is light on the specimen.
4. To see the specimen, look through the eyepiece and slowly increase the distance between the lens and the stage by turning the focus knob until the specimen comes into view. (Note: on some microscopes the stage will move as you turn the knob. On others, the objective lens will move.) Continue turning the knob until the specimen is not blurry. If you have two focus knobs, first turn the coarse knob until the specimen is focused. Then turn the fine focus knob to make the specimen even more finely focused.
5. If your microscope has more than one objective and you wish to see the specimen under higher magnification, rotate the next highest power objective into place. Do this only after you have already focused on the specimen using the lower power objective as described in steps 1–4. Turn the focus knob until the specimen is no longer blurry. If you have two focus knobs, use only the fine focus. (Note: Before moving the more powerful objective into place, **do not turn the focus knob to increase the distance between stage and lens.** This is the most common error that both teachers and students make when focusing.)
6. Be very careful not to smash a higher magnification objective into the slide by turning the coarse focus knob too much. You could damage both the lens and the slide. Your microscope's lenses are its most delicate and expensive parts. To avoid damage, always turn the focus knob slowly and make sure you know which direction to turn the knob to raise or lower the objective (or stage).
7. When you are done looking at your specimen, raise the objective (or lower the stage) using the focus knob. Then remove the slide.
8. When you are done with your microscope for the day, be sure to turn off the microscope light.

Presenting the Activity

During the first 50 minute session, complete Part I and the first part of Part II (through microscopic examination of three different sizes of student handwriting).

PART I. GETTING TO KNOW YOUR MICROSCOPE

Put one microscope on display at the front of the room and have the rest of the microscopes lined up in another part of the room. If you are using more than one brand or type of microscope in your class, display an example of each type.

Ask students if they have ever used a microscope, and if so, what for? Guide the discussion to a statement by students of what microscopes are used for: looking at really small things that we can't see well with our eyes alone.

Show students the overhead diagram of a compound microscope (Overhead 2.1). Draw attention to the microscope's two separate lenses, which work together to give a greater magnification than just one lens could provide. The first lens is in the eyepiece. The second lens is just above the stage and is called the objective. You can introduce the terms "simple microscope" (having one lens) and "compound microscope" (having two lenses) at this point. Point out that some compound microscopes have more than one objective. Referring to the overhead diagram, talk about each of the labeled parts and its function, making sure to mention the stage, objective, eyepiece, focus knob, and light source (may be a light, a mirror, or a prism). You can ask for student volunteers to come to the front of the room and point out the parts on the display microscopes, which will probably not be identical to the microscope in Overhead 2.1. As you introduce the microscope parts, students can label them on the microscope drawing on Student Sheet 2.1. See the glossary for further information on microscope types and parts.

Now ask students to go and get microscopes for themselves and carry them back to their desk. Emphasize that microscopes are expensive scientific tools, not toys, and must be handled carefully. Instruct students to carry the microscopes with two hands, one under the microscope supporting its base and one on the arm connecting the eyepiece to the stage.

Explain that the microscopes the students will be using may not look exactly like the one on the overhead but that they have similar parts. Have students find the parts of their own microscope that correspond to the parts shown on their diagrams. Students can label the parts of their own microscope with pieces of tape.

Talk to students about magnification and how to calculate the total magnification of their microscope. Explain that the magnification of their microscope is the product of the lens magnification in the eyepiece and the magnification in the objective lens. Have them complete the second page of Student Sheet 2.1, which asks about their own microscope and guides them through a magnification calculation.

PART II. OBSERVING SPECIMENS IN YOUR MICROSCOPE

Provide students with Student Sheets 2.2 and 2.3. Student Sheet 2.2 contains instructions for viewing specimens and focusing the microscope and helpful tips for drawing microscopic samples. Students should keep this page and refer to it, if needed, for other microscope activities in this unit. You may want to place copies of Student Sheet 2.2 in plastic sheet protectors and reuse them each year.

Lead the class through preparing their first specimen: a dry mount of a piece of newsprint. Ask students to print their names at the top of a piece of blank newsprint paper using normal sized letters. Then have students cut out their names so that they will fit onto a microscope slide. Ask students to view their names in the microscope. They will need to use a fairly low magnification of 30-50X. Guide them through the instructions step by step. The microscope is a delicate instrument that is most often broken during the focusing process. Emphasize key points from the information given in *Teacher Instructions for Viewing Microscopic Specimens.* **Do not allow students to view specimens before receiving this instruction.** Although students will have their own set of instructions for viewing specimens (Student Sheet 2.2), these instructions are only a summary of what you will tell them in detail the first time they go through the focusing process. They can refer back to their abbreviated instructions on subsequent days to refresh their memories. Circulate around the room to help students with focusing or other difficulties.

For example, some students may need to adjust the amount of light passing through the specimen, which can be done by adjusting the microscope diaphragm. It is helpful to have parent volunteers assisting at this stage. Alternatively, older students from another class may help or you can train a couple of interested students from your own class.

Both newsprint and standard white notebook paper are sufficiently transparent so that letters written on them can be viewed with a standard compound microscope that provides illumination from below the specimen. You will have less success with this activity if students use a thicker grade of paper that is more opaque. Introduce vocabulary words as they arise, such as specimen, cover slip, slide, and dry mount (see *Microscope Glossary*).

As students work through Student Sheet 2.3—preparing dry mounts and focusing their microscopes on specimens—they will gain a sense of the magnifying power of their microscope and learn that images are inverted by a microscope's lenses. Students will also notice that their name does not appear exactly as they have written it. It may be inverted (upside down) and reversed, or right side up and reversed (see Figure 2.1). What they see depends on the lens system of their microscope. If you are using several types of microscopes in your class, some students may get one answer and some another.

If there are at least 20 minutes remaining, and students are still engaged, move on to Student Sheet 2.4, *Observing Salt and Sugar.* Alternatively, save this activity as well as Student Sheet 2.5, *Observing More Specimens*, for the following day.

Pass out Student Sheets 2.4 and 2.5. Students will view salt and sugar with both their naked eye and the microscope. They will draw and describe what they observe on Student Sheet 2.4. They should notice a microscopic difference in the shape of sugar and salt crystals that cannot be observed with the eye alone. Encourage students to create a sense of three dimensions in their drawings.

Finally, allow students to explore items of their choosing. You will want to assemble some of these items before the activity but also give students the freedom to gather objects of their own choice from around the classroom. Some items they might look at include sand, hairs, threads, pencil shavings, facial tissues, fabrics, newspaper with words on it, colored comics from the newspaper, etc. A particularly interesting part of the comics to look at is along the bottom of the page where the color registration marks are arrayed in a line (usually a small circle for each color). Students will find it interesting to learn that each distinct color is made up of a particular combination of different colors of microscopic dots. Ask students to draw three specimens they observe in the microscope on Student Sheet 2.5.

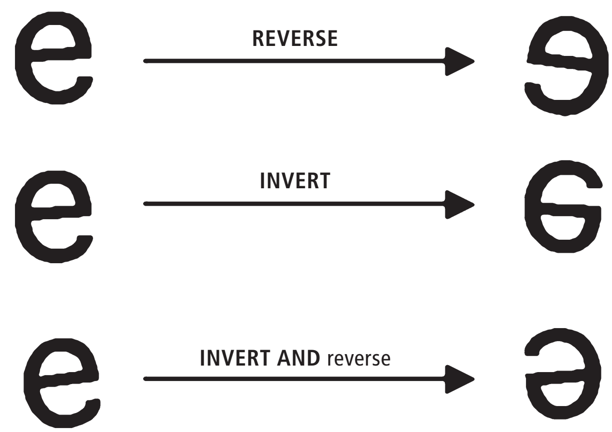


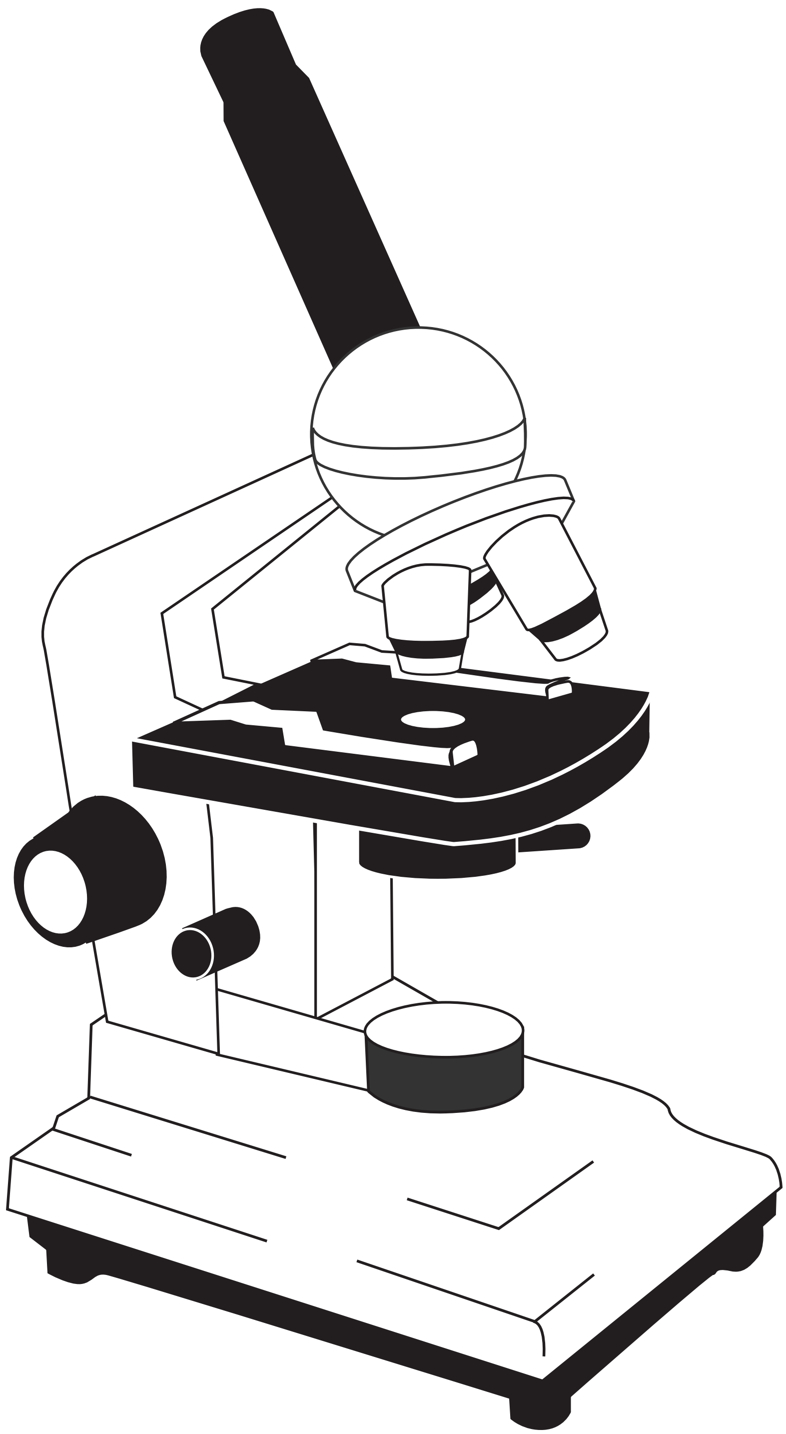
FIGURE 2.1. Inversion and reversal of microscopic images.

Formative Assessment of Student Learning

In this activity, students learn how to use and care for a microscope, observe several objects under a microscope, and make drawings of what they see. Microscopes can be easily damaged if not used correctly, so it is critical that students know the correct procedures before working independently. As the students carry out Activity 2, watch for the following to assess their progress and understanding.

- Do students know the names of the parts of the microscope and what each part does?
- Can students calculate the total magnification achieved with each lens?
- Are students using the microscope as instructed? Are they able to focus on a specimen by moving the lens away from the stage (or the stage away from the lens) so that the lens and stage do not smash into each other? Are they able to adjust the lighting to properly illuminate the specimen?
- Do students recognize that the image they see in the microscope is reversed or upside down (inverted) and reversed?
- Are students able to see a difference between salt and sugar in the microscope?
- As students view specimens in the microscope, are they both able to *write* descriptions of the enhanced detail they see as well as *draw* the objects?
- Do the students' drawings accurately portray what they observe in the microscope (e.g. images reversed relative to the sample, objects drawn in correct proportion to each other and the field of view, details provided when visible in the microscope)?
- Do the students' drawings and written descriptions "match"?

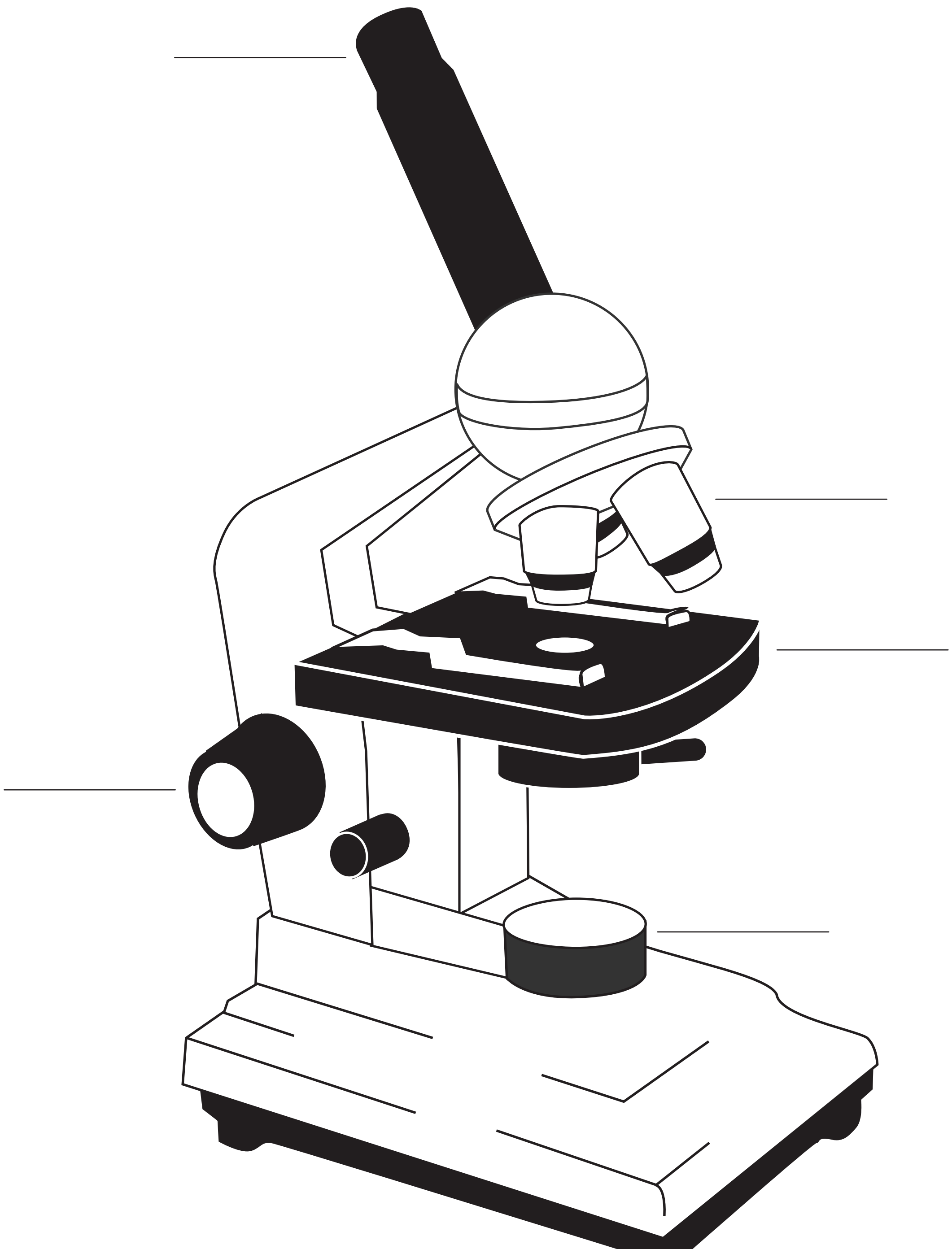
The Compound Microscope



STUDENT SHEET 2.1. NAME ____________________

Getting to Know Your Microscope

As your teacher shows you the parts of a microscope, find them on the drawing below and label them. Keep this page and refer to it as you do the activities in this unit.



Getting to Know Your Microscope

Identify the parts of your microscope, and check them off on the list below as you find them. Label each part with masking tape. Not all microscopes will have all parts.

- ◯ Eyepiece (lens)
- ◯ Objective (lens)
- ◯ Stage
- ◯ Light source
- ◯ Focus knob(s)
- ◯ Other: ____________________
- ◯ Other: ____________________
- ◯ Other: ____________________

Now complete the following about *your* microscope.

My microscope is a simple / compound (CIRCLE ONE) microscope.

My microscope has ______ (NUMBER) objectives

(the lens or lenses not located in the eyepiece)

The magnifications of my objective lens or lenses are:

Objective 1: __________ Objective 2: __________ Objective 3: __________

The magnification of my eyepiece lens is: __________

The lowest total magnification (mag.) for my microscope is:

(______) x (______) = ______

LOWEST OBJECTIVE MAG. EYEPIECE MAG. TOTAL MAG.

The highest total magnification for my microscope is:

(______) x (______) = ______

HIGHEST OBJECTIVE MAG. EYEPIECE MAG. TOTAL MAG.

STUDENT SHEET 2.2.

Instructions for Viewing and Drawing Microscopic Specimens

Follow these instructions whenever you look at a specimen with your microscope.

MICROSCOPE INSTRUCTIONS

- Move your microscope's lowest magnification objective into place. Place a specimen on a microscope slide and set the slide on the stage.
- Turn the focus knob until the objective is just above the specimen, but not touching it.
- Turn on the microscope light.
- Look through the eyepiece and slowly make the lens and stage move apart by turning the focus knob. Turn the knob until the specimen is not blurry. Observe the specimen.
- Turn the next highest objective into place, but don't touch the focus knob before you do this. Once the objective is in place, go ahead and adjust the focus slightly if the specimen is blurry.
- Always be very careful not to smash the objective into the slide by turning the focus knob too much. If you do this, you may damage the lens or the slide.
- When you are done looking at the specimen, raise the objective (or lower the stage) using the focus knob. Remove the slide.
- When you are done with your microscope, turn off the microscope light.

Refer to these instructions for help on drawing specimens you observe in the microscope.

TIPS FOR DRAWING MICROSCOPE SPECIMENS

- Draw a circle to represent the circle of light you see through your microscope (called the field of view). part of the specimen that you can see. (Note: many of your student sheets already have circles drawn for you.)
- Under the circle, write the total magnification you are using to view the specimen.
- Then draw what you see within that circle.
- Make sure what you draw is in proportion to the circle. For example, if what you see only takes up half the space of the circle, don't make it the full size of the circle in your drawing.
- Do not draw all of the specimen if you can only see part of it.

STUDENT SHEET 2.3. NAME ______________________________

Observing Specimens In Your Microscope

1. a) Print your name in normal sized letters on the piece of paper your teacher gives you.
   b) Cut out your name so that it fits onto a microscope slide.
   c) Tape it to the slide and place the slide on the stage.
   d) Focus the microscope using the directions on Student Sheet 2.2. You may need to adjust the microscope to let in more light.
   e) Draw what you see in the Microscope Observations Table (Student Sheet 2.3). Use the tips for drawing provided on Student Sheet 2.2.
   f) When you are done, tape the paper with your name on it into the table.

2. Now print your name really small and look at it with the microscope. Draw what you see.

   Could you see the whole name?

   The circle of light that contains the part of your name that you can see is called the *field of view*.

   Do the letters you've written appear different in any way from how they look without the microscope (besides being bigger)? If you're not sure, concentrate on just one letter, such as "e." Describe what you see.

3. Now move your name from left to right by pulling the slide toward your right hand. As you look through the microscope, in what direction do the letters move?

4. Try to print your name small enough so that you can see the whole thing at once in the microscope. Draw what you see in the Microscope Observations Table.

 NAME ____________________

Microscope Observations Table

Use drawings and words to describe your observations.

Specimen	What it looks like without a microscope	What it looks like with a microscope
1. Your handwritten name (normal size)	(**TAPE PAPER** with name here)	MAGNIFICATION: ____________
2. Your handwritten name (small size)	(**TAPE PAPER** with name here)	MAGNIFICATION: ____________
3. Your handwritten name (smallest size)	(**TAPE PAPER** with name here)	MAGNIFICATION: ____________

STUDENT SHEET 2.4 NAME ____________________

Observing Salt and Sugar

1. Look at salt and sugar with your naked eye and then with the microscope. Draw and describe what you see.

	What it looks like without a microscope	What it looks like with a microscope
Specimen = Salt	Description: Drawing:	Description: Drawing: MAGNIFICATION:__________
Specimen = Sugar	Description: Drawing:	Description: Drawing: MAGNIFICATION:__________

 NAME ______________________

Observing Salt and Sugar

2. List similarities and differences between salt and sugar that you noticed with your naked eye and with the microscope.

Naked Eye Observations

Similarities

Differences

Salt	**Sugar**

Microscope Observations

Similarities

Differences

Salt	**Sugar**

3. What could you see with the microscope that you could not see with your naked eye?

STUDENT SHEET 2.5 NAME ____________________

Observing More Specimens

Choose from a variety of objects your teacher provides or you find around the classroom, and look at them in the microscope. Using words and drawings, describe 3 different specimens.

	Description	Drawing
Specimen =		MAGNIFICATION:__________
Specimen =		MAGNIFICATION:__________
Specimen =		MAGNIFICATION:__________

INTEREST LINK: OPTICS

Have you ever noticed how a glass of water makes whatever is behind it look bigger? As far back as the 1st century A.D., the Roman philosopher Seneca found that viewing small letters through a glass globe filled with water made the letters appear larger and more distinct.

It wasn't until the 2nd century that the Greek astronomer Ptolemy explained that this magnification was related to the bending of light. He discovered that light, which usually travels in a straight line, is bent as it passes from air into water. This bending of light is called refraction and causes objects to appear bigger when viewed through water.

The knowledge that the bending of light can make objects appear bigger was used to make lenses. A lens is a piece of transparent material, such as glass or plastic, with at least one curved surface. The curved surface refracts, or bends, light rays that pass through it. Lenses are important in optical devices that use light, including our eyes, cameras, telescopes, binoculars, microscopes, and projectors.

There are two basic kinds of lenses: concave and convex (Figure 1). Concave lenses are thicker at their edges than at their center. Convex lenses are thicker in the center than at their edges.

Concave lenses make light rays passing through them bend outward or diverge. Objects may look smaller when viewed through a concave lens. Convex lenses, on the other hand, cause light rays passing through them to come together or focus (Figure 2).

Objects examined through a convex lens look bigger or magnified. The image of the object viewed through the lens (an arrow in Figure 3 below) is also often inverted.

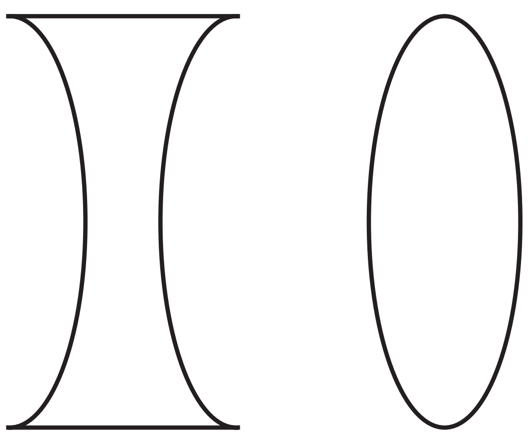


FIGURE 1. Concave (left) and convex (right) lenses

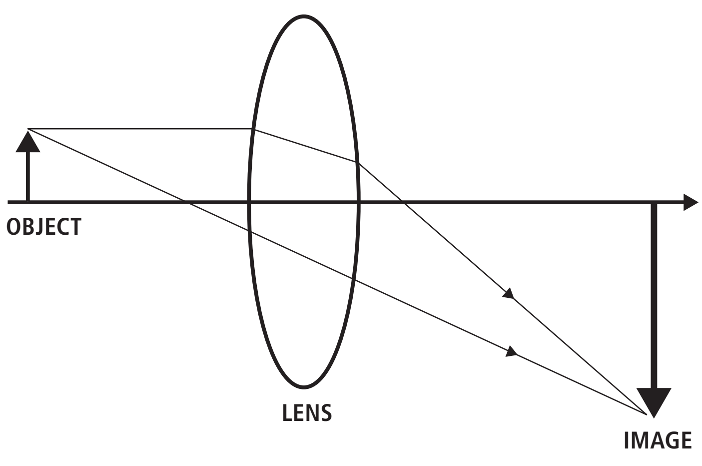


FIGURE 2. A concave lens spreads light (left). A convex lens focuses light (right). Light rays are traveling from left to right in this figure.

A single lens, also called a "simple" lens, doesn't form images that are very sharp. To solve this problem, several lenses may be combined in one optical device. The resulting lens is called a "complex" lens. For example, most microscopes contain at least two lenses, one in the eyepiece and one in the objective. Complicated cameras or camcorders may contain a half dozen lenses or more!

The magnifying property of lenses enables us to look at many things that we cannot see with just our eyes. You have observed that salt and sugar look very similar to our naked eye but have a very different crystal structure when viewed through a microscope. Cells are another example of things we can see only with the aid of a microscope's lenses.

LEARN MORE ABOUT OPTICS

Optics for Kids (OPTICAL RESEARCH ASSOCIATES)

http://www.opticalres.com/kidoptx_f.html
Information on light, lenses, lasers, and optics careers.

Optics for Kids (OPTICAL SOCIETY OF AMERICA)

http://www.opticsforkids.com/optics_for_kids.html
Optics activities, experiments, word finds, and optical illusions.

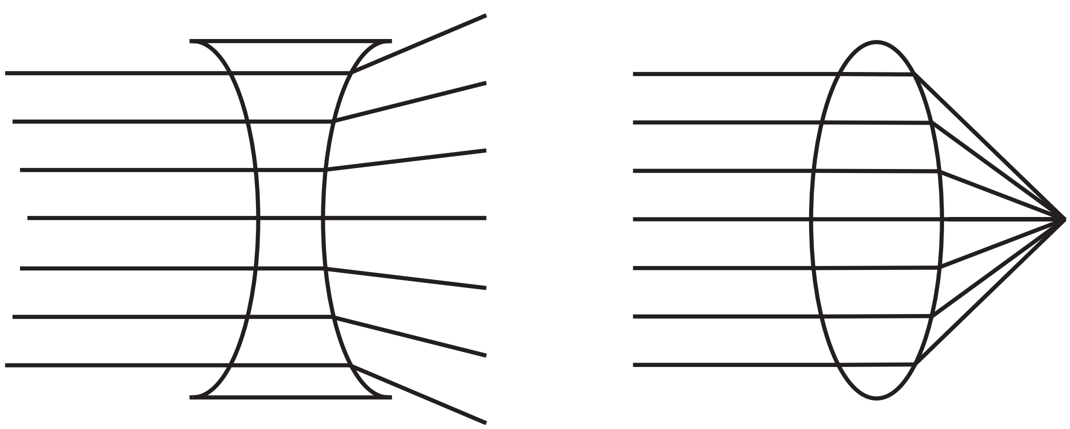


FIGURE 3. Rays of light are bent as they pass through this convex lens, causing the object's image to appear larger and upside down (inverted).

ACTIVITY 3.

Field of View

TIME One to two 50 minute sessions.

CONCEPTS

- Microscopes are scientific instruments used to examine objects too small to observe with the naked eye.
- Microscopic objects are measured in very small units called micrometers. There are 1000 micrometers per millimeter.
- A microscope's field of view is the circular area seen when looking through the eyepiece.
- The field of view diameter can be measured, and its size depends on the magnification.
- The field of view can be used to measure microscopic objects.

SKILLS

- Converting one unit of linear metric measurement to another, e.g. mm to µm.
- Choosing the most appropriate unit of measurement for measuring small objects.
- Measuring the diameter of the microscope's field of view at different magnifications.
- Measuring very small objects in the microscope by comparing them to the measured diameter of the field of view.

Overview

Students learn about a microscope's field of view and how to use it to measure the size of microscopic objects. Students will use this knowledge and skill again when they examine cells in the microscope (Activity 4) and draw microscopic objects to scale (Activity 6).

MATERIALS

for the teacher

- Overhead Master 3.1, *Field of View Measurements*
- Overhead Master 3.2, *Measuring Objects in the Microscope*
- Table 3.1, *Microscopic Measurements Reference for Teachers*

for each student

- Student Sheet 3.1, *Metric System Review*
- Student Sheet 3.2, *Measuring Very Small Objects*
- Student Sheet 3.3, *Microscopic Measurements*
- Student Sheet 3.4, *Seed Observations*

for each group of 2-3 students

- Microscope (The ideal microscope is a compound microscope having two lenses—eyepiece and objective—with a lowest total magnification of 30-50X.)
- Various small seeds, including poppy seeds
- Transparent metric ruler, unbeveled
- Microscope slides
- Paper Cupcake Liners (used to carry seeds)

GETTING READY

1) Assemble an assortment of common seeds, all fairly small. Use common kitchen seeds, vegetable and flower seeds from packets, or seeds collected from outdoors. Students can gather the seeds from home. **Be sure to include poppy seeds**, which are very small, and at least one seed too large to measure with the microscope (e.g. coriander, radish, dandelion). Thyme seeds may be substituted for poppy. For seed ideas, refer to Table 3.1, *Microscopic Measurements Reference for Teachers*.
2) Using the lowest possible magnification, preview the seed types in the microscope and screen out most of those that are too big to fit in the field of view. These seeds cannot be measured microscopically. Note that the higher the magnification of the microscopes you will be using, the smaller the seeds should be. If you will be using 50X magnification, which is at the top of the magnification range for what is ideal for this activity, you will need to choose fairly small seeds. If you will be using 30–40X magnification, you will be able to choose from a greater variety of seeds. **Remember, the higher your total magnification, the smaller your objects must be.**

Background Information for Teachers

TABLE 3.1. Microscopic Measurements Reference for Teachers

Item	Magnification used	Items/diameter	Calculation: field diameter /number of items	length of item (mm)	length (um)
Field diameter	40X	1	none	4 (direct measure)	4000
Field diameter	100X	1	none	1.5 (direct measure)	1500
Field diameter	400X	1	none	0.375	375
Hair	40X	45	4 mm/45 hair widths	0.089	89
Onion cell	40X	15	4 mm/15 cells	0.27	270
Onion cell	100X	6	1.5 mm/6 cells	0.25	250
Spinach cell	100X	10	1.5 mm/10 cells	0.15	150
Human cheek cell	400X	8	0.375 mm/8 cells	0.047	47
Poppy seed	40X	4	4 mm/4 seeds	1	1000
Black mustard seed	40X	3	4 mm/3 seeds	1.33	1330
Celery seed	40X	3	4 mm/3 seeds	1.33	1330
Basil seed	40X	2.5	4 mm/2.5 seeds	1.6	1600
Yellow mustard seed	40X	2	4 mm/2 seeds	2	2000
Carrot seed	40X	2	4 mm/2 seeds	2	2000
Sesame seed	40X	1.5	4 mm/1.5 seeds	2.67	2670
Dill seed	40X	1.25	4 mm/1.25 seeds	3.2	3200
Caraway seed	40X	1	4 mm/ 1 seed	4	4000
Fennel seed	40X	0.75	4 mm/0.75 seeds	5.33	5330
Dandelion seed	40X	too big to measure			
Radish seed	40X	too big to measure			
Coriander seed	40X	too big to measure			

Presenting the Activity

METRIC SYSTEM REVIEW

Review metric measurements with your students. Students can use Student Sheet 3.1, *Metric System Review*, to practice working with metric units of measure. Before proceeding, make sure students know: 1) the divisions on their rulers indicate millimeters (mm) and 2) one mm equals 1000 micrometers (µm).

FIELD OF VIEW

Students will be collecting a lot of data in this activity and must work with Student Sheets 3.2, 3.3, and 3.4 simultaneously.

Begin the activity by asking students to measure a poppy (or thyme) seed with their metric ruler and complete steps 1–3 on Student Sheet 3.2. Discuss the accuracy of their measurements and how difficult it is to measure extremely small objects. This measurement shortcoming creates the need for a better way to measure very small objects. Shortly, students will be able to measure very small items in a more accurate way—using a microscope.

Explain that students will now use their rulers to measure objects in the microscope. This will allow them to get more accurate measurements than they can by eye and ruler alone. They will even be able to measure objects that they cannot see with their naked eye.

Have students look through their microscopes with the lights on. What do they see? Ask them if they remember what field of view means (from Activity 2). Review with them that **field of view is the circle of light they see when they look in their microscope, as well as everything within it**.

Use Overhead 3.1 to walk students through the process of measuring their microscope's field of view for a given magnification. There will be a different field of view to measure for each different objective lens. First, have students practice measuring the field of view shown in #4 on Student Sheet 3.2. Then have students measure the field of view on their microscope, as described in #5 and shown in Figure 3.1. Direct them to place the ruler on the microscope stage with the lowest power objective in place. They should focus the microscope on the ruler so that they can see its divisions. Students should move the ruler so that it stretches lengthwise across the stage exactly in the center of the field of view (lying exactly across the field of view's widest point or diameter). Students can count the divisions on their ruler to measure how wide the field of view is. Ask students what measurement they obtained for the lowest power objective, and write that value on the top line of the table on Overhead 3.1. If students need additional guided practice, you can go through another measurement with them using the next highest power objective. Circulate around the room to help students who are having difficulty. You may find it useful to have parent or older student volunteers at this time. These volunteers should circulate around the room, helping students focus their microscopes, take their field of view measurements, and record their measurements in the table on Student Sheet 3.2. See Table 3.2 below for how you might fill out Overhead 3.1. Note that even if a microscope's objectives have the same magnifications as those shown in Table 3.2, it does not mean the field of views will have the diameters shown in the table. Have students make their own measurements. Then fill in the overhead with their numbers.

TABLE 3.2. Sample Field of View Measurements for Overhead 3.1

Item	Magnification used	Field of View Diameter	
		mm	µm
Field diameter	40X	4	4000
Field diameter	100X	1.5	1500
Field diameter	400X	0.375	375

It may not be possible to measure the field of view at the highest magnification using this method. If this is the case, calculate the field of view by using the measurement obtained with the intermediate objective. For example, if the field of view is 1500 µm at a total magnification of 100X, then it will be 1500 divided by 4, or 375 µm, at a total magnification of 400X (because a 400X magnification results in a 4-fold greater magnification than 100X). Another example: if the field of view is 2000 µm at 100X total magnification, then at 300X, it would be 2000 divided by 3, or 667 µm.

If you run out of time, you can pause here and resume the activity the next day.

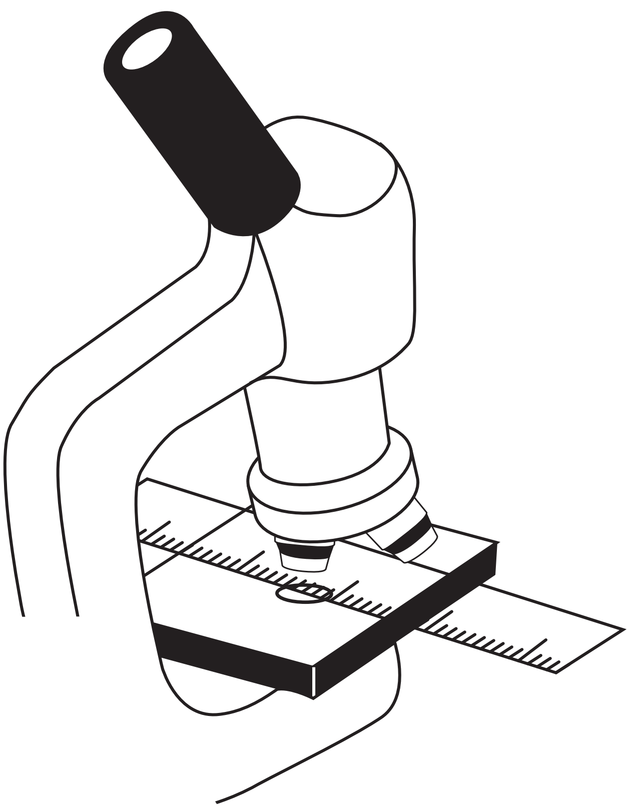


FIGURE 3.1. Measuring a Microscope's Field of View with a Ruler

Have students take a single poppy seed and "measure" its length in the microscope. To avoid dropping and losing their seeds, students can carry them in a paper cupcake liner or similar small container. Rather than using a ruler to measure the seed, students will measure by comparing it to the field of view diameter. Talk through this calculation with the class, using Overhead 3.2 as a guide. For example, if the poppy seed stretches across the entire field diameter, its would be the same size as the field diameter. They would divide by 1 in the calculation column. If it looks like it would take two poppy seeds to stretch across the field diameter, then they would divide by 2 in the calculation column. And so on. In Table 3.3 below, a poppy seed was 1/4 the diameter of the field, so in the calculation column, you divide by 4. You may also use the drawing on Overhead 3.2 (a field of view showing 2 seeds stretching across its diameter) to help explain how to do the calculation. See Table 3.3 for a sample poppy seed measurement. Remember that your students' measurement may not exactly match the measurement in the table because they will be using a different microscope and possibly a different magnification. Fill in the overhead with your students' numbers.

TABLE 3.3. Sample Poppy Seed Measurement and Calculation for Overhead 3.2

Item	Mag. used	Items/ diam	Calculation: (field diam) ÷ (# of items)	length of item (mm)	length (µm)
Poppy seed	40X	4	4 mm* ÷ 4 seeds	1	1000

***NOTE:** students should use their own field of view measurements from student sheet 3.2, not the sample measurement in Table 3.3.

Have students fill in their poppy seed measurement on Student Sheet 3.3. They should also draw pictures of the seeds on Student Sheet 3.4. If needed, you can make additional measurements together as a class using different seeds or at different magnifications.

After students have measured a poppy seed, they should measure two more types of seeds. They should record their measurements on Student Sheet 3.3 and also draw and describe the seeds on Student Sheet 3.4. Measurements of many seed types are provided for teachers as a reference in Table 3.1.

Discuss the accuracy of the student measurements, using the questions at the end of Student Sheet 3.2 as a guide. Make sure students understand that measuring very small objects in the microscope is more accurate than using a ruler, and that even extremely objects that we cannot see with our naked eye can be measured in the microscope.

Formative Assessment of Student Learning

As students are engaged with using their microscopes, circulate around the room and ask yourself these questions to assess student leaning. You may wish to prompt students with questions in order to aid in your assessment of their learning.

- Do students understand that micrometers are the unit used when measuring microscopic objects? Are they able to convert measurements between micrometers and millimeters? Do they understand how small a micrometer really is?
- Do students understand that measuring very small objects with a ruler is not very accurate?
- Do students understand what “field of view” means?
- Are students able to measure their microscope’s field of view with a ruler? Do they realize that the field of view diameter is different at each magnification?
- Are students able to estimate the size of a microscopic object by looking in the microscope and comparing it to the field of view diameter?

Field of View Measurements

Item	Magnification used	Field of View Diameter	
		mm	µm
Field Diameter			
Field Diameter			
Field Diameter			

To estimate the diameter of field of view at the highest magnification, you may need to do a simple calculation.

For example: Field of view diameter at 400X $= \dfrac{\text{Field of view diameter at 100X}}{4}$

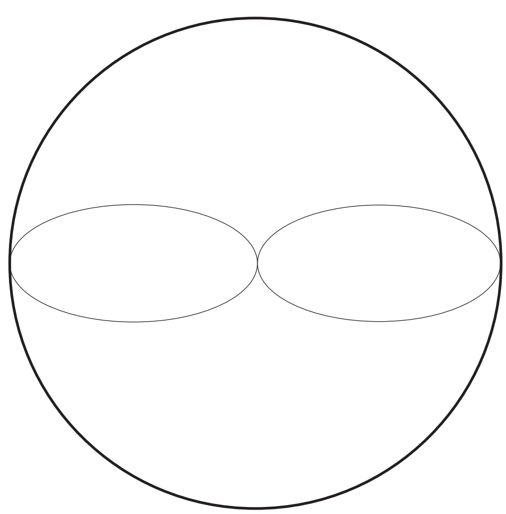
Measuring Objects in the Microscope

Item	Magnification used	Items/ diameter*	field diameter (mm)	Calculation: field diameter ÷ # of items	Length of item (mm)	Length (µm)
Poppy seed						

* how many items fit across one diameter?

Calculation: Measuring object length in the microscope

$$\frac{\text{Field of View Diameter}}{\text{\# of items that stretch across one diameter}} = \text{length of item}$$



STUDENT SHEET 3.1 NAME ____________________

Metric System Review

The metric system of measurement is used by scientists all over the world. The metric system uses multiples of 10 and is based on a standard length of 1 meter, which is just a bit longer than one yard. Microscopic objects are usually measured in either millimeters (mm) or micrometers (µm). When working with microscopes, it is especially important to know that 1 mm equals 1000 µm.

Metric Units

1 meter (m)	=	100 centimeters (cm)
1 centimeter (cm)	=	10 millimeters (mm)
1 millimeter (mm)	=	1000 micrometers (µm)

A. Measure the following in meters (m) and then convert to centimeters (cm).

1. My table/desk length is ____________________ m or ____________________ cm.
2. My table/desk width is ____________________ m or ____________________ cm.

B. Measure the following first in centimeters (cm) and then convert to millimeters (mm).

3. My hand span (tip to thumb to tip of little finger) is ____________________ cm or ____________________ mm.
4. The width of the back of my hand is ____________________ cm or ____________________ mm.
5. The width of this piece of paper is ____________________ cm or ____________________ mm.
6. My pencil length is ____________________ cm or ____________________ mm.

C. Now measure the following in millimeters (mm) and convert to micrometers (µm).

7. The width of my index fingernail is ____________________ mm or ____________________ µm.
8. The pencil width is ____________________ mm or ____________________ µm.
9. The word “cell” is ____________________ mm or ____________________ µm.
10. The letter “e” is ____________________ mm or ____________________ µm.

Measuring Very Small Objects

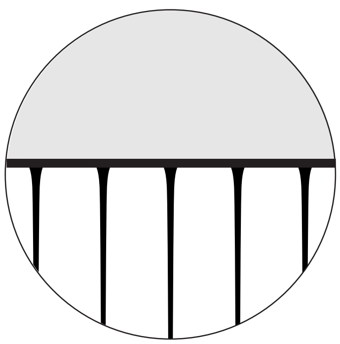
1. Using a metric ruler, measure the length of a poppy or thyme seed in mm.
2. Write the measurement in the table below.
3. Convert the length to μm and record in the table. Remember, 1 mm = 1000 μm.

Seed type	**Length** (mm)	**Length** (μm)

How accurate is your measurement? How could you measure the seed length more accurately?

4. The circle below is a picture of what you would see if you looked through a microscope at a ruler. Measure the diameter of the circle, or field of view, using the ruler that has been drawn in the picture.

   Circle Diameter = ____________________



5. Now use your ruler and microscope together to measure the field of view diameter at all magnifications possible. Start with the lowest magnification.
   a) Turn your lowest power objective lens into place.
   b) Place your ruler across the hole under the objective.
   c) Look at the ruler through the eyepiece. Focus.
   d) Line up the ruler so that it stretches across the full diameter of the field of view.
   e) Count the marks on the ruler to measure how wide the field of view is.
      The distance between marks is 1 mm.
   f) Record your measurement in mm in the Field of View Measurements table below.
   g) Convert the measurement to μm, and record this also.
   h) Make similar measurements using your microscope's other objectives.

 NAME ______________________

Measuring Very Small Objects

Field of View Measurements

Objective magnification x eyepiece magnification =	Total magnification used	Field of View Diameter	
		mm	µm
example: 4X x 10X =	40X		

6. Take a single poppy or thyme seed and look at it in the microscope.
7. Draw what you see on Student Sheet 3.4.
8. Estimate the seed's length in your microscope by comparing it to the diameter of the field of view. Do not use your ruler.

   Does the seed stretch across the entire diameter? If so, is it the same length as the field of view? Would it take two seeds to stretch across the field of view? If so, the seed is half the size of the field of view at that magnification. Use your field of view measurements and the table on Student Sheet 3.3 to guide your calculations of seed length. Fill in the answer in the data table on Student Sheet 3.3.
9. Now measure 2 more types of seeds using the same method and fill in Student Sheets 3.3 and 3.4 with your drawings, measurements, and calculations.

Questions

- Compare your two measurements for the size of a poppy or thyme seed (one measurement made with only a ruler, and the other made with the microscope). Are the two measurements the same?
- Which was more accurate, measuring the seeds with a ruler and your eye or comparing them to the size of the field of view in your microscope? Why?
- We can see seeds with our naked eye, but some objects are so small we can see them only with a microscope. Could we estimate the size of these extremely small objects using the microscope?

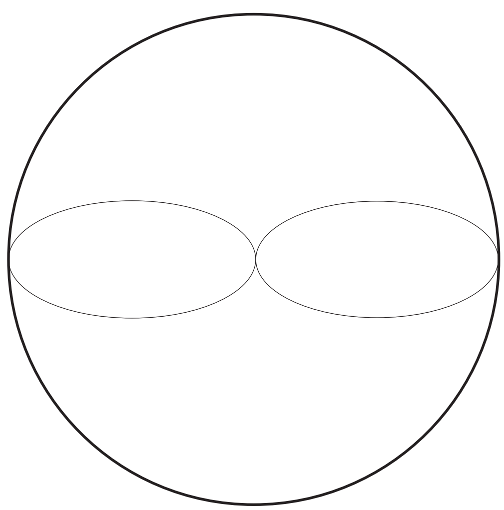
STUDENT SHEET 3.3 NAME ______________________

Microscopic Measurements

(This table will be used in Activity 4 also.)

Item	**Magnification used**	**Items/ diameter***	**Field diameter** (mm)	**Calculation:** field diameter ÷ # of items	**Length of item** (mm)	**Length** (µm)
Poppy seed						

* How many items stretch across one field of view diameter?



STUDENT SHEET 3.4 NAME ____________________

Seed Observations

Observe 3 different seeds (including the poppy seed) in the microscope and draw what you see. Include magnification. Write a few words describing what you see. You may use analogies if you like.

Measure and calculate the size of the seeds using a microscope and your field of view measurements from Student Sheet 3.2. Record size below as well as on Student Sheet 3.3.

Specimen	Description	Drawing	Size (μm)
		MAGNIFICATION:________	
		MAGNIFICATION:________	
		MAGNIFICATION:________	

ACTIVITY 4.

Observing Plant and Animal Cells in the Microscope

TIME One to two 50 minute sessions.

CONCEPTS

- Living things are made up of microscopic units called cells.
- Cells are very small, although different types of cells vary in size and shape.
- Because they are so small, cells are studied with microscopes.
- Cells from plants and animals share certain features such as a distinct outer edge (cell wall or cell membrane), a nucleus, and chromosomes.

SKILLS

- Preparing wet mounts of cells.
- Observing cells in the microscope and making accurate drawings of them.
- Measuring microscopic objects by comparing to the size of the field of view.
- Estimating the size of a microscopic object by comparing to another object in the field.

Overview

Students observe plant and animal cells in the microscope, measure their size, and identify cell parts.

In this activity, students make wet mounts of plant and animal cells and observe them in the microscope. They will be able to see the overall cell shape and identify cell walls in plant cells, cell membranes in animal cells, and the nucleus in both types of cell. In addition, they will be able to observe chromosomes in prepared slides of specially stained onion root tips, although not in the onion skin wet mounts they prepare themselves. The size of the cells will be estimated using the field of view technique introduced in Activity 3. Students will look at the following:

- **Wet mount of onion skin, stained with iodine. Nuclei will stain yellow or brown.**
- **A human hair**
- **Wet mount of their own cheek cells, stained with methylene blue. Nuclei will stain blue.**
- **Commercially prepared slides of onion root tips. Condensed chromosomes will be visible inside the nuclei of some cells.**

MATERIALS

for the teacher

Overhead Master 4.1, *Plant and Animal Cells*

for the general supply station

- Toothpicks (flat style)
- Disinfectant (e.g. Pinesol, for disinfecting used toothpicks from students' mouths)
- Onion
- Cutting Board
- Knife
- Prepared microscope slides showing chromosomes in onion root tip ("Onion mitosis" slides are available from scientific supply companies such as Ward's [www.wardsci.com] or Carolina [www.carolina.com].)
- Eye droppers or transfer pipets
- Iodine solution (1/10X dilution of drugstore iodine)
- Methylene blue solution, 0.05%

for each group of 2–3 students

- Microscope (a compound microscope of at least 100X magnification)
- Transparent metric ruler
- Waste containers (e.g. paper cups), one with disinfectant and one without
- Slides
- Cover slips

for each student

- Student Sheet 4.1a, *Observing and Measuring Cells: Instructions*
- Student Sheet 4.1b, *Observing and Measuring Cells: Data Chart*
- Student Sheet 4.2, *Using a Hair to Measure Human Cheek Cells* (Use this sheet only if the class microscopes are not adequate for measuring. See Getting Ready, #5, below.)
- Student Sheet 4.3, *Observing Onion Root Tip Cells*

GETTING READY

1. Assemble materials.
2. Prepare iodine and methylene blue solutions as follows.

   Iodine. Dilute drugstore iodine 1/10 in water.

   Methylene blue. If you are starting with methylene blue powder, make up a 0.5% stock solution by adding 0.5 g powder to 100 ml water. Dilute some of this stock solution 1/10 by mixing one part stock solution with 9 parts water to make a working solution of 0.05%. Store extra stock solution for future use. If you are starting with a liquid stock of methylene blue (some suppliers ship methylene blue as a solution), dilute it in water to a final concentration of 0.05%. Do not use a more concentrated solution of methylene blue because the cells will be stained a solid blue, and details such as the nucleus will be difficult to observe.
3. Set up a general supply station in the room and arrange materials there that will not be distributed to student groups (see *Materials* above).
4. Cut up onion into chunks using knife and cutting board. Place in the general supply area. You may want to put the cut up onion in a plastic bag to help control the odor.
5. Look at stained human cheek cells in the microscope and determine whether your microscope will allow you to measure the cells using the field of view technique. If not, you will need to use the hair comparison technique. See *Presenting the Activity* for further details. It is important to determine what measurement technique you will use in advance, so that you can tell students which protocol to follow. An additional student worksheet is needed if students will be using the hair comparison technique.

Background Information for Teachers

Glossary for Activities 4 and 5

Introduce terms for the parts of a cell *after* your students have observed them.

Amoeba (PL. AMOEBAS OR AMOEBAE) → A single celled organism that moves by extending a part of the cell called a pseudopodium. Amoebas share many features with the cells of plants and animals: they have a nucleus, chromosomes, and cell membrane.

Bacterium (PL. BACTERIA) → A simple, single celled organism. Bacteria come in different shapes and sizes. Unlike plant and animal cells, bacteria do not have a nucleus, although they have a cell membrane and cell wall. The genetic material is found in the cytoplasm.

Cell → The building block of living organisms, and the smallest unit that can perform all the life processes.

Cell membrane → The outer layer of an animal cell. Plants also have a cell membrane, but it is surrounded by another layer, the cell wall.

Cell wall → The outer layer of a plant cell. It gives the cell strength.

Chromosome → Structures in the nucleus that contain the genetic information.

Cytoplasm → The part of the cell enclosed by the cell membrane, but not including the nucleus.

Nucleus → The area inside a plant or animal cell that contains the genetic information. It is surrounded by a membrane, so it is like a smaller sack inside the cell.

Organ → A structure in a plant or animal made of several different tissues that work together to perform a particular function (e.g. heart, skin).

Paramecium (PL. PARAMECIA) → A motile, single celled organism that lives in pond water. Like the cells of animals and plants, paramecia have a nucleus, chromosomes, and cell membrane.

Tissue → A group of similar cells that function together.

Yeast → A non-motile, single celled organism with a nucleus.

Presenting the Activity

Elicit from students the names of the smallest living organisms they have heard of. They may mention germs, bacteria, yeast, amoebas, and paramecia. Ask them how these organisms can be seen (with a microscope) and what they look like (little sacks or balls or ovals). Then tell them that each of the tiny shapes we see in the microscope when we look at bacteria or yeast is an individual organism. Show students a picture of bacteria or yeast. Organisms that can only be seen with the microscope are called microbes or microorganisms. Each microorganism can carry out the functions of a living organism, including eating, growing, and reproducing. The smallest unit of life that can carry out these essential functions is called a cell. Bacteria and yeast are organisms that consist of only a single cell.

Ask students whether they think larger organisms, like plants, trees, animals, and people, have cells. Cells are the basic building blocks of all living organisms. Complex organisms like plants and animals consist of many types of cells that have different functions. But different types of cells have certain features that are similar. Students will look at cells from two different organisms: onions and humans. They will obtain human cells by scraping cheek cells from the insides of their own mouths. They will use microscopes to see how plant and animal cells are similar and how they are different. They will also estimate the size of these cells by comparing them to the microscope's field of view or a hair. Finally, they will look at prepared slides of onion root tips, a growing part of the onion plant that contains dividing cells. These cells have been stained so that their chromosomes can be seen.

OBSERVING PLANT CELLS (ONION SKIN)

Ask each student group to get a chunk of onion from the general supply station. Demonstrate how to separate the fleshy layers of the onion and peel off the thin skin in between. This skin is made up of a single layer of cells, which allows easy visualization of cells in the microscope. Instruct the students to follow the directions on Student Sheet 4.1a for preparing stained onion cells and looking at them under the microscope. Make sure students get a THIN skin of onion to look at in the microscope. Remind them to follow the directions for correct use of the microscope, starting with the lens just above the slide and then focusing by raising the lens (or lowering the stage). Have students draw what they see on Student Sheet 4.1b. Students should also estimate the length of an onion cell by comparing it to the field of view diameter and record the cell size on Student Sheet 4.1b. You may wish to write the field of view diameter for each magnification (determined in Activity 3) on the blackboard for your students' easy reference.

You may want to lead the students through the preparation of their first wet mount, but after that they should be able to work independently. Allow about 15 minutes for the students to observe the onion cells.

MEASURING THE WIDTH OF A HUMAN HAIR

Students have used the field of view technique to measure an extremely small object, an onion cell. They will now use the microscope to compare the size of an onion cell to the size of an object they are all familiar with and can actually see—a human hair. In this way, students will develop a deeper understanding of the size of a cell. The width of a human hair may be too small to measure using the field of view technique. Instead, students can measure the hair width by comparing the hair to the size of a previously measured microscopic object, the onion cell.

Ask students to pluck a hair from their heads and place it under the cover slip on their microscope slide, next to an onion cell. Students should estimate the width of the hair by comparing it to the length of the cell, which they have already calculated. For example, if their onion cell was 300 μm, and their hair width is 1/2 the length of the cell, then the hair would be 150 μm wide. If needed, you can demonstrate this calculation on the blackboard. Students may be able to measure the hair using the field of view technique. But be aware that this is not possible on all microscopes. **Have students fill in the hair measurement on both Student Sheet 4.1b and Student Sheet 3.3, *Microscopic Measurements.***

NOTE: MEASURING the human hair must be done the same day as viewing the onion cell so that its size in relation to the onion cell can be determined. So if you are running out of time, DO NOT pause the activity BETWEEN the onion cell and the human hair. Pause AFTER the human hair and continue the next day. It is essential to measure the hair in this activity so that students may use their measurement in Activity 6.

OBSERVING ANIMAL CELLS (HUMAN CHEEK CELLS)

Students will now prepare a wet mount of their own cheek cells. Students will place a drop of 0.05% Methylene Blue on a slide and use a toothpick to *gently* scrape some cells from the inside of their cheeks. To transfer cells to the slide, students should touch the end of the toothpick to the drop on the slide and swirl it gently. Since students are working with human tissue, instruct them to put their toothpicks into a cup of disinfectant as soon as they use them. Students should not share toothpicks. Next, students should cover the cells with a cover slip and allow five minutes for the cells to take up the stain. Make sure that students do not use a solution of methylene blue that is too concentrated because the cells will appear solid blue, and students will not be able to observe details such as the nucleus.

Have students describe and draw the cheek cells on Student Sheet 4.1b. Their descriptions should include how cheek cells are similar to onion cells and how they are different.

Students can estimate the size of the cheek cells either by comparing them to the field of view diameter or to the width of a strand of their hair, which they have previously measured. If your microscopes are not powerful enough, students may not be able to use the field of view technique to measure objects as small as a cheek cell. In this case, your students will need to use the hair comparison method. You should determine what method your students will use in advance. If you cannot measure the cells using the field of view technique, have your students estimate cheek cell size by comparing them to a human hair. In this case, provide students with Student Sheet 4.2, *Using A Hair to Measure Human Cheek Cells*. Do not provide the students with this sheet otherwise.

USING A HUMAN HAIR TO ESTIMATE THE SIZE OF CHEEK CELLS

Use this technique only if your microscopes are not powerful enough to use the field of view technique to determine the size of cheek cells. Students will first measure the width of a human hair with the field of view technique and then estimate the size of cheek cells by comparing them to the width of a hair. Have students follow the instructions on Student Sheet 4.2. You may need to walk them through a sample calculation. Because hair width varies greatly from person to person, student groups must use hair from the same person whose hair they measured previously.

OBSERVING ONION ROOT TIPS AND CHROMOSOMES

Have the students look at the commercially prepared slide of onion root tips. These cells have been stained to highlight certain structures inside the cells, including the chromosomes. Root tips contain cells that are growing and dividing. Just before cell division, the chromosomes become tightly packed and take up the stain. As a result, students may be able to see them inside the nuclei of some of the cells. They will look like squiggly lines.

Have the students complete their observations and answer the questions at the end of Student Sheet 4.3.

ADAPTING THE ACTIVITY FOR MIDDLE SCHOOL STUDENTS

Because younger students learn best when they have concrete examples, we have not introduced any organelles or cell parts in this activity that they cannot observe themselves. However, in middle school, students frequently learn about the parts of a cell in more depth than is presented here. They may learn about the structure and function of organelles such as the golgi apparatus, endoplasmic reticulum, mitochondria, chloroplast, and ribosomes. If you would like your students to learn about these organelles, you can supplement this activity with a more detailed reading or activity. Be sure to relate the functions of the organelles back to the functions students identified in Activity 1, *Living and Non-living*. If you want students to view the organelles firsthand, provide them with prepared slides of cells that have been stained for specific organelles. These slides can be purchased from science education supply houses, such as Carolina Biological (http://www.carolina.com) and Ward's (http://www.wardsci.com).

Discussion

Bring the group together and have them share their drawings. Lead a discussion and incorporate some of the questions and suggestions below.

What are some of the things you observed in your microscope?

Did you observe any parts or structures within the cells?

How are plant cells like animal cells? How are they different?

In stained onion skin, students should be able to see well-defined cell walls around the outside of cells. They should also be able to clearly see a nucleus in most cells. Animal cells such as those from human cheek have a cell membrane, but they do not have a cell wall. Explain that plants do not have skeletons, so they have rigid cell walls to provide strength. Students should have noticed the stringy material inside the nuclei of some of the onion root tip cells. Allow the students to describe the cell parts before you introduce vocabulary words such as nucleus, cell membrane, and chromosomes. Then show students Overhead 4.1, which shows drawings of generic plant and animal cells with cell membrane, cell wall, nucleus, and chromosomes. Instruct the students to label the cell parts in each of their drawings on Student Sheets 4.1b and 4.3.

As students describe the cells, encourage them to make analogies to objects in the macroscopic world. Ask:

What does onion skin seen under the microscope remind you of?

For example, the sheet of onion cells may remind them of a brick wall. When you're far away from the brick building, you don't notice each individual brick, just as you don't see each cell when you look at a sheet of onion cells with the unaided eye. But when you get closer to the wall, you can see individual bricks, just as you see individual cells when you look at the onion skin through the microscope.

Point out that there are many structures inside the cells that can only be seen with certain stains or with special microscopes. Ask students:

Was there anything you could observe in the onion root tip cells that you couldn't see in the onion skin or cheek cells?

The nucleus contains an organism's genetic material in structures called chromosomes. When students stained onion skin with iodine, they did not observe any chromosomes within the nuclei. This is because chromosomes are usually long and stringy and cannot be seen under a microscope. But just before cells are ready to divide, the chromosomes become tightly condensed, and these condensed chromosomes can be stained with special dyes, as in the prepared onion root tip slides. Students were able to observe chromosomes firsthand by viewing the prepared slides of dividing onion root tip cells.

In this activity students examined one type of plant cell and one type of animal cell. There are many different types of cells in plants and animals. These vary greatly in size, shape, and specialized function. Based on their observations of onion and cheek cells, students may conclude that plant cells are bigger than animal cells. Point out that they have looked at only one type of animal and plant cell and that they would have to look at many more types before they could make that conclusion. Students can read about different types of human cells in the interest link that follows Activity 5, *Specialized Cells.*

Formative Assessment of Student Learning

As students are working on the activity and using their microscopes, circulate around the room and ask yourself these questions to assess student learning. You may wish to prompt students with questions in order to aid your assessment of their learning.

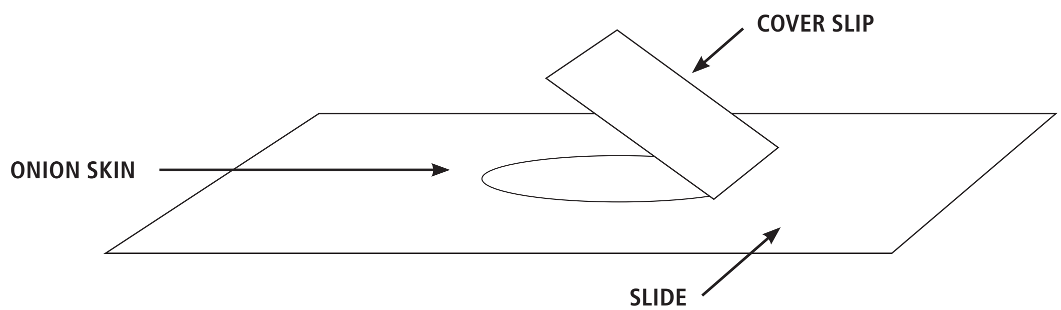
- Are students using the microscopes correctly as described in the directions?
- Are students following the procedures for making wet mounts and staining cells?
- Are students actively involved in observing their specimens, describing characteristic shapes and sizes, noticing internal structures, and using accurate descriptive words and analogies to discuss what they see?
- Are the students making accurate and detailed drawings of their specimens, representing them in correct proportion relative to the field of view and other items in the field, and including all structures they observe?
- Are the students noticing similarities and differences between different cell types?
- Do the students grasp the concept of estimating size in relation to the field of view or another object in the field, and do they make reasonable estimates?

STUDENT SHEET 4.1a. **NAME** ______________________

Observing and Measuring Cells: Instructions

Onion cells

1. To prepare a wet mount of onion cells, take a small chunk of onion and peel off a layer of the paper-like skin between the onion's fleshy layers.
2. Lay the onion skin on the center of the slide. Try to avoid wrinkles. The piece of onion skin should be smaller than the cover slip.
3. Using an eye dropper or pipet, put 1–2 drops of 1/10 X iodine solution on top of the onion skin.
4. Place a cover slip on top of the onion skin by holding it at an angle over the specimen and gently laying it flat, as shown below. Try not to trap bubbles underneath the cover slip.



5. Observe onion cells in the microscope and draw and describe what you see on Student Sheet 4.1b.
6. Determine the length of an onion cell by comparing it to the diameter of the field of view, as you did in Activity 3. Record on Student Sheet 4.1b and also on the large data table on Student Sheet 3.3 from Activity 3.

Remember: Cell Length = Field of View Diameter ÷ number of cells stretching across the field

Human Hair

How wide is a human hair? How does a hair's width compare to the size of an onion cell?
Try measuring the width of a strand of your hair by comparing it to an onion cell.

1. Place a strand of your hair on the same slide as the onion cells, *under* the cover slip.
2. Observe the hair in the microscope and draw and describe what you see on Student Sheet 4.1b.
3. Estimate how wide the hair is compared to the length of a nearby onion cell, which you have already determined. Record the hair width below and on Student Sheets 4.1b and 3.3.

For example, if the width of your hair is half the length of an onion cell, then you would write down one half the length of the onion cell in the space below.

The width of my hair is: ________________ μm

Cheek cells

Now observe animal cells. Observe your own cells by scraping a few cheek cells from the inside of your mouth.

1. Place a drop of 0.05% methylene blue solution on the slide.
2. Scrape the inside of your mouth gently with a toothpick.
3. Swirl the toothpick in the drop of liquid.
4. Cover with a cover slip, wait 5 minutes for the stain to enter the cells, and examine in the microscope.

   CAUTION: Because you are looking at human tissue, place all toothpicks, slides, and cover slips used with cheek cells in disinfectant after use. Only prepare slides with your own cells. Wash your hands when you finish working with the cheek cells.

5. Draw and describe the cells on Student Sheet 4.1b. In your description, compare what you see to onion cells.
6. Determine the length of the cheek cells by comparing them to the diameter of the field of view, just as you did for the onion cells and in Activity 3.

   NOTE: Some microscopes may not allow the cheek cells to be measured. In this case, your teacher will tell you a different method to measure the cells.

7. Record cell size on Student Sheet 4.1b as well as in the large data table from Activity 3 on Student Sheet 3.3.

Remember: Cell Length = Field of View Diameter ÷ number of cells stretching across the field

STUDENT SHEET 4.1b. NAME ________________________

Observing and Measuring Cells: Data Chart

To calculate size: Cell Length = Field of View Diameter ÷ number of cells stretching across the field

Specimen	Description	Drawing	Size (μm)
Onion skin stained with iodine		MAGNIFICATION:__________	Length
Human hair		MAGNIFICATION:__________	Width
Cheek cells stained with methylene blue		MAGNIFICATION:__________	Length

STUDENT SHEET 4.2. NAME ____________________

Using a Hair to Measure Human Cheek Cells

Note: Use this sheet only if you cannot measure the length of a cheek cell using the field of view technique.

Now that you have measured the extremely small width of a human hair, you can measure the size of items that were too small to measure using the field of view technique, such as a human cheek cell. To do this, compare the size of the cheek cell to something you have already measured, a human hair.

You could also use this technique to measure other microscopic objects that are too small to measure using the field of view technique, such as bacteria.

1. Place a human hair next to human cheek cells on a microscope slide and cover with cover slip. Because hair width varies greatly from person to person, make sure to use hair from the same person whose hair you measured earlier (on Student Sheet 4.1).
2. Look in the microscope and find a field that shows the human hair and at least one cheek cell. Estimate how many cells it would take to stretch end to end across the *width* of the hair.
3. Fill out the table below and calculate the length of a human cheek cell by comparing it to the width of a human hair, which you have already measured.
4. Record the length of a cheek cell on Student Sheets 4.1b and 3.3.

Calculation: Measuring cheek cell using a human hair

$$\frac{\textbf{Human Hair Width}}{\textbf{\# of cheek cells that stretch across one hair width}} = \textbf{length of cell}$$

Item	Human hair width in µm (previously measured)	number of cells per width of a human hair	Calculation: hair width / # of cells	length of cell (µm)
Cheek cell				

STUDENT SHEET 4.3. NAME ______________________________

Observing Onion Root Tip Cells

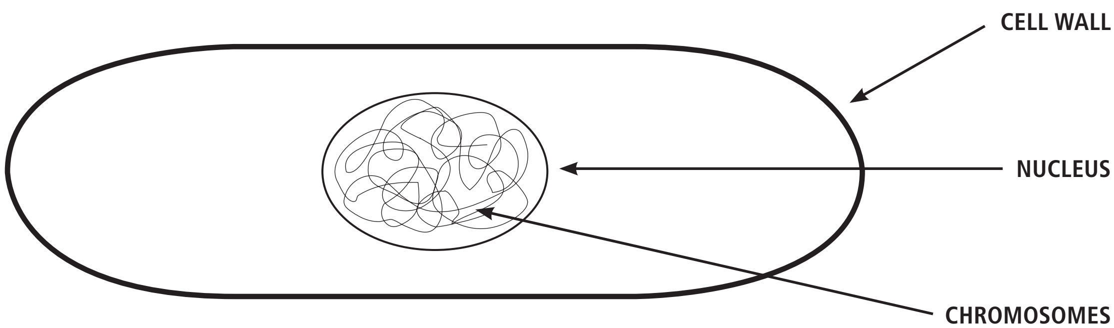
Prepared slides of onion root tip. The onion cells on these slides have been treated with a dye that stains structures inside of the cell. Root tips contain cells that are growing and dividing.

1. Examine the root tip slides in the microscope.
2. Draw and describe what you observe in the chart below.
3. What do you see in this slide that you didn't see in the iodine stained onion cells?

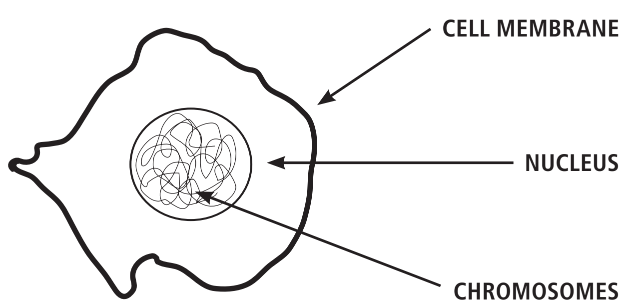
Specimen	Description	Drawing
Onion skin stained with iodine		MAGNIFICATION:__________

Plant and Animal Cells

Plant Cell



Animal Cell



INTEREST LINK: CAREERS IN CELL BIOLOGY

Cell biologists are scientists who study cells. They can do many different types of jobs and work in lots of different types of places. Some cell biologists study the cells of large organisms such as humans. They may work in laboratories and hospitals and specialize in researching how cells perform essential life functions such as eating, growing, and breathing. For example, understanding how cells grow and divide can help scientists learn more about cancer, a disease that occurs when cells divide uncontrollably.

Microbiologists are a type of cell biologist. They study cells too, but they focus on *microbes*—very small organisms such as bacteria, viruses, and fungi that can be seen only with a microscope. They study harmful microbes and also develop ways to use microbes to help us in medicine, agriculture, industry, and the environment. *Food safety inspectors* are microbiologists who work to keep our food supply safe by making sure it is free of harmful microbes. For example, they may inspect restaurants to make sure meat is cooked at temperatures high enough to kill bacteria. Scientists working in the field of *bioremediation* may use bacteria to remove or break down polluting chemicals, such as oil. *Agricultural scientists* may study molds, a type of fungi, that grow on vegetables and cause them to rot before they are ripe. Or they may study how to spray plants with microbes that can kill leaf-damaging insects.

Forensic scientists examine physical evidence that can be used to solve crimes. They may have training in chemistry, biology, and microscopy. Forensic scientists examine the evidence and determine whether or not it can be linked to the suspect. In this way, they can help to prove the suspect's innocence or guilt. For example, hairs and clothing fibers found at the crime scene can be examined microscopically to try to match them to a suspect. Paint left from a hit and run accident can be traced to the exact make, model, and year of the car. Even animal hairs have been used to help solve crimes (see sidebar).

REFERENCES

The Case of Snowball the Cat

SYRACUSE UNIVERSITY MAGAZINE

http://sumagazine.syr.edu/summer01/features/brightideas

Careers in the Microbiological Sciences

AMERICAN SOCIETY FOR MICROBIOLOGY

http://www.asm.org/Education/index.asp?bid=1272

CAT HAIR HELPS CONVICT A MURDERER

In 1994, a cat named Snowball helped to solve the murder of a 32 year old mother of five on Prince Edward Island, Canada. The victim's body was found in a shallow grave a few months after she disappeared. The Royal Canadian Mounted Police suspected her former husband had murdered her, but they did not have any evidence against him. A leather jacket found near the body contained two important pieces of evidence—blood stains and several white hairs that looked like animal hairs. Forensic scientists determined the blood came from the victim. The Mounties remembered that the suspect's parents, with whom he was living, had a white cat named Snowball. A lab that specialized in cat DNA was contacted and asked to analyze the white hairs. By comparing DNA from the hairs on the jacket to Snowball's DNA, the lab showed that the white hairs belonged to Snowball. This evidence helped to convict the suspect of the murder, and this case opened the door to the use of animal DNA in many later cases.

ACTIVITY 5.

Modeling Cells

TIME One 50 minute session.

CONCEPTS

- Scientists build models to help them understand how something works, what it looks like, or how its parts interact.
- Cells have several parts such as the cell wall or membrane, the nucleus, and the chromosomes.
- Cells can interact with each other in different ways to form tissues. Tissues interact to form organs.

SKILLS

- Taking real observations and using them to create a model
- Working together cooperatively to build s omething

Overview

Students build a simple cell model and use it to show how similar cells interact to form a tissue and how tissues interact to form an organ.

MATERIALS

for each student

- Student Sheet 5.1, *Making Models of Cells, Tissues, and Organs*
- Large resealable plastic bag
- Small resealable plastic bag
  (MUST FIT INTO LARGE PLASTIC BAG)
- 12 feet of yarn

for each group of students

- Tape

for the teacher

- Green onion

GETTING READY

1. Photocopy Student Sheet 5.1.
2. Cut yarn into 12 foot sections.
3. Gather materials (Resealable bags, yarn, tape).
   Note: A good combination of large and small bags is gallon and quart-sized bags. You can also use sandwich bags (about 6 inches x 5 inches) in combination with 3.5 inch x 3 inch bags, which are available at specialty stores.

Background Information for Teachers

Cells are the basic building blocks of all living organisms. Complex organisms like plants and animals are composed of many types of cells, each with a different function. But all cells share certain features. As students observed in the last activity, plant and animal cells have a nucleus, a cell wall or cell membrane, and cytoplasm.

In organisms, groups of similar cells combine with each other to form tissues. For example, bundles of muscle cells stretched out side by side form muscle tissue. The onion cells students looked at were also arranged in a tissue, onion skin.

In both plants and animals, tissues are organized into different body parts or organs. An organ is a structure that has a specific function and is made up of several different kinds of tissues. Some examples of organs that students are familiar with include heart, lung, eyes, and kidneys.

In this activity, students use simple materials to model what they observed in the microscope when they looked at onion and cheek cells. Students will make three models. First, each student makes a single cell. As a larger group, students assemble their cells into a tissue, onion skin. Finally, they make a model of a simple plant part, an onion stem, by rolling their onion skin model into a tube.

Teachers frequently use models and model building to represent objects, demonstrate processes, or to assess student knowledge. Models allow students to handle or manipulate an object that might otherwise be inaccessible, perhaps because it is too small, too large, or too remote. It is important to keep in mind that all models have limitations. For example, the materials used to make a model may have different properties from the actual object, or we may not be able to represent distances accurately. Students need to be aware of these limitations.

Scientists use models in a variety of ways, including representing inaccessible objects or abstract concepts. They can even use models experimentally to predict a molecular structure that is consistent with experimental data. An excellent example of this is the discovery of the structure of DNA by James Watson and Francis Crick in 1953. Their monumental paper was based on the three-dimensional model of DNA they built. This model took into account a wide variety of experimental data gathered by other scientists. The strength of their model and the reason that it was accepted by the scientific community lay in the fact that it was consistent with all the existing information about DNA, it explained many observations about the properties of DNA, and it allowed scientists to make testable predictions about DNA.

RESOURCES

BA Education. *The people responsible for the discovery of DNA*

http://www.ba-education.demon.co.uk/for/science/dnamain.html

Chemical Heritage Foundation. Chemical Archives: The Human Face of the Chemical Sciences.
James Watson, Francis Crick, Maurice Wilkins, and Rosalind Franklin

http://www.chemheritage.org/classroom/chemach/pharmaceuticals/watson-crick.html

Presenting the Activity

MAKING A CELL MODEL

Students create a cell model to represent what they saw when they observed onion skin cells under the microscope. Review the features they observed in the onion skin and cheek cells, including the cell wall of the onion cells, the cell membrane of the cheek cells, and the nucleus in both cell types. You will need to tell them that the squiggly material inside the nuclei of the onion cells is the genetic material for the cell, the chromosomes (or DNA).

Provide each student with Student Sheet 5.1, one small and one large resealable plastic bag, and a twelve foot length of yarn. Instruct them to make a model of a cell with these materials, as stated in Student Sheet 5.1. They should be able to create a simple cell model by placing the yarn inside the small bag and then placing this inside the larger bag, as shown in Figure 5.1. The students should draw and label their cell model on Student Sheet 5.1 or in their student notebook, as instructed in their directions.

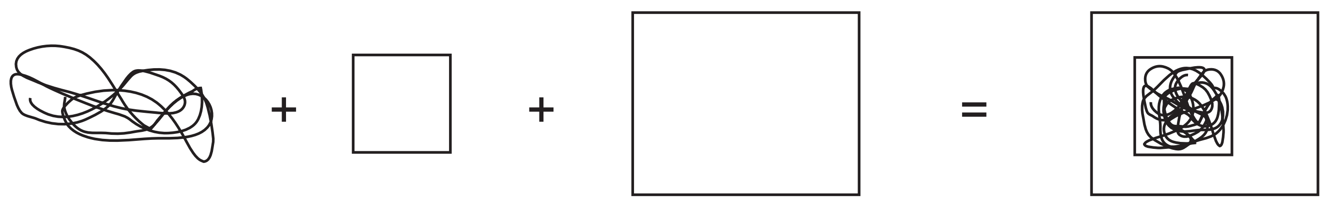


FIGURE 5.1. A cell model

MAKING A TISSUE MODEL

Explain to the students that in organisms, groups of similar cells combine with each other to form tissues. For example, the layer of onion skin they observed under the microscope is a tissue.

Split the class into two groups. Challenge each team to recreate what they saw when they looked at the sheet of onion skin, using their cell models and tape. The students should figure out that they can use the tape to join all their cells together to create one big sheet of onion skin, as shown in Figure 5.2. As specified on their student sheet, students should draw their tissue model in their notebook or on Student Sheet 5.1.

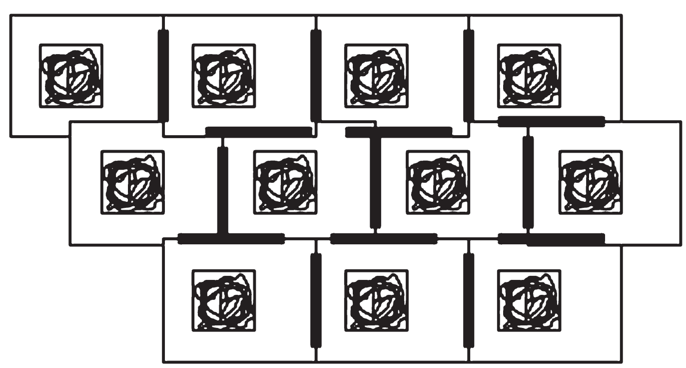


FIGURE 5.2. A tissue model

MAKING A MODEL OF AN ORGAN

Explain to your students that different kinds of tissues are organized together to form body parts or organs. An organ is a body structure with a specialized function, and it is usually made up of several tissue types. Ask students to name some of the organs in their bodies and describe their functions.

Show the students a stem of green onion (an onion stem is really a leaf!). Challenge the student teams to use their layer of onion skin to form an onion stem. They should recognize that they can roll their layer of cells into a tube to represent the hollow stem. The teams might also choose to stack two layers of cells and then roll them together, forming a tube with concentric layers. Tell students to draw and label their models in their student notebooks or on Student Sheet 5.1.

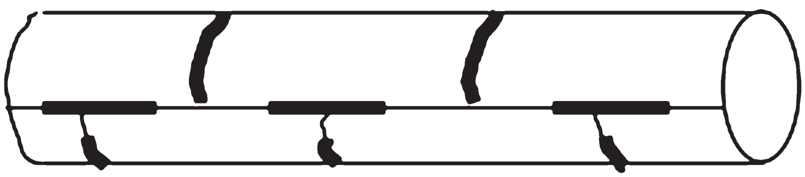


FIGURE 5.3. Model of an organ

DISCUSSION QUESTIONS

After the students have constructed and drawn their three models, ask them to discuss the three questions on the bottom of Student Sheet 5.1 with the other people in their group and then write their answers on the student sheet or in their notebook. Then discuss these questions as a class.

ASSESSMENT STRATEGY

As homework or an in class assignment, ask students to write a paragraph that describes how a brick is similar to an onion cell. Tell them to discuss how bricks are used to make structures that are analogous to tissues and organs.

Formative Assessment of Student Learning

As the students carry out this activity, watch for the following to assess their progress and understanding.

- Do students use the materials provided to build a cell model that is similar to the onion skin cells they observed, using the large resealable bag for the cell wall, the smaller bag for the nucleus, and the yarn for the DNA?
- Do students use their cell models to show how cells can be joined to form a tissue, and tissues formed into structures or organs?
- Do students understand the meaning of cells, tissues, and organs, and do they recognize that they have organs in their own bodies?
- Do students recognize the usefulness, as well as the shortcomings, of building models?

STUDENT SHEET 5.1. NAME ______________________________

Making Models of Cells, Tissues, and Organs

Making a Cell Model

Use one large and one small plastic bag and 12 feet of yarn to create a model of an onion cell. Draw your cell model in the space below or in your notebook, and label its parts.

Making a Tissue Model

Inside the bodies of living organisms, groups of similar cells combine with each other to form tissues. For example, muscle tissue is made up of bundles of muscle cells arranged side by side. The onion cells you looked at were also arranged in a tissue.

Your teacher will divide your class into two groups. Using tape, work with your group to combine all of your cell models to make a tissue like the onion skin you looked at. Draw and label your model of onion skin in the space below or your notebook.

Making a Model of an Organ

An organ is a body structure with a specialized function, and it is usually made up of several tissue types. The stem of a green onion is a simple plant part that is made of plant tissue organized in a certain way.

Use your model layer of onion skin cells and the tape to show how onion skin can be formed into a green onion stem. Draw and label your onion stem model in your notebook.

Discussion Questions

Discuss the following questions with the students in your group.
Write your answers in the space below or in your notebook.

In what ways are the three models you built similar to the things they represent?

In what ways are each of your models different from the real thing?

How can models help us understand how something works? What are some disadvantages of models?

INTEREST LINK: SPECIALIZED CELLS

The human body is made up trillions of cells. Cells make up your skin, muscles, and internal organs. Even your bones contain cells. Cells need the same things to stay alive that living organisms do, like oxygen, food, water, and a way to get rid of waste. But not all cells in our bodies are alike. We have hundreds of different types of cells that are specialized to carry out the many functions of a living organism. For example, the muscle cells that make up the walls of your heart cause its rhythmic beating. The cells in your pancreas produce a hormone called insulin that helps you control the levels of sugar in your blood. Neurons (nerve cells) communicate information between your brain and all parts of your body.

Muscle cells not only make up all the muscles in your body, like the biceps in your arms, but are an important part of many organs too. The walls of your heart are made up of long muscle cells, arranged side by side (top panel of figure). These muscle cells contract (grow shorter) and expand (grow longer) in unison to cause your heart to beat rhythmically. This pumps blood throughout your body. The heart contains other types of cells too. Without muscle cells, your heart would be unable to beat.

Glands are organs that help regulate many of your body's functions, like growing, maturing, and using food. The specialized cells of glands make chemical messengers called hormones that they release into the blood. The hormones travel in the bloodstream throughout the body, finding the places where they perform their jobs. One gland, the pancreas, is about the size of your fist and is located right behind your stomach. Beta cells in the pancreas produce the hormone insulin (middle panel of figure). Insulin helps control your blood sugar levels. If your blood sugar levels are too high or low, you can become sick. Diabetes is a disease that occurs when your body either doesn't make enough insulin or doesn't respond to it correctly. People with diabetes can control their blood sugar levels by controlling what foods they eat, exercising, and in some cases by taking insulin shots several times a day.

Neurons are the cells of your nervous system, which includes your brain, your spinal cord, and the many nerve cells throughout your body (bottom panel of figure). Neurons communicate with each other and with muscle and gland cells by sending and receiving both chemical and electrical signals. In this way, neurons can carry information from all parts of your body to your brain and back again in nanoseconds (1/1,000,000,000 second). For example, if you touch a hot stove, the nerves in your finger send a message to your brain that says "hot" and "ow!" The neurons in your brain immediately send a message back to the muscles in your arm and finger saying "take your hand off of the stove NOW!" Neurons come in many different shapes and sizes. As you can see in the picture, neurons are unusual looking. They have a cell body with branching dendrites and an axon. The cell body can be up to 100 micrometers wide (about 1/10 the width of a poppy seed) or as small as 4 micrometers. The really amazing thing about neurons is that they can be over a meter long—some neurons stretch all the way from the tip of your big toe to your brain!

We've looked at only three of your different cell types—muscle, gland, and neuron—but there are many, many more. All of your different cell types work together to make a living, breathing, functioning human—you.

REFERENCES

Kids Online
Juvenile Diabetes Research Foundation

http://kids.jdrf.org/

Neuroscience for Kids
University of Washington

http://faculty.washington.edu/chudler/neurok.html

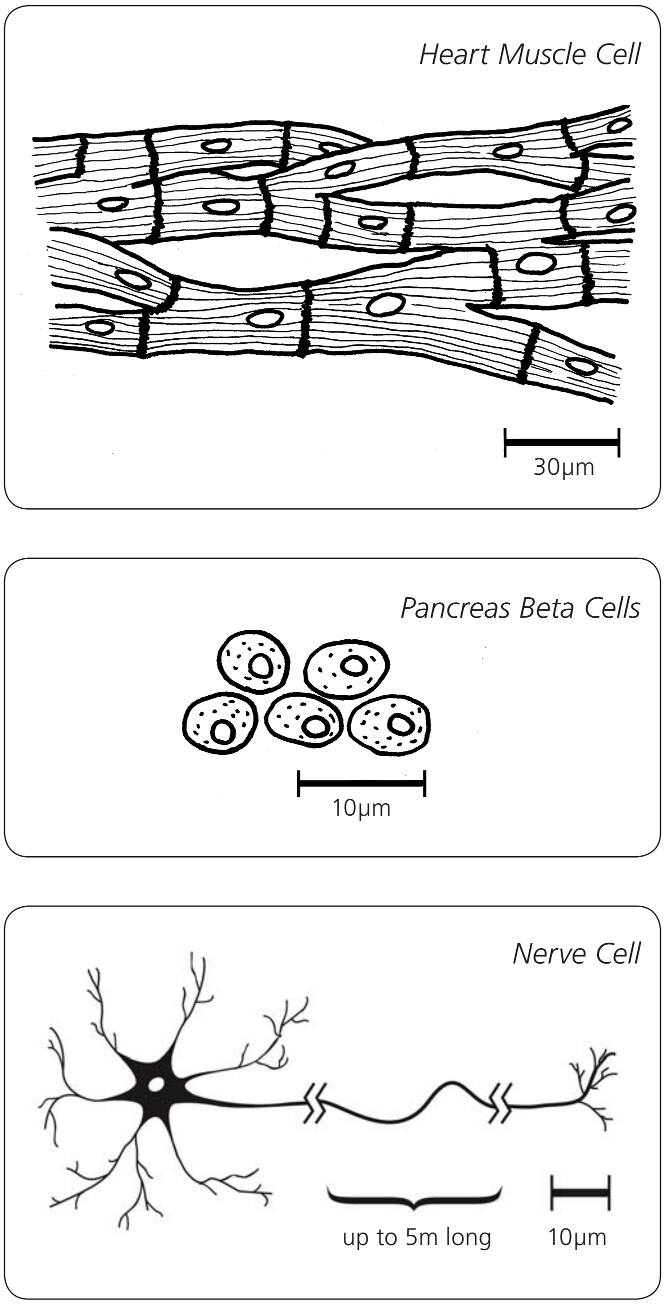


FIGURE 1. Top panel, heart muscle cells. Scale bar = 30 μm. Middle panel, pancreas beta cells. Scale bar = 10 μm. Bottom panel, nerve cell. Scale bar = 10 μm.

ACTIVITY 6.

Drawing to Scale

TIME One 50 minute session.

CONCEPTS

- Cells are very small.
- Scaled or proportional drawings show the relative sizes of objects.

SKILLS

- Calculating how large microscopic objects would be if scaled up 100 fold
- Drawing objects to scale

Overview

Students draw to scale several microscopic objects, including cells. They will use their previously determined field of view measurements from Activities 3 and 4 to calculate the size they should draw each object when scaled up 100 fold. Drawing cells in proportion to very small objects that are visible to the naked eye, like tiny seeds, will help students truly understand just how small cells really are.

MATERIALS

for each student

- Student Sheet 6.1, *Scaling Up Microscopic Objects*
- Seed and cell measurements from Student Sheets 3.3, 4.2, and 4.3
- Metric ruler
- Colored pencils, crayons, or markers
- Drawing or notebook paper

for the teacher

- Overhead Master 6.1, *Scaling Up Microscopic Objects*

Presenting the Activity

Explain to students that they will be calculating the sizes of microscopic objects if the objects were 100 fold (100X) bigger than they really are. This is called "scaling up." Students will use this idea again in Activity 7, *Sizing Up Cells*.

Use Overhead Master 6.1 to help students visualize what it means to scale up an object and to guide them through a sample scaling calculation. This overhead contains a picture of a square that has been scaled up 2, 4, 10, and 20 fold, as well as a table for making scaling calculations. A sample calculation for an object of 100 µm is provided in the table below. Use this example to fill in the first line on the overhead table as you explain how to do the calculation.

The table below also provides actual and scaled up sizes for several microscopic objects. Students will choose at least two different types of seeds, two cell types, and a human hair for their drawing, using data they have recorded on Student Sheets 3.3, 4.2, and 4.3. After entering the name and actual size of each object onto the table on Student Sheet 6.1, they will calculate the 100X size of each object in both mm and cm, as you have just demonstrated. While the students are doing their own calculations, ask for a few examples to add to the overhead table so they can see the range of sizes for each object they measured. For example, onion cells may be as small as 100 µm and as large as 300 µm, and this will result in different sizes when they are scaled up.

Next, students will use the calculated numbers from the table to make a 100X drawing of these objects, as shown in the sample drawing in Figure 6.1. They can imagine they are using a microscope to look at all of the objects at the same time in one field of view. Since the objects are in the same field, they will all be magnified to the same extent—100 fold. Make sure students do not confuse the scale factor of 100 with the magnification of the microscope that they used during their microscopic observations. You may want to show the sample drawing to the students, but don't give them a copy or they may be tempted to make their drawings just the same.

Instruct the students to use a metric ruler and pencil to lightly mark the size of each object on their paper before they sketch it. Confirm students' measurements before allowing them to proceed with their drawings. Make sure that the relative sizes of their objects make sense (e.g. that an onion cell is not drawn bigger than a carrot seed). Provide students with colored pens, pencils, or crayons to complete their drawings, and encourage them to show the same details that they observed through the microscope.

The drawings can be quite colorful and beautiful. You may wish to mount them on colored construction paper and display them around the room. Or the pictures could be mounted and taped together to form a large classroom "quilt" of microscopic objects.

Sample data for teacher reference

object	actual size (µm)	actual size (mm)	size in mm if scaled up 100X	size in cm if scaled up 100X
EXAMPLE	100	0.1	10	1
Onion cell	250	0.250	25	2.5
Cheek cell	50	0.050	5	0.5
Human hair	90	0.090	9	0.9
Poppy seed	1000	1	100	10
Carrot seed	2000	2	200	20

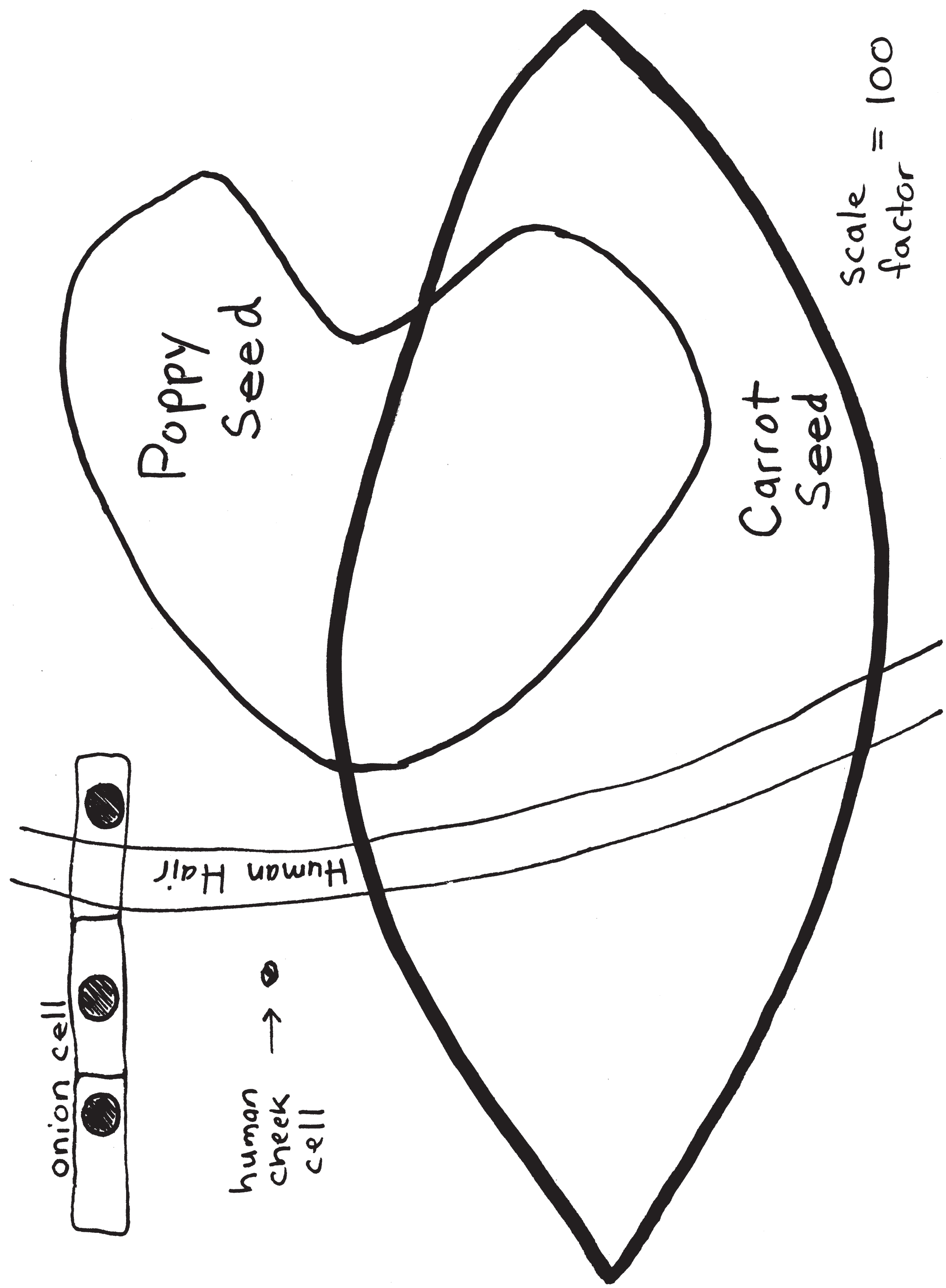


FIGURE 6.1. Sample Drawing of Scaled Up Microscopic Objects

Formative Assessment of Student Learning

- Can students accurately calculate the size that objects would be if scaled up by a factor of 100? Do they correctly fill in the table on Student Sheet 6.1?
- When planning their drawings, do students use a ruler to mark the scaled up size of each object on their paper?
- Do the students' drawings make sense? Are the seeds bigger than the onion or cheek cells? Is the width of the hair smaller than the seed? Are the dimensions of each object scaled up proportionally?
- Do students' drawings show the level of detail that they observed in the microscope?

Scaling Up Microscopic Objects

Fill in columns 1 and 2 of the table below with the names of several objects and their sizes from Activities 3 and 4, which you have recorded on Student Sheets 3.3, 4.2, and 4.3. Include *at least* two different types of seeds, two cell types, and a human hair.

Fill in the other columns for each object by calculating how big the object would be in mm and cm if magnified or scaled up 100 fold (100X).

For example, in the first line of the table below, the object was measured to be 100 μm long. This number was converted to millimeters, and 0.1 mm was recorded in column 3. When this measurement is scaled up 100 fold, it is 100 x 0.1 mm or 10 mm (column 4) or 1 cm (column 5).

object	**actual size** (μm)	**actual size** (mm)	**size in mm if scaled up 100X**	**size in cm if scaled up 100X**
EXAMPLE	100	0.1	10	1

To convert actual size from μm to mm, divide by 1000.

To scale up actual size in mm to 100X size in mm, multiply by 100.

To convert 100X size in mm to 100X size in cm, divide by 10.

As you make your drawing, pretend you are looking at all of the objects in the microscope at the same time in one field of view. Make sure to keep all items in proportion to each other.

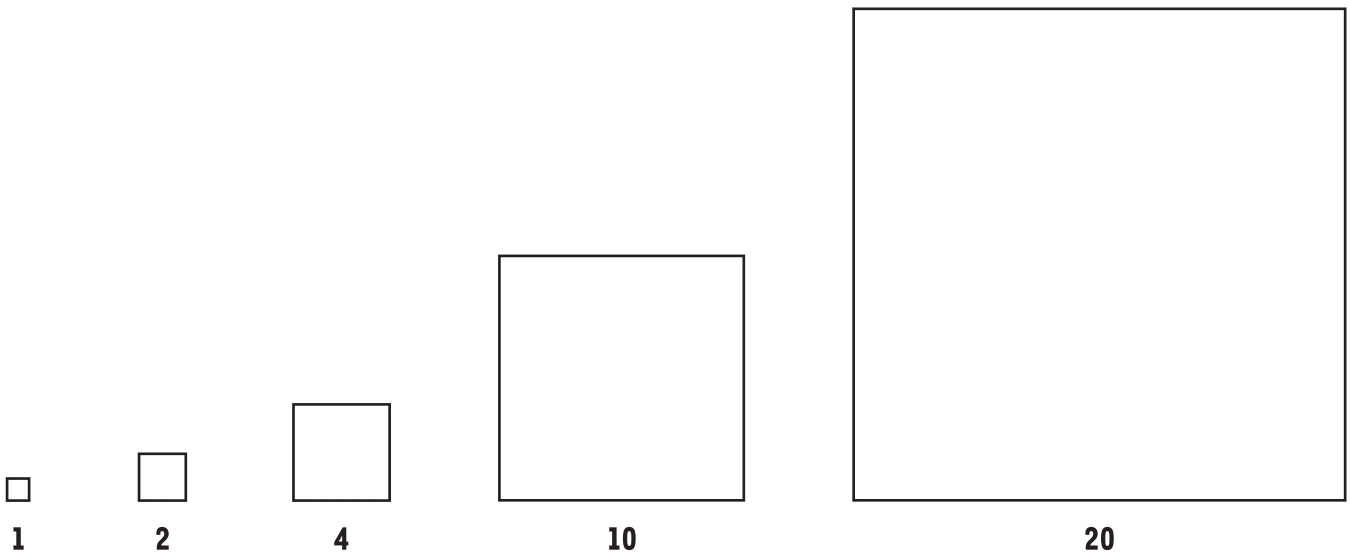
Use a metric ruler and pencil to lightly mark the size of each object on your paper before you sketch it, using the sizes from column 4 or 5 of the table above. Do the sizes you have drawn make sense to you? Are the seeds bigger than the cells? Is the onion cell bigger than the cheek cell? Show your marked paper to your teacher before doing the drawing.

Note: if you cannot fit the entire object on your paper, draw only part of it.

Use colored pencils, markers, or crayons to draw the picture. Be sure to include all of the details you observed when you looked at the objects in the microscope.

Scaling Up Microscopic Objects

How big will a microscopic object be if it is scaled it up 100 fold?



object	actual size (μm)	actual size (mm)	size in mm if scaled up 100X	size in cm if scaled up 100X
EXAMPLE	100			

To convert actual size from μm to mm, divide by 1000.

To scale up actual size in mm to 100X size in mm, multiple by 100.

To convert 100X size in mm to 100X size in cm, divide by 10.

FIGURE 1. Emma Noyes examines bacteria at the University of Washington.

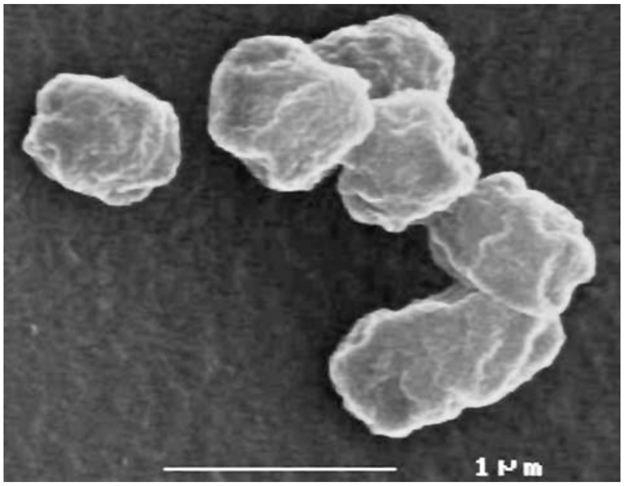


FIGURE 2. *Labrys methylaminiphilus*, as seen with a scanning electron microscope. The bumpy surface of the cells may be caused by the imaging technique. Image courtesy of Dr. Jimmie C. Lara. This work is funded by the National Science Foundation as part of the Microbial Observatories program.

How old do you have to be to make a scientific discovery? For Emma Noyes of Omak, Washington, the answer is about 17. That's how old Emma was when she discovered a new bacterium in the mud at the bottom of Lake Washington.

While in the 11th grade, Emma worked for six weeks in the lab of Dr. Mary Lidstrom at the University of Washington (UW). The Lidstrom lab studies how bacteria can be used as tiny "factories" to carry out chemical reactions used in manufacturing and other processes. The lab is especially interested in learning how bacteria can be used to clean up the environment. For example, bacteria can be used to get rid of methane, a gas that causes global warming. Working with Dr. Marina Kalyuzhnaya, a scientist in the lab, Emma set out to find bacteria that feed on methane or related compounds.

The first step in Emma's experiment was a lot of fun. She took a boat to the middle of Lake Washington and collected cores of mud from the bottom of the lake. Emma took the core samples back to the lab, where she mixed small amounts of the mud with a nutrient broth and allowed bacteria in the mud to grow. Then she spread this bacteria solution onto a gelatin-like substance called agar. On the agar, each bacterial cell grew and divided until it formed a large group of identical cells called a colony. Colonies made by different bacteria vary in their size and shape. Based on these differences, Emma selected several colonies for further experiments. The Lidstrom lab analyzed the DNA inside each of the isolated bacteria and discovered that one of them was a new bacterium, which they named *Labrys methylaminiphilus*.

But why all the fuss about a new kind of bacterium? One reason, says Emma, is that "science is all about learning more about the earth we live on." Emma's bacterium, shown in Figure 2, is an oval shaped cell about 0.8 μm long and 0.5 μm wide (remember, 1 μm is 1/1000 of a millimeter). That's about 1/50th the size of the human cheek cell you looked at in Activity 4. The bacterium is surrounded by a thick coat called a capsule. It feeds on methylamine, a compound produced mainly by the decay of animals. Its name, *methylaminiphilus*, in fact, means "methylamine loving." This bacterium can also digest humic acids, compounds made when dead trees rot. In this way, it contributes to the natural recycling of substances that are a part of all living things.

What led Emma, a high school student from a town of 5000 people, to a research lab hundreds of miles away at the UW? As a little girl, Emma was fascinated by disease and liked to pretend that she had bubonic plague and had to find the cure. Although her parents are not scientists (her mother is an elementary school counselor and her father is a Native American artist), they supported Emma's interest in science. In high school, Emma's teachers encouraged her to take challenging math and science courses, which gave her the background to do research at the UW. After completing high school, Emma became a student at the UW, where she now studies science and math. She plans to pursue a career in public health and one day return to Omak to educate her community about healthy lifestyles.

What advice would Emma give to middle school students who are making choices about the future? She would encourage them to explore different options. In Emma's words, "Don't close any doors before you know what's behind them."

ACTIVITY 7.

Sizing Up Cells

TIME ***What is Diffusion?*** **takes about 15 minutes to complete.** *Is Bigger Better?* **takes students approximately 15 minutes to set up, and is followed by a 2–3 hour observation period and a 15 minute discussion.** *Paper Bag Cells* **can be completed in 15–20 minutes, and the extension,** *Comparing Cubic Cells,* **requires about 50 minutes.**

CONCEPTS

- **Diffusion is the process of movement of a material from an area of high concentration to an area of lower concentration, resulting in even distribution of the material.**
- **Cells exchange materials with the outside through diffusion, moving nutrients in and wastes out.**
- **A cell's surface area, volume, and shape affect exchange of materials between the inside and the outside of the cell.**
- **Cells are small so that they can exchange materials efficiently.**

SKILLS

- **Developing and justifying an experimental hypothesis**
- **Observing and recording experimental results**
- **Using experimental results from a model system to expand understanding of the biological system**
- **Estimating relative volumes and surface areas of cubes**
- **Calculating volumes and surface areas of cubes** (EXTENSION ACTIVITY)
- **Converting a list of characteristics to a definition.**
- **Writing persuasively to justify why an object is living or non-living.**

Overview

Students learn that most cells are small so that nutrients can easily move into them and spread throughout the cell interior, and waste products inside the cells can move out. To study the role of diffusion in the movement of materials into and out of cells, students do an experiment using cubes of gelatin. By comparing paper bags or cubes of different sizes, they explore the effect of varying cell dimensions on surface area and volume. Then they discuss how cell size might affect the exchange of materials across the membrane.

ACTIVITY COMPONENTS

1. **What is Diffusion?** Students observe what happens over time when a drop of food coloring is added to a cup of water.
2. **Is Bigger Better?** Students predict how size will affect the diffusion of a substance into a cube of gelatin and test their hypothesis experimentally.
3. **Paper Bag Cells.** During this class demonstration, students make observations about the volumes and surface areas of different sized cubes that have been constructed of paper bags.
4. **Comparing Cubic Cells** (OPTIONAL EXTENSION ACTIVITY). Students build paper models of different sized cubic "cells" and calculate their volume and surface area. They discuss how increasing the size of a cell changes its surface area to volume ratio and may affect how well materials can diffuse into or out of the cell. This extension activity is intended for middle school students who have previously learned about ratios, as well as how to calculate the volume and surface area of cubes, in their math classes.
5. **Interest Link: There Are Exceptions to Every Rule.** Students read about some very large cells and learn how they manage to get nutrients.

MATERIALS

for each student:

- Student Sheet 7.1, *What is Diffusion?*
- Student Sheet 7.2, *Is Bigger Better?*
- Student Sheet 7.3a, *Comparing Cubic Cells* (only if students will be doing this extension activity)

for each student group:

What is Diffusion? (STUDENTS WORK IN PAIRS)

- Food coloring (red, green, or blue)
- 50 ml water in clear plastic cup

Is Bigger Better? (STUDENTS WORK IN PAIRS)

- Gelatin slab (3 cm x 2 cm x 2 cm) on piece of plastic wrap
- 50 ml baking soda solution in clear plastic cup
- Metric ruler
- Plastic knife and spoon

Comparing Cubic Cells (STUDENTS WORK IN GROUPS OF FOUR)

- Scissors
- Cellophane tape
- Student sheet 7.3b, *Large Cube Template*
- Student sheet 7.3c, *Small Cube Template* (2 copies)

for teacher:

Is Bigger Better?

- 9 inch x 6 inch rectangular plastic or glass dish
- 3 packages Knox™ unflavored gelatin powder
- Bromothymol Blue Solution (Freshwater pH Test Kit)
- Spatula

Paper Bag Cells

- 4 paper lunch bags (5 1/2 inches x 3 1/2 inches x 10 1/2 inches)
- 1 large paper grocery bag (12 inches x 7 inches x 14 inches)
- Cellophane tape
- Scissors

Concluding the Activity

- Overhead transparency of list of characteristics of living things from Activity 1

GETTING READY

1. One to two days before doing this activity, make the gelatin-bromothymol blue mix (see recipe at right). The gelatin can be stored in the refrigerator for 1–2 weeks, as long as it is covered with plastic wrap. Be sure to label the dish "inedible" so no one eats it.
2. On the day of the experiment, cut the gelatin into 3 cm x 2 cm x 2 cm slabs, using a plastic knife (one slab for each lab group). Remove from the pan with a spatula.
3. Make a solution of baking soda by adding 40 grams (about 2 level tablespoons) baking soda to 1 liter of water (about 4 1/4 cups).
4. Photocopy student sheets.
5. Prepare paper bags for the *Paper Bag Cells* demonstration. (SEE *PREPARING PAPER BAGS FOR PAPER BAG CELLS*.)
6. Review math curriculum to determine whether students will be able to do the extension activity, which requires volume, surface area, and ratio calculations.
7. Prepare an overhead transparency that contains a list of the characteristics of living things that your students came up with in Activity 1.

Gelatin-Bromothymol Blue Mix

- **2/3 cup cold water**
- **2 1/3 cups boiling water**
- **3 packages Knox™ unflavored gelatin powder**
- **2 teaspoons Bromothymol Blue Solution (Freshwater pH Test Kit)***

Pour 2/3 cup cold water into a saucepan and sprinkle the gelatin powder on top. Allow the gelatin to soften for a few minutes, and then add 2 1/3 cups boiling water. Stir until gelatin is completely dissolved, heating briefly if necessary. Allow to cool for about 5 minutes, and then add 2 teaspoons Bromothymol Blue Solution.

The gelatin should be yellow in color. If it is blue, then add a small amount of vinegar, about 1/8 teaspoon, just enough to turn the gelatin yellow. Pour into a 9 inch x 6 inch dish to a depth of 2 cm (use a ruler to measure the depth of the liquid gelatin). Cover with plastic wrap and place in the refrigerator until set. Label the dish "inedible" so no one eats the gelatin. Although a dilute solution of bromothymol blue is not known to be a health hazard, it is good lab safety practice not to ingest or handle non-food chemicals or put them near eyes, and to wash hands after contact.

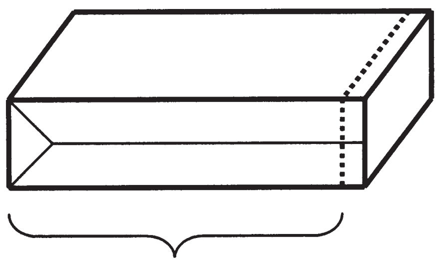
* Bromothymol Blue Solution (Freshwater pH Test Kit) is distributed by Aquarium Pharmaceuticals, Inc. and can be purchased from many pet or aquarium stores for about $6. To locate a store near you, visit **http://www.aquariumpharm.com**.

Teacher Instructions: Preparing paper bags for Paper Bag Cells

MATERIALS

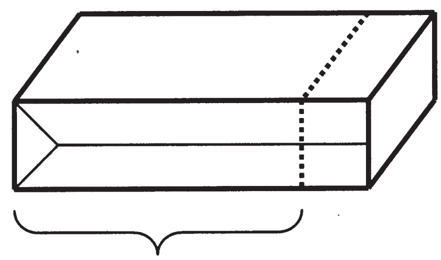
4 paper lunch bags (5 1/2 inches x 3 1/2 inches x 10 1/2 inches)
1 large paper grocery bag (12 inches x 7 inches x 14 inches)

Follow the directions below to make each of the 5 bags into a rectangular box.



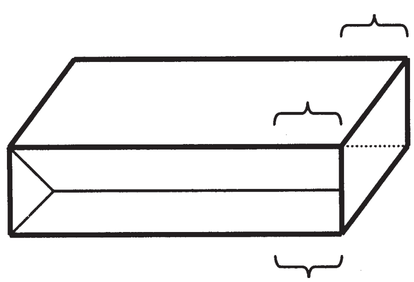
10 inches

SMALL BAGS: Cut each small bag across the top, 10 inches from the bottom.



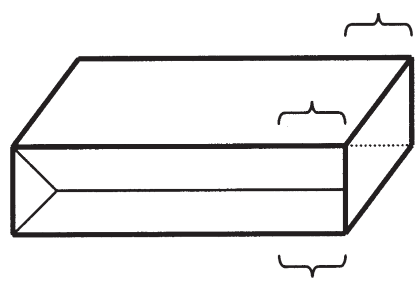
11 7/8 inches

LARGE BAG: Cut the large bag across the top, 11 7/8 inches from the bottom.



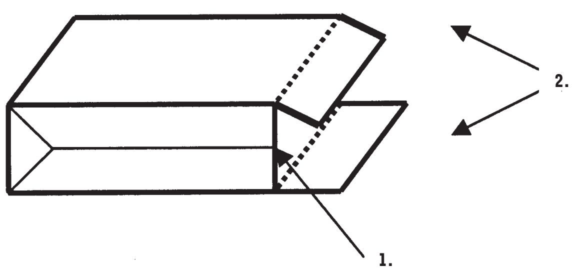
1 5/8 inches

SMALL BAGS: Make a 1 5/8 inch cut on each of the four corners of the bag from the top of the bag toward the bottom.



3 1/2 inches

LARGE BAG: Make a 3 1/2 inch cut on each of the four corners of the bag from the top of the bag toward the bottom.



SMALL AND LARGE BAGS: 1. Cut off the side flaps. 2. Fold top and bottom flaps toward each other and tape together in the middle.

Background Information for Teachers

All living organisms, from the tiniest bacterium to the largest whale, are made of cells. Cells carry out all the functions that define living organisms, such as consuming food, producing waste, respiring, reproducing, and dying (see Activity 1, *Living and Non-living*). Many life forms live as single cells, while more complex organisms are made up of many different kinds of specialized cells that cannot survive on their own.

In spite of the huge range in the size of multicellular organisms, the sizes of the cells that comprise them are very similar. Plant and animal cells are usually between 10 and 300 µm in diameter (recall from Activity 2, that 300 µm is 0.3 mm). Large plants or animals are large because they have more cells than smaller organisms, not because they have larger cells. For example, the 1 mm long roundworm called *Caenorhabditis elegans*, which has been studied extensively by scientists, has about 1000 cells, while a human has approximately one hundred trillion cells (100,000,000,000,000).

Why do large organisms have more cells, rather than having larger cells? The answer lies in the rate that materials can diffuse into and out of the cell and penetrate to all its parts. The flow rate of materials such as nutrients and wastes into or out of a cell is proportional to its surface area. These materials must be able to reach the entire volume of the cell. As cell size increases, the ratio of surface area to volume decreases, so the ability to exchange materials also decreases.

Presenting the Activity

WHAT IS DIFFUSION?

Engage students' interest by asking them to predict what will happen when they add a drop of food coloring to a glass of water, and have them write their hypothesis on Student Sheet 7.1. Provide each student pair with a clear plastic cup of water. Then add a drop of food coloring to each cup (or have the students add it), and leave the cups undisturbed for 5 minutes. Instruct students to record their observations with drawings and a few words immediately after the food coloring is added and 5 minutes later.

After students have made their observations, discuss their results as a class. Students should notice that the food coloring mixes with the water, so that the color becomes less intense at the place where the drop was first added and more evenly spread throughout the cup. Introduce diffusion, the process by which a material spontaneously moves from an area of high concentration to an area of lower concentration. Explain that diffusion is an important process for moving materials in and out of cells. When the concentration of a nutrient is higher outside a cell than inside, the nutrient moves by diffusion into the cell. At first, the concentration of the nutrient is higher just inside the cell membrane than in the rest of the cell, but it quickly diffuses throughout the entire cell.

IS BIGGER BETTER?

Review the list of characteristics of living things that students identified in Activity 1, *Living and Non-living.* Tell the students that cells need to do all the things that living organisms do, including taking in food and getting rid of waste. Cells take in food through their cell membrane, and the food diffuses to all parts of the cell. Waste inside the cell passes through the cell membrane and diffuses into the liquid outside the cell. Explain to students that they will use cubes of gelatin to model cells of different sizes. They will measure how fast a substance, baking soda dissolved in water, soaks completely into the different sized cubes. Students should work in groups of two or three.

Students use 0.5 cm, 1 cm, and 2 cm cubes of gelatin to represent cells. The gelatin contains Bromothymol Blue (BTB), a pH indicator that is yellow in weak acid and blue in weak base. At the beginning of the experiment the gelatin is slightly acidic, so it is yellow. Students soak the cubes in a solution of baking soda, which is basic. When the soda enters the gelatin cube, the BTB turns blue. Students can monitor how far the baking soda has diffused into the cubes by observing the thickness of the blue cube edges.

Demonstrate how to cut the cubes using a plastic knife. This can be done on an overhead projector so students can clearly see what you are doing. Then ask students to cut their three cubes to the correct sizes (0.5, 1, and 2 cm), also using plastic knives. It can be difficult to cut the cubes to exactly the right dimensions, so reassure your students that the cubes don't need to be perfect.

Before the students place their cubes in the baking soda solution, ask them to form a hypothesis about which cube will turn blue the fastest and record it on Student Sheet 7.2. Have the students submerge their cubes in the baking soda solution and observe how long it takes for each of the three cubes to turn completely blue. They should make their observations every five minutes for the first 15 minutes and then every 30 minutes after that. It takes a fairly long time for the center of each cube to become completely blue (about 10 minutes for the 0.5 cm cube, 55 minutes for the 1 cm cube, and over 2 hours for the 2 cm cube). You may want to focus on other subjects while students are waiting for the larger cubes to turn blue. In a middle school setting where you see students for 50–60 minute classes, you may want to set up a series of 2 cm cubes at 30 minute intervals prior to the start of class so students can follow diffusion over a longer time than the class allows.

Conclude the activity by discussing the reason why cells are small. Based on their gelatin cube experiment, students should recognize that being small makes it easier for cells to take in nutrients and get rid of wastes.

PAPER BAG CELLS

Use the paper bag "cells" you prepared in advance (see *Preparing Bags for Paper Bag Cells*) to demonstrate the relationship between volume and surface area. Have a student stack the four smaller bags so they have the same overall shape as the larger bag. Students should notice that the volume of the large bag cell is four times the volume of each small bag cell. Then ask students which will have the larger surface area, the large bag cell or four smaller ones. To answer this question, cut the bags so you can spread them out flat and compare the surface areas of the large bag cell and the four smaller ones. Even though the 4 small bags had the same volume as the large cell, students will see that the 4 small bag cells have a much greater combined surface area than the large bag cell.

Proceed next to either the optional extension activity or to the concluding Interest Link, *There are Exceptions to Every Rule.*

COMPARING CUBIC CELLS (OPTIONAL EXTENSION ACTIVITY)

The extension activity allows students to further explore the relationship between volume and surface area for cells of different sizes. This activity is intended for students who understand ratios and can calculate surface area and volume. Teachers may want to review these calculations before beginning. In this activity, students make one 4 cm cube and eight 2 cm cubes and compare the surface area, volume, and ratio of surface area to volume for the large cube and eight small cubes. They will then consider what this ratio might tell them about how well materials can diffuse into cells of different sizes.

Instruct the students to cut out the shapes and form them into cubes by folding along the solid lines, tucking in the flaps, and taping in place. They should notice that the eight small cubes fill the same volume as the one large cube. Have the students follow the directions on student sheet 7.3a to calculate the surface area, volume, and ratio of surface area to volume for the large cube and eight small cubes and answer the discussion questions.

Finish the activity with a discussion of results and answers to the questions on Student Sheet 7.3a. Students may need some guidance in making the connection between the surface area of the cell and how much material can enter a cell from the outside. As cells get larger, both the surface area and the volume increase, but the volume increases more than the surface area does. Thus, students should be able to predict that it would be harder for a large cell to get food to all its parts than a small cell.

Answers to Student Sheet 7.3a

Surface area of cube: Add the areas for each side of the cube. Area of a square is L x L, where L is the length of one side. Since a cube has 6 equal sides, the surface area of the cube is 6 x (L x L).

Volume of cube: volume = L x L x L

Cube	Length of each side (cm)	Surface area (SA)(cm^2)	Volume (V) (cm^3)	Surface area/volume (SA/V)
large	4	96	64	1.5
1 small	2	24	8	3.0
8 small	4 (when stacked to have same shape as large cube)	192	64	3.0

Discussion Questions and Answers

Tell the students to discuss these questions in their groups and then as a class:

- Which dimension—surface area or volume—is important for determining how much food can pass into a cell?

  The surface area is important for determining how much food can pass into a cell.

- Which dimension—surface area or volume—tells us how much space inside the cell needs to get food?

  The volume tells us how much space inside the cell needs to get food.

- What happens to the ratio of surface area to volume when the cubes get larger?

  When cubes get larger, the ratio of surface area to volume gets smaller.

- What does this ratio tell us about how well the baking soda moved into your gelatin cubes and how well a substance can move into a cell?

  The smaller the cube, the faster the baking soda can reach the cube center because the ratio of surface area to volume increases as the size of the cube decreases. The same is true for cells. A small cell would be able to exchange materials faster than a large cell because the ratio of its surface area to volume is greater than the ratio for the large cell.

INTEREST LINK: THERE ARE EXCEPTIONS TO EVERY RULE

In this reading, students first learn about unusually large cells that seem to contradict the rule that cells need to be small. They go on to learn why each of these cell types can survive, in spite of their large size.

CONCLUDING THE ACTIVITY

Wrap up the activity by making connections to concepts students have learned throughout the Amazing Cells unit. In Activities 3 and 4, students measured the dimensions of a variety of items, including two types of cells. They will have noticed that cells are quite small compared to many of the things they examined, including tiny seeds like poppy seeds. In Activity 7, students carried out several activities that helped them to understand that cells are small so that they can efficiently exchange materials between their interior and the surrounding environment. Show students an overhead transparency of the list of characteristics of living things that they discussed in Activity 1, which should have included the requirements for food and getting rid of waste. Help them recognize that these characteristics are important for cells as well as whole organisms, and that cell size is important for obtaining nourishment and getting rid of waste. The questions below may help to guide this discussion.

Discussion Questions and Answers

- What are some features of cells that you learned from the Amazing Cells unit?

  Students will give a variety of answers, such as: most cells are very small (microscopic), cells are surrounded by a cell wall or cell membrane, cells have a nucleus, cells contain DNA, cells come in many different shapes and sizes.

- Look at the "Definition of a Living Thing" that your teacher has put on the overhead projector. Which of these characteristics also apply to cells?

  Students should recognize that cells require food and water and need to get rid of waste. Based on their observation of chromosomes inside the prepared slides of mitotic cells, they may realize that cells reproduce. They should also realize that cells die. At this point, students do not have the background to make the connection between breathing to exchange gases (oxygen into the organism and carbon dioxide out of the organism) and cellular respiration, which is what happens to oxygen at the level of the cell. You may want to tell students that cells in multicellular organisms and many free living cells use oxygen and give off carbon dioxide.

- Why are cells sometimes called the "building blocks of life?"

  Cells are called the building blocks of life because all living organisms are made up of cells, and the smallest organisms consist of single cells.

Formative Assessment of Student Learning

During this activity, students do several interconnected activities to develop an understanding for why cells are small. Each segment builds on the concepts learned in the previous segments, so it is important that students understand the key concepts introduced at each step. The following questions will help you to guide student learning and assess students' understanding.

- Can students describe and draw what is happening to the food coloring as it sits in the glass of water?
- Do students form a plausible hypothesis prior to the experiment with the gelatin cubes, and can they justify their hypothesis?
- Do students make observations about the relative volumes and surface areas of the one large and four small bags?
- Do students understand the significance of the ratio of surface area to volume for the exchange of materials in cells?
- Can students calculate surface area, volume, and ratio of surface area to volume correctly? (extension only)

STUDENT SHEET 7.1. NAME ______________________

What is Diffusion?

In this experiment you will add a drop of food coloring into a cup of water and observe what happens over the next 5 minutes.

Forming a hypothesis: Predict what will happen when you first drop the food coloring into the water. Predict what it will look like after it has been in the water for 5 minutes.

Procedure: Add 1 drop of food coloring to a cup of water. Record the appearance of the food coloring and water immediately after you add the food coloring and after 5 minutes.

Results:

Appearance immediately after food coloring is added	Appearance after 5 minutes

Questions:

1. Describe the changes you observed.

2. What do you think caused these changes?

STUDENT SHEET 7.2. NAME ___________________________

Is Bigger Better?

In this experiment you will test whether materials diffuse more quickly throughout a small cell or a large cell. To model cells of different sizes, you will use cubes of gelatin that are 0.5 cm, 1 cm, or 2 cm on each side. You will soak the cubes in baking soda solution. The gelatin contains a color indicator that is yellow to begin with and turns blue when it reacts with baking soda. You will record the time it takes for each of the cubes to turn completely blue.

SAFETY TIP: Do not eat the gelatin or put it near your mouth or eyes. Although there are no known health hazards for this color indicator, it is good lab practice to keep all chemicals away from your mouth and eyes and to wash your hands after touching.

Forming a hypothesis: Predict which of the three cubes will turn entirely blue the quickest; the 0.5 cm, 1 cm, or the 2 cm cube. Explain why you think this.

Procedure: Work in pairs.

1. Place your chunk of gelatin on a piece of plastic wrap. Use the knife and ruler to cut three cubes; one with sides of 0.5 cm, one with sides of 1 cm, and one with sides of 2 cm.
2. Place the cubes in the cup of baking soda solution.
3. Observe the cubes every five minutes for the first 15 minutes and every 30 minutes after that. Record what you see and the time it takes for each cube to become all blue.

Cube Size	Observations during soaking	Time for cube to turn all blue (minutes)
0.5 cm		
1 cm		
2 cm		

Questions:

1. How did the size of the cube affect how quickly the cube turned all blue?

2. Discuss what your experimental results tell you about the size of cells. How might cell size affect how well a cell would survive?

 NAME ____

Comparing Cubic Cells

A cell takes up food from its surroundings through its outer surface (the cell membrane or the cell wall). Nutrients have to diffuse from the surface of the cell to all parts of its interior. As a cell gets bigger, its surface area gets bigger, but so does the space inside, its volume.

In this activity, you will make one large and eight small paper cubes and calculate their volume and surface area. Then you will discuss how the size of cells would affect how well food could diffuse into them.

Procedure:

1. Work in groups of four. Cut out the shapes on Student Sheets 7.3b and 7.3c and make them into paper cubes by folding along the sides of the cubes, tucking in the tabs, and taping in place.
2. Stack the eight small cubes so they have the same shape as the larger cube.
3. Answer the following question: What do you notice about the total volume of the eight small cubes compared to the one large cube?
4. Now calculate the surface area, volume, and ratio of surface area to volume for the large cube and eight small ones.

Cube Calculations:

Surface area of cube → Add the areas for each side of the cube. Area of a square is L x L, where L is the length of one side. Since a cube has 6 equal sides, the surface area of the cube is 6 x (L x L).

Volume of cube → volume = L x L x L

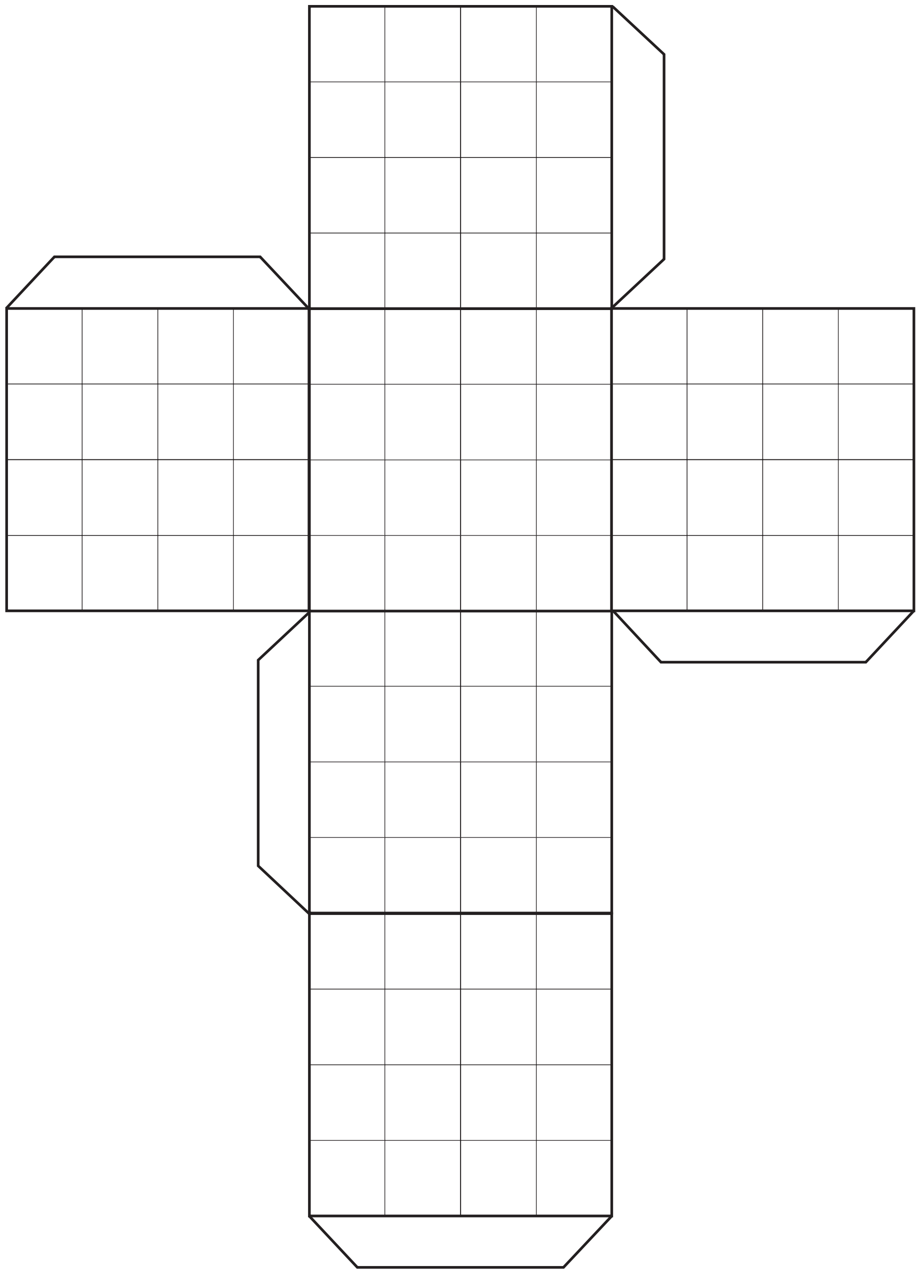
Cube	**Length of each side** (cm)	**Surface area** (SA)(cm^2)	**Volume** (V) (cm^3)	**Surface area/volume** (SA/V)
large				
1 small				
8 small				

Discussion Questions: In your group, answer the following questions.

- Which dimension—surface area or volume—is important for determining how much food can pass into a cell?
- Which dimension—surface area or volume—tells us how much space inside the cell needs to get food?
- What happens to the ratio of surface area to volume when the cubes get larger?
- What does this ratio tell us about how well the baking soda moved into your gelatin cubes and how well a substance can move into a cell?

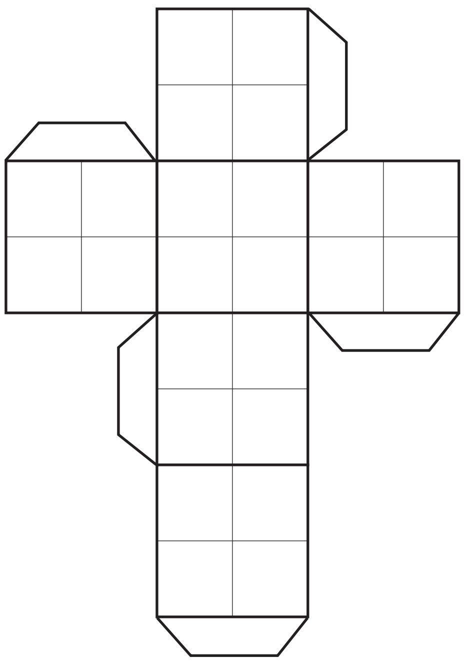
STUDENT SHEET 7.3b

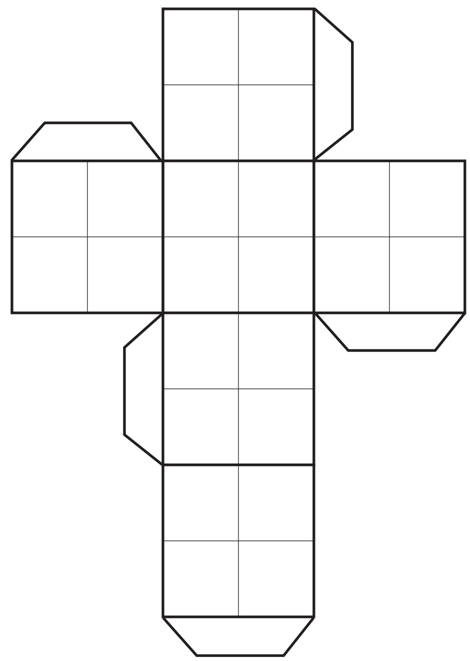
Large Cube Template

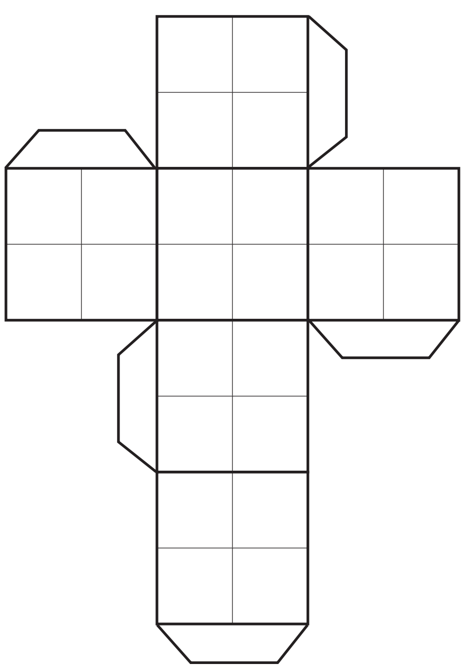


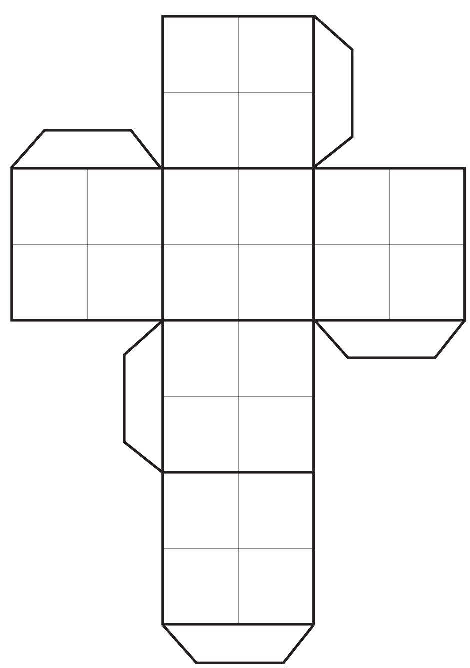
STUDENT SHEET 7.3c

Small Cube Template







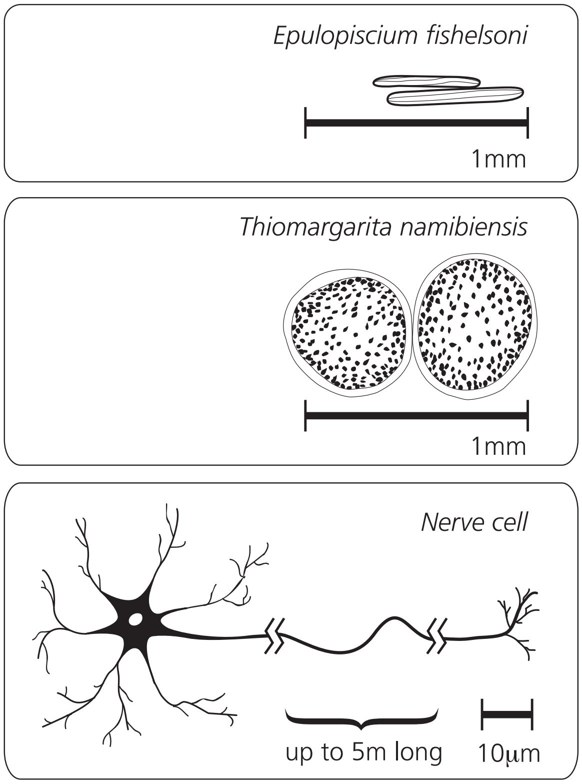


INTEREST LINK: THERE ARE EXCEPTIONS TO EVERY RULE

You have learned that cells are small so that nutrients can diffuse into them and waste products can diffuse out. But here are some very unusual cells that don't seem to pay attention to this "rule."

Part 1. Meet the Giant Cells

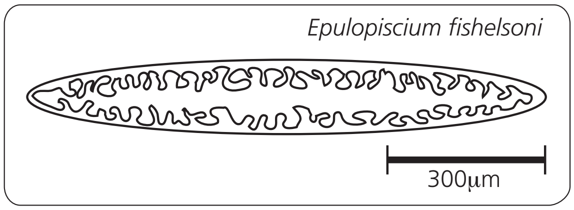
1. *Epulopiscium fishelsoni* is a giant bacterium that lives in the gut of the brown surgeonfish. It is large enough to be seen with the naked eye and is a little smaller than this hyphen (-). While most bacteria are 0.5–10 µm long, *E. fishelsoni* can be as big as 600 µm X 80 µm.
2. The largest known bacterium is *Thiomargarita namibiensis*, which is a sphere-shaped cell ranging in size from 100–750 µm, about the size of this dot (•). It was discovered in ocean sediments off the shores of the African nation of Namibia. *T. namibiensis* uses sulfates for food and "breathes" compounds called nitrates instead of oxygen. Usually the levels of nitrates in the water where it lives are low, but during major storms, the mud on the ocean floor is stirred up, releasing nitrates. *T. namibiensis* stores nitrate-rich water inside itself after a storm.
3. The longest known cells are the **nerve cells of the giraffe** that extend from the base of the neck to the tip of the toe. These sensory neurons can be up to 5 meters in length.
4. The yolk of a bird's egg is also a single cell. The largest yolk is—you guessed it—the **ostrich egg yolk**, which is about 100 mm in diameter. That's bigger than a tennis ball!

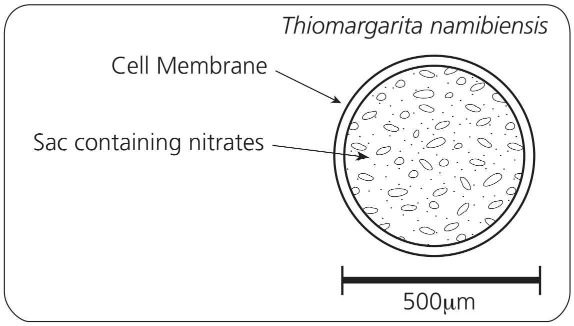


How can these cells be so large? Spend a few minutes brainstorming with your lab partners about how these giant cells can survive in spite of their large size. Then read Part 2 to find out how these cells solve the problem of transporting materials into and out of themselves.

Part 2. How do they do it?

1. *E. fishelsoni* is so large— how can it transport enough nutrients into itself and get rid of its wastes? The answer is that it has a very wavy and folded cell membrane. The waves and folds create a large surface area and reduce the volume inside the cell.
2. The inside of *T. namibiensis* contains a large sac filled with nitrate-rich water. This sac fills up 97% of the cell, and so the part of the cell that needs to absorb nutrients or get rid of waste is only the thin layer just under the cell membrane.
3. Although some giraffe nerve cells are several meters long, they are also very thin, about 25 μm. Materials can easily diffuse into and out of the cell because the distance from the middle of the cell to the membrane is very short (see picture of nerve cell on previous page).
4. Most of the yolk of an ostrich egg (or any bird's egg) consists of food that is used to build the chick as it develops. In a tiny region on the top of the yolk is the part of the cell that will grow into the chick after being fertilized. This regions the size of a typical cell, about 50–100 μm. this small part of the cell needs to exchange nutrients and wastes.





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