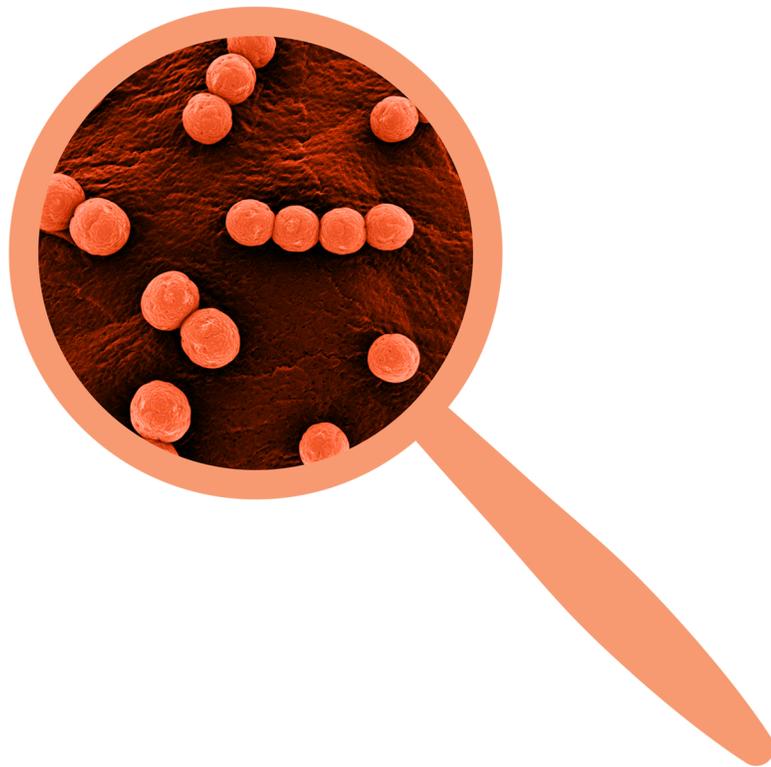


Think Like a Microbiologist



by
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Christopher Burnett, James Denk, Nancy Moreno

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Safety Notes

Always follow district and school laboratory safety procedures. It is a good idea for students to wash their hands with soap and water before and after any science activity.

Unless noted, each activity in this guide is designed for students working in groups of four (see “Using Cooperative Groups in the Classroom”).

Using Cooperative Groups in the Classroom

Cooperative learning is a systematic way for students to work together in groups of two to four. It provides organized group interaction and enables students to share ideas and to learn from one another. Students in such an environment are more likely to take responsibility for their own learning. Cooperative groups enable the teacher to conduct hands-on investigations with fewer materials.

Organization is essential for cooperative learning to occur in a hands-on science classroom. Materials must be managed, investigations conducted, results recorded, and clean-up directed and carried out. Each student must have a specific role, or chaos may result. The Teaming Up! model* provides an efficient system for cooperative learning. Four “jobs” entail specific duties. Students wear job badges that describe their duties. Tasks are rotated within each group for different activities, so that each student has a chance to experience all roles. For groups with fewer than four students, job assignments can be combined.

Once a cooperative model for learning is established in the classroom, students are able to conduct science activities in an organized and effective manner. The job titles and responsibilities are as follow.

Principal Investigator

- Reads the directions
- Asks questions of the instructor/teacher
- Checks the work

Maintenance Director

- Ensures that safety rules are followed
- Directs the cleanup
- Asks others to help

Reporter

- Records observations and results
- Shares results with group or class
- Tells the teacher when the investigation is complete

Materials Manager

- Picks up the materials
- Directs use of equipment
- Returns the materials

* Jones, R.M. 1990. Teaming Up! LaPorte, Texas: ITGROUP.

Unit Materials

for 24 students, working in groups of 4

Activity 1A

Per Class:

- 1 small container Glo Germ powder
- 1 Large black light
- Bar Soap
- Liquid Soap
- Pre-moistened towels
- Antibacterial cleaner
- 1 Roll Paper towels

Activity 1B

Per Class:

- Nutrient Agar (see set-up)

Per Student:

- Petri Dish (see set-up)
- Potato slice (Idaho bakers)
- 3 Cotton-tipped applicators (like Q-tips)
- Plastic sandwich bag

Per Student Pair:

- Small Cup
- Distilled/Filtered water
- Permanent marker pen
- 2 Hand Lenses
- Clear tape

For Disposal:

- Bleach OR Small plastic trash bag

Activity 2A

Per Student Pair:

- 2 Clear plastic 7-8 oz cups
- Set of materials in plastic bag including loose and tightly woven fabric, feather, penny, pencil, piece of dollar bill, newsprint, ...
- Clear flat-sided takeout salad box
- Cooking oil
- Paper towel
- Eye dropper
- 2 Hand Lenses

Activity 2B

Per Group :

- 4 hand lenses or magnifiers
- 4 index cards (or similarly sized sections of cardstock)
- 4 pairs of scissors
- 4 pieces of newsprint, about 2 cm x 10 cm each. Select pieces that have newsprint on one side only so that print will not show through under the microscope.
- 4 pipettes or droppers

4 plastic cover slips

- 4 plastic or glass microscope slides
- 4 rulers (measurements in cm)
- Microscope (any kind)
- Other objects to observe, such as a leaf, coin, dollar bill, etc.
- Set of colored pencils or markers
- Sheet of wax paper (6 cm in length)
- Small container of tap water
- Transparent tape

Per Student:

- Copies of *Magnification Observations and The Compound Microscope* student sheets

Activity 3A

Per Class:

- Note cards
- Scissors
- Tape
- Selected materials
- Microscopes
- Copies of *Mystery Slide Investigations* sheet

Activity 3B

Per Class:

- Sharp knife
- 1 white onion
- Several stalks of Elodea plant
- Computer with internet access
- Projector

Per Group:

- Microscope
- 4 pairs of safety goggles
- 4 microscope slides
- 2 pairs of forceps
- 1/6 of an onion, vertical slice
- Small stalk of Elodea leaves
- Iodine solution in small portion cup
- Water in small portion cup
- 2 pipettes (droppers)
- Science notebooks or drawing paper
- 4 copies *Preparing and Viewing* student sheet

Activity 4A

Per Group:

- 4 magnifiers
- Microscope
- 4 sets of gloves
- 4 goggles
- 4 pipettes or droppers
- 4 microscope slides
- 50 ml of pond water in clear plastic cup
- 4 index cards
- colored pencils
- Small portion cup with glycerin
- 4 sheets of blank paper for graphic organizer
- 4 scissors

Activity 4B

Per Class:

- Large paper square 2.5 m x 2.5 m (Butcher paper)

Per Group:

- Set of 4 prepared text strips
- 4 hand lenses
- 4 metric rulers marked in millimeters
- 4 Scissors
- Assorted markers or colored pencils
- Meter stick
- Paper or science notebook
- Several sheets of colored or plain paper, or roll of chart or craft paper
- Tape or glue
- Copy of the Microbe Scaling Chart student sheet

Activity 5

Per Class:

- 12 sheets of cardstock (to prepare cards)
- 6 resealable plastic bags

Per Group:

- Set of 4 *Microbe Groups* cards and 20 *Microbe Examples* cards

Activity 6

Part 1

Per Group:

- Four-part London Soho district map copies
- Victim list copies
- Overhead projector transparency sheets for printers
- Clear tape
- Scissors

Part 2

Per Student:

- Information on Dr. Snow copies

1A. Microbes are Invisible to Humans

Time Needed

1 sessions

Before You Start

If using a black light fixture, set up an area of the room to place the fixture.

You'll Need This Stuff

Glo Germ® powder
Fluorescent "black light" lamp with fixture - (18 to 24 inch tube), compact fluorescent black light, or a small hand held UV light.

Several types of hand soap (bar and Liquid), pre-moistened towels, antibacterial cleaner
Paper towels
Access to sink

Notes about sources:

Glo Germ® powder is available from science supply companies and the Glo Germ company www.glogerm.com

Fluorescent black lights and hand-held UV lights are available from a variety of sources including Amazon.com, science supply catalogs, and from the Glo Germ Company.

Students are familiar with the term "germ." From a young age they are told that germs are everywhere and are told to wash their hands, cover their cough or sneeze, or not to share food or drink.

"Germ" is a generic term that is used for a variety of disease-causing microbes. Microbes are the most prevalent organisms on our planet, both in mass and number. They comprise a diverse group and include bacteria, microscopic algae, yeast cells, and even protozoa. Most biologists also consider viruses to be microbes, even though according to many definitions, viruses are not true "living" organisms.

Not all microbes are disease-causing germs. Their roles are many. In this unit, we focus primarily on microbes directly related to our health. In this unit students become amateur microbiologists as they study the roles of these tiny organisms that consist of a single cell or a cluster of a few similar cells.

What's the Question?

Microbes are microscopic. That means we can't see them unless we magnify them using a microscope. How do microbes (germs) spread?

What To Do

1. Rub Glo Germ® powder on your hands and then casually shake hands with all students as they enter the room or as appropriate.
2. For two minutes, have students, working with partners, make a list of everything they can see in their immediate environment.
3. Have each team share their observations, one at a time in a round robin discussion. List each observation on a white board. If a team runs out of new things to add to the list they can pass. Continue until all teams run out of observations.
4. Ask students, *What is missing?* (Things that you cannot see! Germs.) Germ is a generic term for what are considered bad microbes. Microbes are organisms too small to be observed by the naked eye. Have students examine their hands. Ask, do you see anything? Why do you wash your hands before eating? (Germs.)

5. Explain that you have used a model germ that they can only see under black (ultraviolet or UV) light. Ask your students “Do you have any “germs?”
6. If using UV lights, invite teams of students to examine their hands, pencils, paper, etc.
7. Ask, “How did the mystery substance spread?” Discuss.
8. Explain to the students that during the course of the next 2 weeks they will think like a microbiologist by investigating the way germs spread as they collect, grow, observe and make models of microbes. They will also solve an epidemiological mystery as they track down the cause of an infectious disease.
9. Have students, working in teams of two, set up a hand-washing investigation with variables such as type of soap, water temperature, and length of time washing. Display a number of types of cleaners, including bars and bottles of soap, pre-moistened towels, and anti-biotic liquid for students to choose from. Have students devise a uniform strategy for “infecting” their hands with Glo Germ® powder before they begin the investigation and then examine them under the black light after washing. Have students compare and contrast methods and results. Ask, what worked best? Was time important factor? Other factors?

Wrap It Up

Ask your students what conclusions can be drawn from the way the Glo Germ® powder spread? Like the powder, germs are insidious. They are everywhere! Proper washing is important.

Extension

- Have students create hand washing posters for school restrooms. The poster shown is an example of a poster from Yale University.

Patrick Lynch, Yale University.



1B. Microbe Scavenger Hunt

Time Needed

1 session to collect and transfer samples

3 to 7 days of observation for incubation of samples

1 session to compare samples after incubation

Before You Start

Order a nutrient agar kit from a school science supplier or order individually 20 Petri dishes and nutrient agar. (See instructions for preparing Petri plates and the option to use potato slices instead of agar. If you choose this option, you will need white potatoes.)

You'll Need This Stuff

per team of students:

2-4 prepared nutrient agar
Petri plates or Petri dishes with potato slices. You can substitute plastic bags for the Petri dishes if working with potato slices.
2 Cotton-tipped applicators (like Q-tips) per sample
Small container for water
Permanent marker pen
Magnifying Lenses
Colored pencils or markers
4-8 Plastic sandwich bags
Clear tape

What It's About

Our world is filled with microorganisms. A microorganism or microbe is simply a very tiny organism that requires a microscope to be seen. Generally, the term applies to one-cell living things such as bacteria, fungi, and plankton. Of major concern to our health are harmful microorganisms which can lead to infections.

Because bacteria are microscopic, we are mostly unaware of our contact with them. Usually, exposure is benign but occasionally harmful microorganisms enter our systems. Touching a surface, such as a doorknob, can lead to an infection if bacterium present finds a way past the body's defenses. For example, someone who has failed to wash his or her hands after going to the bathroom touches a doorknob transfers small moist droplets to its surface. Those microorganisms are then transferred to your hand when you touch the knob. If you bring your hands to your mouth, rub your eyes, or have an open sore, the bacteria can enter into your body.

In this activity, students conduct a microbe scavenger hunt. Using cotton swabs, students will collect samples of microorganisms from various surfaces such as doorknobs, computer keys, light switches, desktops, pencils and pens, etc. They will then inoculate, or transfer the sample to the surface of the nutrient agar or potato plates. The nutrient agar or potato provides nourishment for any bacteria or fungi that contacts them and the microorganisms begins to reproduce and grow into a visible colony (only certain microbes will find the medium suitable for growth). After a few days of incubation, students will compare the plates and determine which surfaces had the most microbes.

What's the Question?

Which surfaces (doorknobs, computer keyboards, counter tops, sinks, toilets, etc.) produce the greatest bacterial or mold growth? What can we do about these surfaces to reduce our chances for infection?

Preparing the Petri Dishes

Follow the directions that come with the nutrient agar. Heat the agar in a microwave until it melts. Remove Petri dish lids and place them upside down in an area where they will not be disturbed. Pour just enough nutrient agar into the bottom plate and allow to cool.

Cover with lids when cooled. Turn the petri dishes over and draw a line across the middle with permanent marker.

Option: As an alternative to nutrient agar, white potatoes can serve as the media. Boil a couple of white potatoes until almost cooked. Cut the potatoes into $\frac{1}{4}$ to $\frac{3}{8}$ th inch slices and place one slice in each Petri dish being careful not to contaminate them. While in the Petri dishes, slice the potatoes in half so that there are two half circle pieces in each. Allow the slices to cool and cover with the lids. If using plastic bags for the slices, the slices can be cut in half and the halves placed in separate bags.

Tip: You can slice the potatoes at home and transport them in the boiled water.

What to Do

1. Announce to your students that they will embark on a Microbe Scavenger Hunt. Microorganisms, or microbes, are very tiny life forms, some of which are beneficial and some of which can transmit diseases to humans. They will be looking at a particular kind of microbe called bacteria although they may also find another kind of microbe called mold, a form of fungi. They will swab various surfaces with moistened cotton-tipped applicators and then transfer any microbes picked up from those surfaces to agar or potato plates.

2. Demonstrate the sampling procedure below. Mention to students that they will not be able to see the microbes that they are transferring. The same basic procedure should be used for agar or for potato slices and Petri dishes/plastic bags.

- Wash hands thoroughly before collecting samples. (Ask students if they have ever seen television shows where doctors and nurses are washing their hands. Why do they do this?)

- Hold the cotton swab on one end only and do not touch or breathe on the other end. (Discuss why this is important. What might happen if they touch or breathe on the sample end?)

- Dip the swab in the bottled water and shake off the excess. Stick the moistened end into a plastic sandwich bag to cover it until needed.

- Select a surface to sample and lightly rub the moistened swab over that surface. Twirl the swab to make sure the entire swab end contacts the surface. The moisture on the swab will pick up some of the microbes on the surface being tested.

- Remove the lid of the Petri dish, being careful not to touch the inside of the dish or the lid. Lightly rub the moistened swab (inoculate), now with the sample, across $\frac{1}{2}$ of the agar or over a half potato slice several times in a zigzag pattern. (Doing so will transfer some of the sample to the medium.)

- Cover the Petri dish with the lid and write on the edge of the lid where the sample was taken. Set the covered Petri dish in a place where it will be undisturbed for several days at room temperature. If using plastic bags, seal the bags when inoculated with microbe and mark the source

Tip: Use a bit of cellophane tape to seal the Petri dish lids to prevent accidentally opening after inoculation with microbes.

3. Give the students the sampling instructions and send them out in the building to sample two different surfaces. Each student should carry a prepared Petri dish (covered) or two plastic bags, one with potatoes as well as one with two moistened cotton swabs with the moistened end protected by a plastic bag.
4. When students return, place the Petri dishes (or bags) in a designated location. Dispose of the cotton swabs and sandwich bags in the trash.

Three to Seven Days Later

Microbes transferred to the agar or potato plates will have found an environment to grow and reproduce. Spots of growth or zigzag growth will cover the surface of the agar or the potato slice. Depending on what is found on the surfaces sampled, the growth may consist of bacterial or mold colonies. Bacteria colonies tend to be circular and may be colorful. Molds tend to be fibrous and may grow upward from the agar or potato surface.

1. Have student teams examine their Petri dishes as often as possible using hand lenses. Do not let teams open the dishes.
2. Have teams make sketches and observations for their lab notebooks. Encourage students to create a picture timeline, a flipbook, or a foldable showing the microbe growth.
3. Hold a group discussion and have teams report their results. How many different colonies did they discover and where were their samples collected? Which sample locations seemed to produce the most colonies? Were there any similar looking samples? Where did they find the most microbes? Were there any surprises?

Disposal

At the end of the activity, dispose of all of the Petri dishes and the samples they contain. Seal them in several layers of plastic bags and place them in the trash. A more proper way to dispose of the samples is to immerse the Petri dishes in a 10% chlorine bleach solution. This will require opening the dishes to disinfect the insides. Wear hand and eye protection while doing this. Remove the dishes and seal them in a plastic bag and place them in the trash.

Wrap It Up

Hold a discussion with the group. Ask what they learned by collecting and growing microbe samples. Explain that the technique they followed to explore for microbes will be used again as a way of testing the effectiveness of ways of fighting infectious disease. For example, do disinfectants really work? Can harmful bacteria be removed from water to make the water safe to drink? These are questions that sampling can help answer.

Extension

- Microbiologists have discovered that bacteria and slime mold colonies can be beautiful. With a little bit of imagination, many microbiologists have been creating interesting microbial art, even holding microbial art competitions.
<http://www.microbialart.com/more/>

Words To Know

Bacteria: (singular, bacterium – plural) Single cell prokaryote microorganisms. Prokaryote microorganisms are single cell life forms that lack a nucleus or other membrane-bound organelles (Golgi apparatus, mitochondria, etc.)

Bacteriologist: A scientist who studies bacteria.

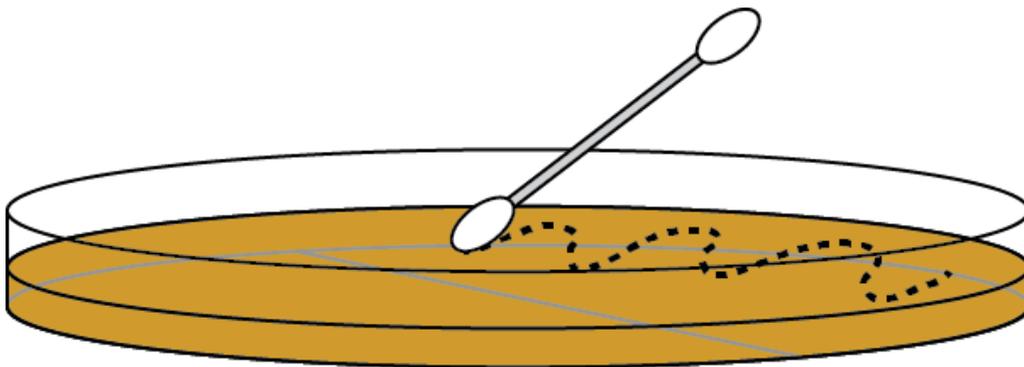
Microorganism: (also called microbe) Organisms too small to be seen with the naked eye.

Fungi: A group of organisms that build cell walls with materials that typically do not contain cellulose (plant do have cell walls made with cellulose). Fungi do not produce their own food but gain energy by absorbing organic substances. Yeasts and molds are microscopic fungi.

Microbe Hunters

Sampling Instructions- Petri Dishes (Agar or Potato Slice)

- Wash hands thoroughly before collecting samples.
- With the Petri dish still covered or the plastic bags still sealed, write the locations and surfaces where the samples will be taken on the dish side or the upper edge of the bag.
- Hold the cotton swabs on one end only and do not touch or breathe on the other end.
- Dip the swabs in water and shake off the excess. Stick the moistened ends into a plastic sandwich bag to cover them until needed.
- Select your first sampling location and lightly rub the moistened swab over the surface you selected. Twirl the swab as you do this to make sure the entire swab end contacts the surface.
- Remove the lid of the Petri dish or open the first bag, being careful not to touch the inside of the dish or the lid or bag. Lightly rub the moistened swab (now with the sample) across one half of the agar or across the potato slice several times in a zigzag pattern. Twirl the swab as you do so. Discard the swab in the trash.
- Cover the Petri dish or close the bag until you repeat the procedure with your second sampling location.
- Cover the Petri dish with its lid or seal the bags. Set them in a place where they will be undisturbed for several days.
- Wash your hands thoroughly after collecting samples.



2A. Magnification

Time Needed:

Set-up: 15 minutes to
prepare bags of materials
1 session

Before You Start

Set up a computer and
LCD projector to show the
“Powers of Ten” video.
Find the video at:

www.powersof10.com/film

Prepare sets of materials
for observation in small
plastic bags. See the list
below for materials ideas.

You'll Need This Stuff

for each group:

- 2 Clear plastic cups, one
half filled with water
- 2 Pennies
- Pencil
- Set of materials including
fabric, feather, penny,
newsprint, etc.
- 4 5-cm square pieces of
clear plastic cut from a
flat-sided takeout salad
box

- Cooking oil
- 4 Paper towels
- Index card
- Eye dropper
- 4 hand lenses
- (Optional) One clear
marble and one large
“glass gem” (See
Wrapping Up section for
note about sources and
instructions.)

What It's About

The world contains much more than we can see or imagine. Beneath the normal range of our vision lies a universe of microorganisms thriving on nearly every surface. To see this universe, we need magnification.

Magnifiers and microscopes consist of curved transparent lenses that bend light, making tiny objects appear larger to our eyes. Hand magnifiers, consisting of a single lens, usually double or triple the normal size of objects. (Note: Lenses do not have to be made of glass or plastic. A water drop makes a great magnifier.) When lenses are combined, the magnifying power is increased many times. Jeweler's eye loupes consist of two or three lenses that magnify 10 times or more. Microscopes are tubes with lenses mounted on opposite ends. Depending upon the curvature of the lenses, microscopes can magnify several hundred times to more than 1,000 times. It is with microscopes that we can explore the tiny world of microbes.

In this activity students will examine and sketch common materials and objects using simple magnifiers. In doing so, they will begin to learn about how we view the tiny world and about how lenses work to magnify the miniscule.

What's The Question?

What causes magnification?
How does the appearance of objects/materials change when viewed through a convex transparent material?

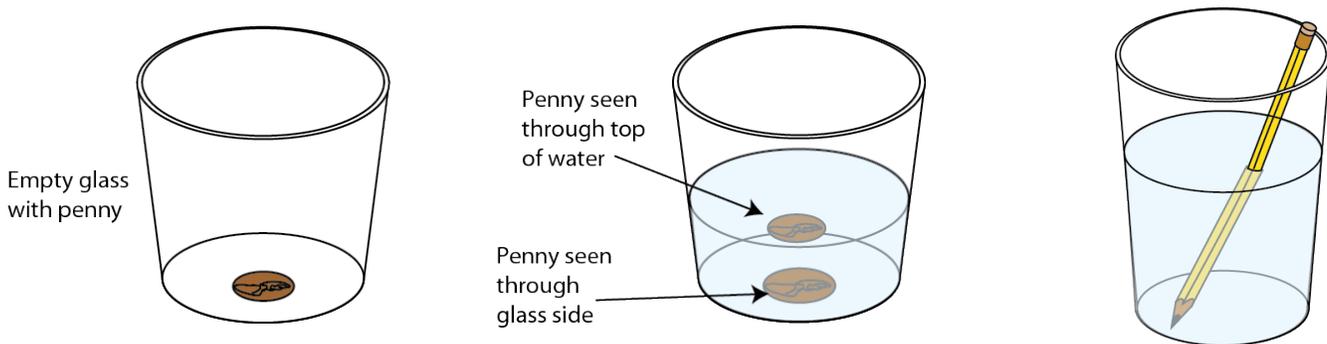
What To Do?

1. Introduce students to the world of the seemingly invisible by showing students the nine-minute “Powers of Ten” video. This famous 1968 video begins with a couple having a picnic in a Chicago park near Lake Michigan. Every ten seconds, the view zooms outward to a distance ten times farther away. Soon, we are carried to the edge of the universe. The view then reverses and zeros in on a hand of one of the picnickers. The view is magnified ten times every ten seconds. The journey continues until it reaches a proton of a carbon atom within a DNA molecule in a white blood cell. This is a true journey of scale. It is a real magnification experience.

2. Discuss the video with students and how the magnification changed by powers of 10. (If appropriate for your students, discuss exponential numbers. See FYI below.) Explain that they will be investigating how magnification works. Ask if anyone has any ideas about how magnification is possible. Let students share ideas.

FYI: Powers of Ten. The *Powers of Ten* video takes our imagination on a trip from a tiny space 0.000,000,000,000,000,1 meters across to a space 1,000,000,000,000,000,000,000,000 meters across. Scientists prefer to use a mathematical shortcut for these numbers. The number 0.000,000,000,000,000,1 is 10^{-16} . The number 1,000,000,000,000,000,000,000,000 is 10^{24} . These shortcut numbers are called scientific notation (count the zeros). Scientific notation is based on powers of 10, which is where the movie title comes from.

3. Next, have students place a penny in the center of the bottom of a clear plastic cup. Ask them to observe the penny in the cup from different sides and heights. Next, have students fill the cup half full with water and again observe from different positions. Ask, does the penny always look the same? Hopefully they will notice that the penny looks larger when viewed from the side of the glass, but not from the top!



4. After observations, ask students if they know why the penny looks larger when viewed through the side of the cup filled with water. Encourage students to share possible explanations. The light bends as it passes from one substance (air) into another (water) of different density. To demonstrate the bending, have students place a pencil in the cup of water. Does the pencil still look straight? Why or why not? Ask, how might this relate to a magnifying glass (hand lens) or glasses? Discuss.
5. Hold up a magnifier or hand lens. Ask students, How many of you have used something like this? What can it be used for? (Lenses can be used to focus light on a single point, and also are used in eyeglasses, cameras, etc.) Tell students they will be using hand lenses to make observations.
6. Distribute material sets to each team of students. Have students observe and draw each item in their bags using the hand lenses. Ask, Did you discover anything on these objects that you have never observed before? Have students report their observations informally. If you have Lincoln pennies from 1959-2008, ask students how many Lincolns are on the penny. (There are two - check the inside of the Lincoln Memorial with a lens.)
7. Have students observe the same materials through a clear marble and draw what they observe. It is necessary to hold the marble close to the eye when observing objects. Ask students to estimate how many times the marble magnifies objects.

8. Next, have each student make a water drop magnifier following these steps.
 - Cut out a 5 cm square of flat plastic from the side of a takeout salad box or other clear flat-sided plastic food package.
 - Lightly coat one side of the square with cooking oil by dabbing a piece of paper towel into the oil and wiping the plastic surface.
 - Transfer a drop of water to the oil side of the plastic. Replace the water drop as needed.

Note: Oil and water do not mix which causes the water drop to be more spherical and produce a greater magnification. Have students compare a drop on an oiled surface with a drop on a surface without oil. Ask if students see a difference? If yes, what is the difference and why?

9. Next direct students to observe the newsprint through water drop and the other items in the bag of materials. Have students draw their observations as before.
10. Discuss students' observations. Ask, what happened when they looked through the water drop? (print and other objects were magnified) "Are there any similarities between the magnifier, the marble, and the drop?" (clear, transparent, curved surface) Help students understand that the magnifying lens, marble and the water drop share similar characteristics. If students need additional clarification, have them observe the newsprint through a glass or plastic slide or other flat clear surface. The slide will not magnify (or shrink) the image, because the surface is not curved.

Wrap it up

Discuss the importance of magnification to the detection of disease. Knowing what is causing a person to get sick helps the doctor determine the treatment. Microbes cause many diseases. One-way to be sure which microbe(s) are causing the problem is to examine samples under a microscope. Magnifiers and microscopes are important tools for medical science.

Extensions

- Tell students they will be making a magnifier that they can keep. They will need a "glass gem" and some wet-dry sandpaper. See the source notes below for where to get the materials. As students make their magnifiers, have them do before and after observations of each step. Ask students to explain why the view through their magnifiers improves with each sanding step.
 - Pick out a gem with a relatively smooth flat bottom. Using the coarsest wet-dry paper, sand the bottom as smooth as possible. To do so, place the paper on a flat surface and wet it slightly with a few drops of water. Press the gem to the paper and rub it several hundred times.
 - Repeat the rubbing with a finer piece of wet-dry paper.
 - Repeat twice more, each time with a finer piece of wet-dry paper. Then wash off the lens. It is ready to be used.

Source for Glass Gems

"Glass gems" are available in craft stores, usually in the floral section. They are used for decorative accents for vases. Choose the largest clear gems available. The gems are round glass drops flat on one side and convex on the other.

Source for Wet-Dry (emery) Paper

Wet-dry paper is a high-grade form of sand paper used for producing glossy finishes for auto touch-ups and for polishing glass. You can find the paper at auto, boat, and hardware stores. Pick several grades - coarse 220 grit, medium 320 grit, fine 600 grit, and very fine 1,000 grit. Start

with the coarse grit to get rid of large bumps in the glass gem bottom. Work your way up to the finest grit. Each finer grade will improve the glass surface than the previous grit. After the 1,000 grit, the lens is ready to be used.

- Take a peak at the microscopic world with these online resources:

Secret Worlds: the Universe Within

<http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/index.html>

Virtual Scanning Electron Microscope:

<http://micro.magnet.fsu.edu/primer/java/electronmicroscopy/magnify1/index.html>

2B. Magnification Tools

Time Needed

1 session

Before You Start

Make copies of the student sheets. Place materials for each group on trays in a central location.

Before allowing students to carry microscopes to their work areas, demonstrate how to hold a microscope by placing one hand on the microscope stand (arm) and the other under the base (foot).

Have students work in groups of four.

You'll Need This Stuff

Per Group:

- 4 hand lenses or magnifiers
- 4 index cards (or similarly sized sections of cardstock)
- 4 pairs of scissors
- 4 pieces of newsprint, about 2 cm x 10 cm each. Select pieces that have newsprint on one side only so that print will not show through under the microscope.
- 4 pipettes or droppers
- 4 plastic cover slips
- 4 plastic or glass microscope slides
- 4 rulers (measurements in cm)
- Microscope (any kind)
- Other objects to observe, such as a leaf, coin, dollar bill, etc.
- Set of colored pencils or markers
- Sheet of wax paper (6 cm in length)
- Small container of tap water
- Transparent tape

Per Student:

- Copies of *Magnification Observations* and *The Compound Microscope* student sheets

What It's About

Scientific progress often is tied to the development of new tools and technologies. For example, until magnifying lenses were developed, people were able to see only as much of the world as their naked eyes would allow. The development of high quality magnifiers and microscopes opened up the world of cells and microorganisms for exploration by generations of scientists.

Lenses are made of transparent materials and have one or two curved surfaces. They work by refraction, which means that the pathway of light is altered as it passes from one clear material, such as air, into another of a different density, such as glass. Magnifying glasses are single lenses that are convex on both sides. The compound light, or optical, microscope uses two magnifying lenses in series to make things appear much larger to the eye than would be possible with a single lens. The simplest compound microscopes consist of tubes with lenses at each end. Objects can be magnified up to 2,000 times using a high quality compound microscope.

The invention of the transmission electron microscope (TEM) in the mid-20th Century made it possible to view objects even tinier than cells, such as viruses. This type of microscope magnifies objects up to two million times by passing a beam of electrons through a very thin specimen and recording changes in the electron beam.

Zacharias Janssen is credited with developing the first compound microscope around 1595. But in 1665, scientist Robert Hooke was the first to use such an instrument to observe the division of plant tissues into tiny compartments, which he termed "cellulae," or cells. Inspired by the work of Hooke, Anton van Leeuwenhoek, a Dutch inventor, used simple (one lens) microscopes to describe bacteria and protists. Van Leeuwenhoek's well-made microscopes magnified objects more than 200 times and allowed him to make very detailed observations.

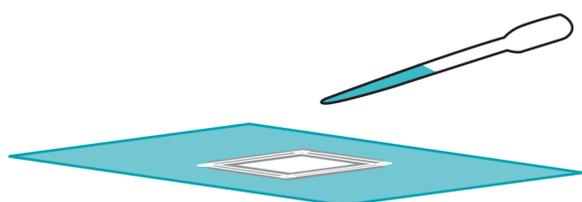
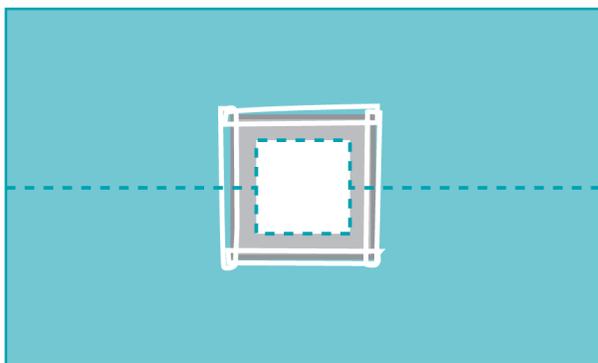
What's The Question?

What are the parts and powers of a microscope?

What To Do?

Part 1. Lenses & Magnification

1. Hold up a magnifier or hand lens. Ask students, *How many of you have used something like this? What can it be used for?* (Lenses can be used to focus light on a single point, and also are used in



(opening will be 2 cm x 2 cm).

- Cut a 3-cm x 3-cm square of wax paper.
 - Place wax paper over the opening and secure it with tape.
5. Direct students to observe the newspaper through the wax paper window. Next, have students place a single drop of water (using a pipette or dropper) in the center of the wax paper window, and observe the newspaper through the water drop. Have students draw their observations as before.
 6. Discuss students' observations. Ask, *What happened when you looked at the newspaper through wax paper?* (no change) *When observed through the water drop?* (print was magnified) *Are there any similarities between the magnifier and the drop?* (clear, transparent, curved surface) Help students understand that the magnifier lens and the water drop shared similar characteristics. If students need additional clarification, have them observe the newspaper through a glass or plastic slide, which is flat. The slide will not magnify (or shrink) the image, because the surface is not curved.

Part 2. Microscopes

1. Ask, *What could we use to magnify the materials further?* Distribute the microscopes and allow groups to examine them for a few minutes. Then ask, *Where is the lens? Is there more than one lens?* (yes, in the eyepiece and at the bases of the objectives) Ask, *What do you notice about the lenses?* Students should note the curvature of the lens and the "X" markings on the sides of the eyepiece and objective. Ask, *What does "X" usually mean in mathematics?* (multiplication or "times") Explain that the bottom lens number (on the objective in use) and the top lens number (on the eyepiece) are multiplied to indicate the total number of times a specimen is magnified when observed. For example, an eyepiece of 10x with an objective of 4x will magnify an image 40 times ($10 \times 4 = 40$).
2. If students are not familiar with microscopes, help them locate the basic parts. For example, tell students, *One part of the microscope is called the stage. It is similar to a stage for a performance. Can you find it? What about the arm?* Have students use *The Compound Microscope* sheet to find the eyepiece, objectives, coarse and fine focus knobs, arm, stage, and light source of their microscopes. Many microscopes also have a condenser to intensify the light and a diaphragm aperture to adjust the amount of light passing from the light source up through the object. Encourage students to examine the microscope and propose the function of each part.

eyeglasses, cameras, etc.) Tell students they will be using hand lenses to make observations.

2. Distribute materials to each team of students. Direct students to observe each item on the tray with the hand lens. Ask, *Did you observe anything on any of the objects that you have never noticed before?* Let students report their observations informally.

3. Tell students to use a hand lens to observe the newspaper and draw what they observe on their student sheets.

4. Next, have each student make a magnifier following these steps.

- Fold index cards in half lengthwise (see Water Drop Magnifier, to the left).

- Cut an opening about 2 cm long and 1 cm wide in the center of the card. Open the card

3. Finally, have students create a temporary slide, called a “wet mount.” Instruct students to cut out a 1-cm x 1-cm piece of newsprint, and to put the piece of newsprint in the center of a clean microscope slide. Have students place a drop of water on the paper, cover the drop gently with a cover slip and then place the slide on the microscope stage. If the stage has clips, have students place the clips over the slide to hold it in place.

If the microscope has a light source, make sure the light is aimed up through the paper. Initially, the diaphragm should be adjusted to its largest opening. If the image is too bright (seems “washed out”) when viewed, help students reduce the amount of light by partially closing the diaphragm.

Note: Low-power “dissecting-type” microscopes may not have a light source below the stage.

4. Direct students to move the lowest power objective into place above the print material (not all microscopes have multiple objectives) and to use the coarse focus knob to lower the tip of the objective until it is just above the coverslip. Students should look through the eyepiece and use the coarse focus knob (depending on the microscope) to move the objective gradually upwards until the printing on the paper comes into view.

Remind students that the object sample will come into focus when the objective is very close to the stage. Tell students to use the fine focus knob to sharpen the appearance of the image, and use caution not to break the coverslip. Each student should have an opportunity to adjust and focus the microscope.

5. Have students draw their observations of the newsprint on the *Magnification Observations* sheet. Some students may wish to study the newsprint at a higher magnification by first centering the object in the field of view, then gently rotating the middle objective into position and adjusting the focus using the fine focus knob only.

Wrapping Up

Discuss students' observations or have them answer the following questions in their science notebooks. Ask, *Which tool provided the greatest magnification? What did all of the tools have in common? What were the differences between each of the tools?*

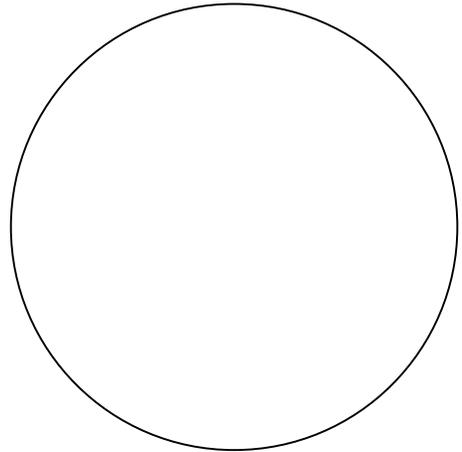
Magnification Observations

OBSERVATION 1

Tool Used:

Magnification (if known):

Notes and Observations:

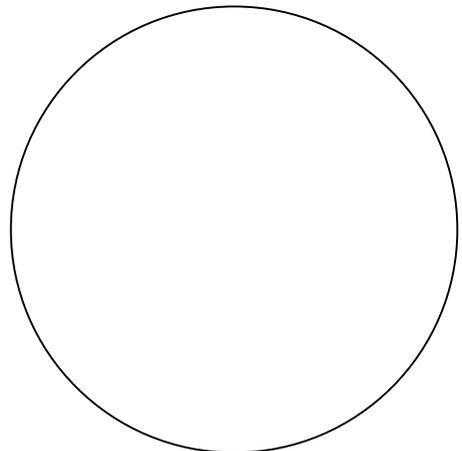


OBSERVATION 2

Tool Used:

Magnification (if known):

Notes and Observations:

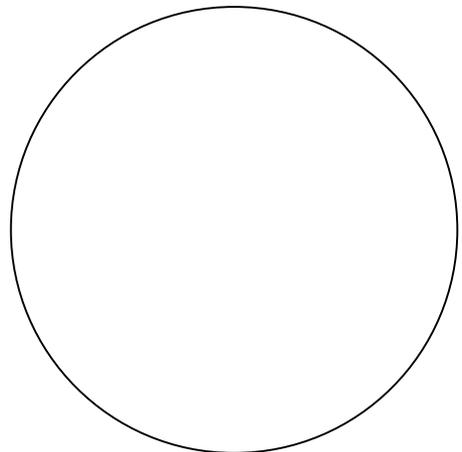


OBSERVATION 3

Tool Used:

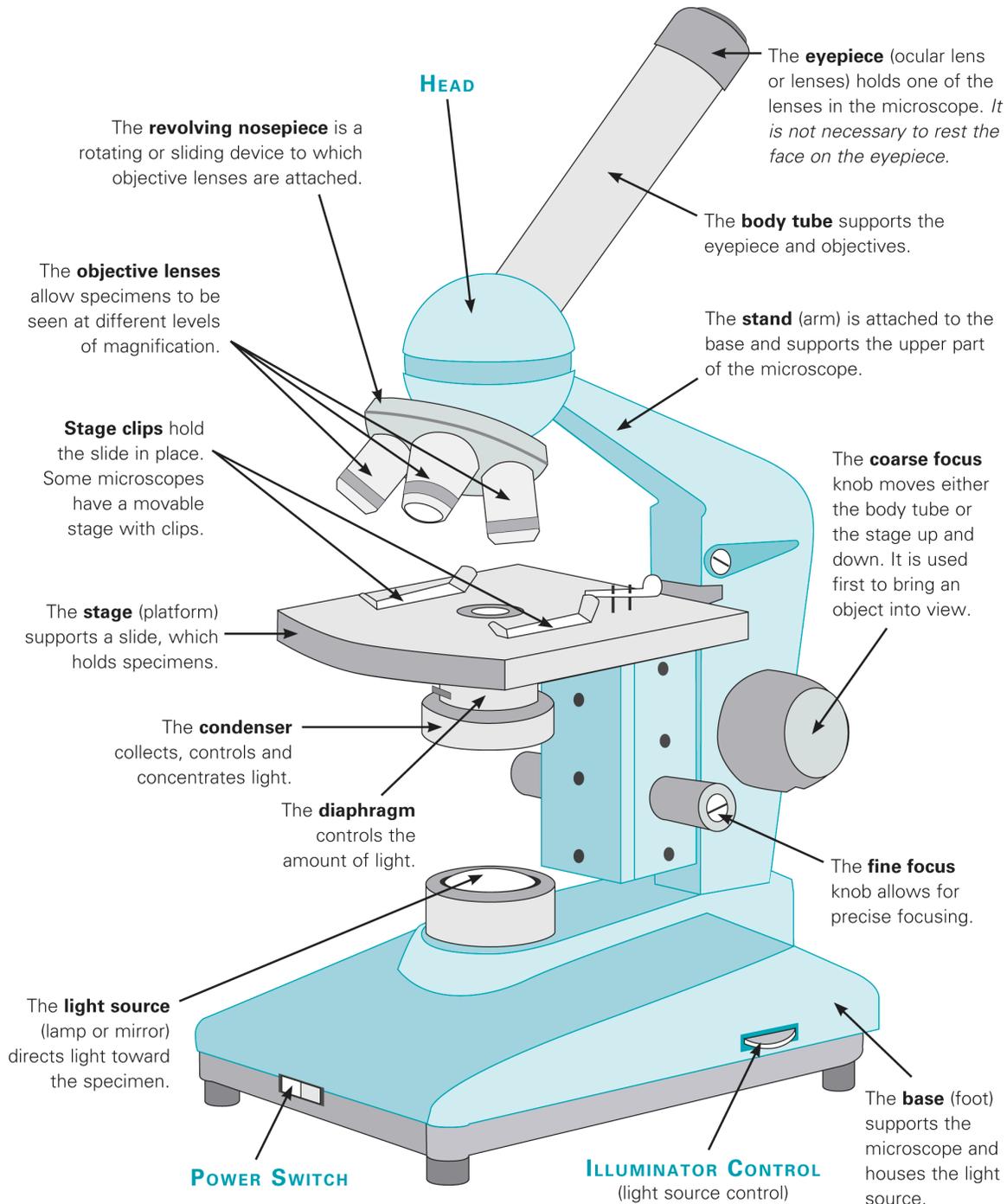
Magnification (if known):

Notes and Observations:



The Compound Microscope

When you look through a microscope, lenses make what you are looking at appear larger. For example, a 10-power lens (10x) makes objects appear ten times larger than their actual size. With the right combination of lenses, a very good compound light microscope can magnify objects as much as 2,000 times (2000x).



3A. Exploring with the Microscope

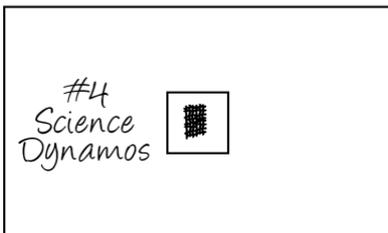
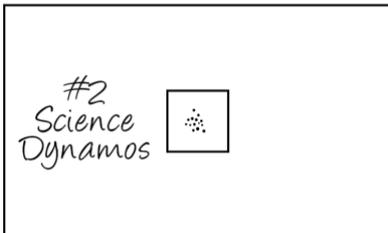
Time Needed

1 session

You Need This Stuff

Per Class

- Note cards
- Scissors
- Tape
- Selected materials
- Microscopes
- Copies of *Mystery Slide Investigations* sheet



What It's About

Before the discovery of magnification the microscopic world was invisible. From the time of Aristotle there was a belief or supposition that "stuff" could be divided to near infinity – with there being an ultimately "small" particle, one that could not be seen.

Although Zacharias Janssen is credited with inventing the compound microscope, which has two lenses, Anton van Leeuwenhoek and Robert Hooke created the first microscopes that enable the viewing of the microscopic world. They were simple by today's standards, but these early microscopes allowed scientists to see tiny insects, plant cells, bacteria and protozoans for the first time. Hooke was the first person to use the word "cell" in biology. Van Leeuwenhoek perfected the process for making glass lenses. He made detailed observations of tiny organisms never seen before, and was the first person actually to see bacterial cells. Over the course of his lifetime, he made more than 400 microscopes by hand.

What's The Question?

What do you notice about a specimen observed as the power of magnification increases?

Before You Start

Collect materials for students that may not have remembered to bring in a specimen and/or go outside with students to collect specimen for their slides.

What To Do

1. Remind students of how they made the note card slide and explain that they each have the opportunity to create another of their choice. They will challenge another team to identify the material on their slides.
2. Student teams will create a set of 4 slides, labeled 1-4 and include their group number or group name.
3. Each team member will choose something to place on their slide, for example a piece of grass, a leaf, dirt or sand, egg shell, or pencil lead.
4. Groups will examine their slides and answer the questions on the "Mystery Slides Investigation" student page, beginning with the one each individual created and then reviewing others.
5. Next, after each group's four slides have been examined, they will trade with another group and repeat. If time permits,

encourage students to view all the slides available and record the possible identity of each specimen.

6. Ask, *Were you able to identify all the specimens?* Have each group share with the class the identity of their four specimens. Ask, *Were there any surprises?*

Wrapping Up

Show students photos from the Amazing Scanning Electron Microscope

<http://www.youtube.com/watch?v=f37FQ1u2p8QTEXT>

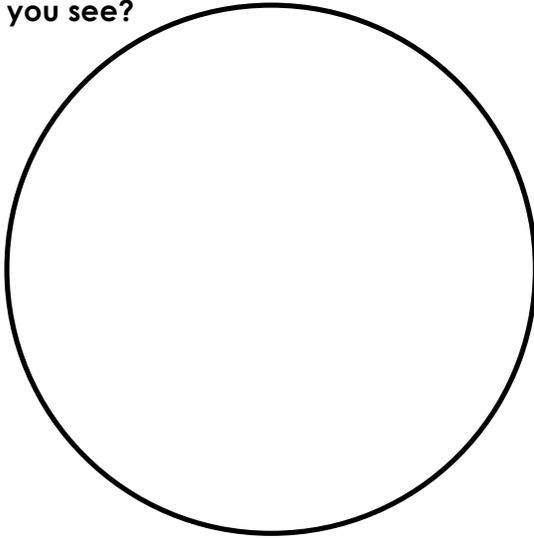
In order to download a YouTube video for use in your classroom:

1. Copy the YouTube video URL
2. Go to <http://www.keepvid.com>
3. Paste the copied YouTube Video URL into the box at the top.
4. Click download (ignore the other downloads and pop ups)
5. After a few seconds it will ask you what format and where to save the file.

Mystery Slides Investigation Page 1 of 2

Group # or name _____

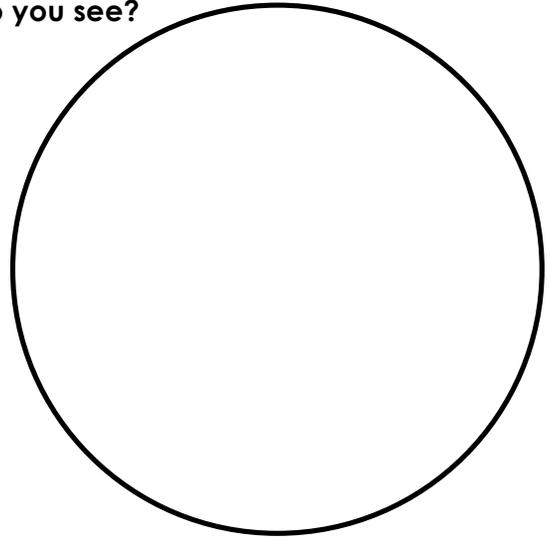
What do you see?



What does it look like? _____

What can it be? _____

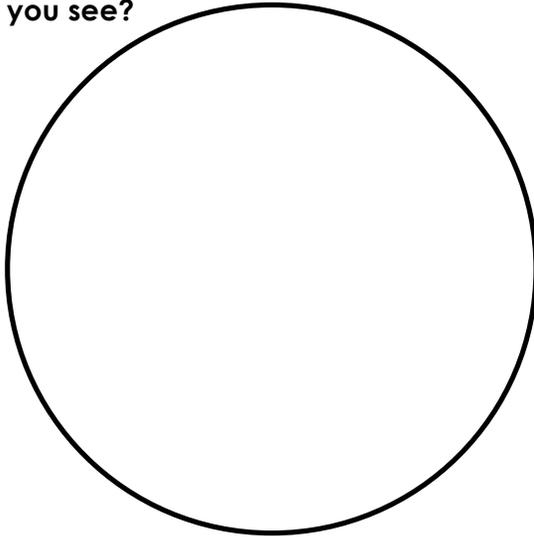
What do you see?



What does it look like? _____

What can it be? _____

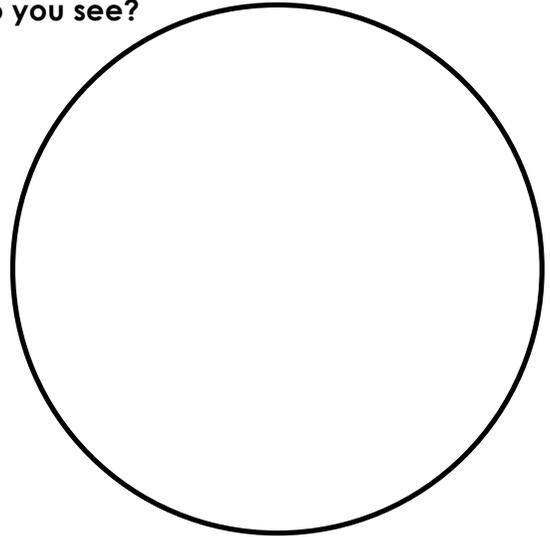
What do you see?



What does it look like? _____

What can it be? _____

What do you see?

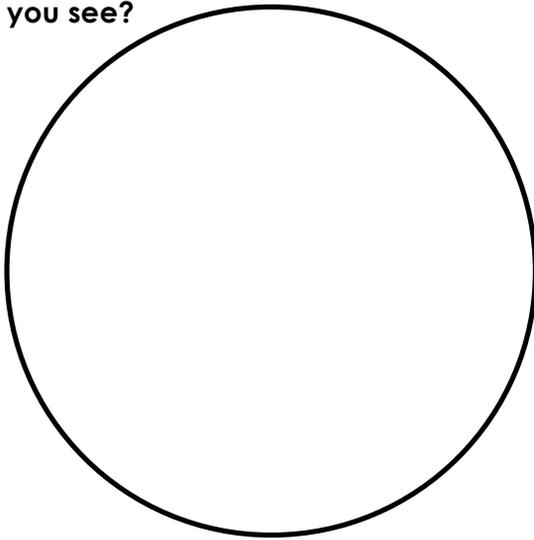


What does it look like? _____

What can it be? _____

Mystery Slides Investigation Page 2 of 2

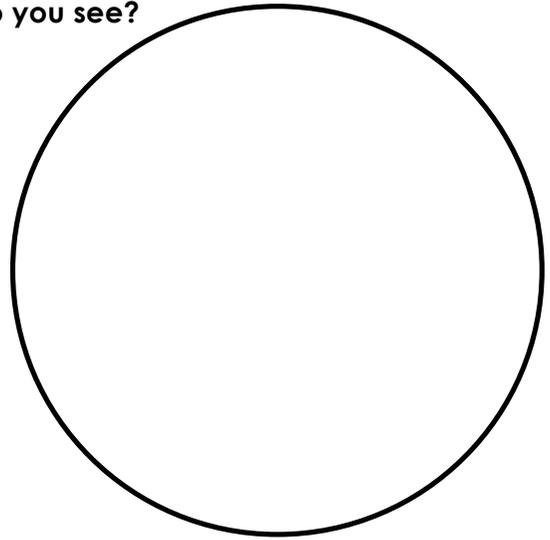
What do you see?



What does it look like? _____

What can it be? _____

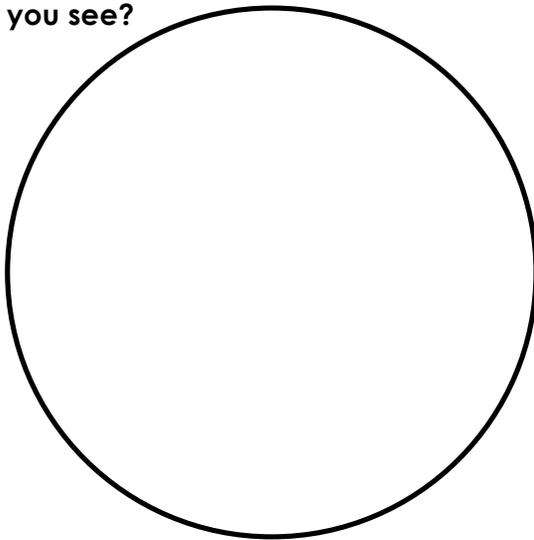
What do you see?



What does it look like? _____

What can it be? _____

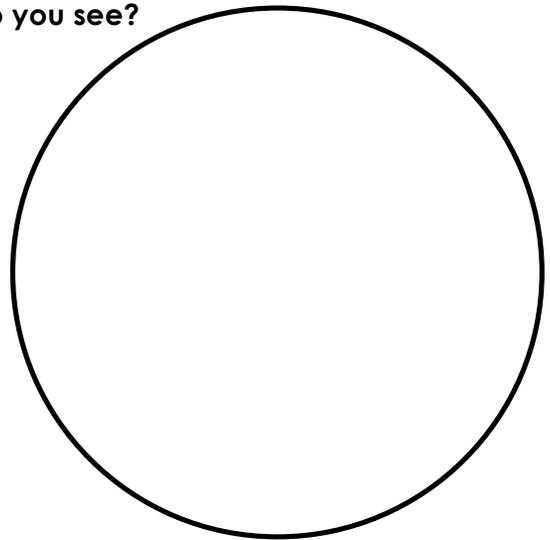
What do you see?



What does it look like? _____

What can it be? _____

What do you see?



What does it look like? _____

What can it be? _____

3B. Magnifying and Observing Cells

Time Needed

1 Session

You Need This Stuff

Per Class:

- Sharp knife
- 1 white onion
- Several stalks of Elodea plant
- Computer with internet access
- Projector
- Activity 3 PowerPoint at:
<http://goo.gl/ELzmgi>

Per Group:

- Microscope
- 4 pairs of safety goggles
- 4 microscope slides
- 2 pairs of forceps
- 1/6 of an onion, vertical slice
- Small stalk of Elodea leaves
- Iodine solution in small portion cup
- Water in small portion cup
- 2 pipettes (droppers)
- Science notebooks or drawing paper
- 4 copies *Preparing and Viewing* student sheet

What It's About

Every living thing is composed of cells, the microscopic building blocks of life. In fact, most life forms exist as single cells that carry out all functions needed for their own independent existence. Examples of common single-celled organisms are bacteria (tiny organisms found in almost every habitat on Earth), diatoms (algae that are common components of phytoplankton), and yeast (a kind of fungus). Multicellular organisms consist of several to many cells. Single-celled and small multicellular organisms that must be magnified to be observed are called microbes or microorganisms.

Plants and animals are examples of multicellular organisms visible to the naked eye. These macroscopic multicellular organisms can have up to trillions of cells that carry out specialized functions.

In this activity, students will observe onion cells (in the thin membrane around each onion layer) and a leaf from *Elodea*, a *water plant*. With these examples, students will be able to see basic plant cell parts, including the nucleus (structure in the center of the cell that holds genetic information), cytoplasm (gel that fills the cell), cell wall (rigid outer boundary of plant and other kinds of cells), and chloroplasts (large green structures in which photosynthesis occurs).

What's The Question?

What are cells? What are some characteristics of plant cells?

Before You Start

Download the Activity PowerPoint from the following url:

<http://goo.gl/ELzmgi>

If you prefer to select your own images of a plant cell and animal cell, refer to the website listed in the "Extensions" section of this activity. Do not have the images labeled or identified except on the last slide.

Make copies of the *Preparing & Viewing Slides* student page. Have students work in groups of two or four, depending on resources. Prepare a tray with all group materials and place in a central location. Optional: If *Elodea* is not available, new growth celery leaves may be substituted.

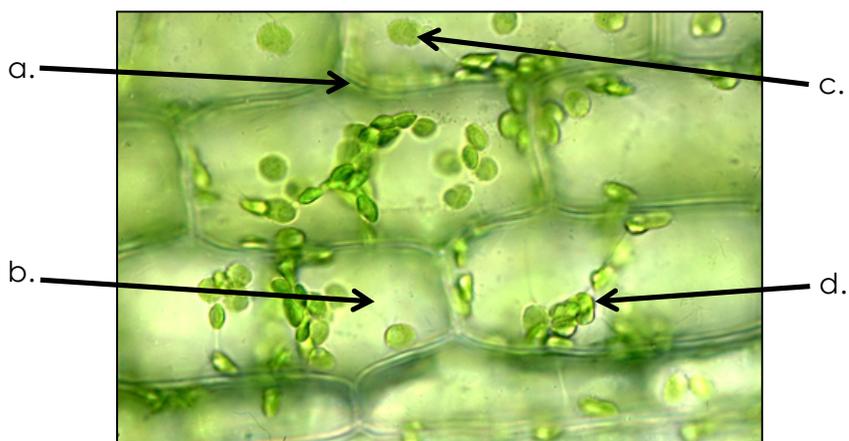
Portion out iodine into small cups for use by students.

Have students wear goggles when working with iodine, which is poisonous if ingested and can stain clothing permanently. Some students may be allergic to iodine. Methylene blue may be used instead of iodine, but it also can cause skin or eye irritation and should not be ingested. If skin is exposed

to either stain, wash with soap and water. If stain gets into the eyes, rinse eyes with water for at least 15 minutes. Have students wash their hands before and after any lab activity.

What To Do

1. Show the activity PowerPoint presentation to students. Do not tell them what they are looking at.
2. Ask, *What can you tell me about the pictures? (cells) Are there any similarities? Can you identify any parts?*
3. Explain that the images show different types of cells. Ask students, *What do you know about cells?* Have them work in groups to write down what they know and share. Mention that cells are the basic component of living organisms and that some life forms are only made of one cell (single-celled) and others are made of many (multicellular).
4. Show the final slide, an image of a plant cell with the following labeled parts on the PowerPoint. (see photo below)
 - a. Cell wall – strong wall outside of a plant cell that provides support
 - b. Cytoplasm – the gel-like content in a cell
 - c. Nucleus – a structure in the cell containing genetic material
 - d. Chloroplast – a small structure that contains a green substance called chlorophyll which is involved in photosynthesis



5. Explain that these and other structures cannot be seen without magnification. Tell students that they will be making their own slides to observe plant cells.
6. Point out that they will look for similar structures in their specimens.
7. If necessary, review microscope use with all students before preparing slides.
8. Have students work in groups to make their slides by following the instructions on the Preparing & Viewing student sheet or demonstrate the procedure.
9. Have students take turns observing and drawing the specimens (noting the magnification being used). Have students first examine the cells using low power (40X) and then switch objectives to achieve higher power. Remind them of the cell parts discussed in step #4. Instruct students to make detailed drawings and to label any cell parts that are recognizable. Tell students that some parts of a cell may not be visible when viewed under a microscope.

Note: Have students determine the total magnification by multiplying the power stamped on the eyepiece (for example, 10x) by the power of the objective.

10. Students usually will be able to observe the cell nuclei in the stained onion skin cells. They also should be able to observe cell walls and cytoplasm in both kinds of cells, and to identify chloroplasts in the *Elodea* cells.
11. Encourage groups to discuss what they observed. Ask, *Are all the cells about the same size? Could you see the nucleus inside all the cells? If not, why do you think this is the case?*

Wrapping Up

Discuss why the onion cells were not green like the *Elodea* cells. Remind students that photosynthesis, the process that converts water and carbon dioxide into sugar using sunlight, occurs in plant leaves. The onion bulb has a different function than the leaves. This plant part is found underground and stores energy for new growth. Ask students to think about what differences animal cells may have compared to plant cells. Revisit the PowerPoint and have students look at the structures of plant and animal cells and compare. They may notice that animal cells do not have green chloroplasts or cell walls.

Extension

Color images of cells used in this lesson may be viewed from the Kuhn Photo website at <http://dkphoto.photoshelter.com/gallery/Microscopic-Plant-Cells/G00005I.MbuYRzEQ/C0000oyPxKwu0APU>.

Preparing and Viewing Slides

ONION SKIN

- A. Follow steps 1–3 below to prepare the slide for viewing.
 1. Using a pipette or dropper, place one drop each of water and iodine in the center of a slide.
 2. Carefully remove a small, thin, transparent section of skin from the onion's inside layer. Use forceps to place the skin on top of the drops.
 3. Slowly place another slide over the skin and drops, trying not to squeeze any liquid out of the slides.
- B. To examine the onionskin with a microscope, follow the steps below.
 1. Place the slide on the microscope stage.
 2. Focus the low-power magnification (40X) to find an area of the slide that has some of your sample. Avoid bubbles (clear circles with heavy black borders).
 3. Once you have found a section with onionskin, examine the cells. Center the object in the field of view. Change to a medium-power (100X) or high-power magnification (500X).
- C. Draw what you observe and label any parts you recognize.
- D. Record the magnification at which you made your observations.

ELODEA LEAF

- A. Follow steps 1–3 below to prepare the slide for viewing.
 1. Using a pipette or dropper, place one drop of water in the center of a slide.
 2. Carefully remove a small, thin leaf from the plant. Use forceps to place the leaf on top of the drop.
 3. Slowly place another slide over the leaf and drop, trying not to squeeze any liquid out of the slides.
- B. To examine the leaf using the microscope, follow the steps below.
 1. Place the slide on the microscope stage.
 2. Focus the low-power magnification (40X) to find an area of the slide that has some of your sample. Avoid bubbles (clear circles with heavy black borders).
 3. Once you have found a section with leaf sample, examine the cells. Center the object in the field of view. Change to a medium-power (100X) or high-power magnification (400X).
- C. Draw what you observe and label any parts you recognize. (Note: The Elodea leaf has two layers that can be observed separately by slowly changing the focus.)
- D. Record the magnification at which you made your observations.

4A. Observing Different Microbes

Time Needed

1 Session for observations

You Need This Stuff

Per Group:

- 4 magnifiers
- Microscope
- 4 sets of gloves
- 4 goggles
- 4 pipettes or droppers
- 4 microscope slides
- 50 ml of pond water in clear plastic cup
- 4 index cards
- colored pencils
- Small portion cup with glycerin
- 4 sheets of blank paper for graphic organizer
- 4 scissors

What is it About?

Microbes are organisms too small to be seen with the naked eye. There are enormous variations in the kinds and sizes of microbes. A drop of pond water can potentially contain thousands of organisms. Some are single-celled while many are multicellular. One group of microbes that can be found in pond water includes large eukaryotic (containing DNA within nucleus) microorganisms called protists. Some protists are "plant-like", undergoing photosynthesis to make their own food (autotrophic). Others are "animal-like", consuming other microbes for energy (heterotrophic).

Protists are an extremely diverse, informal group of microorganisms that vary in size and structure. Some are microscopic, some are single-celled, and some are multicellular. Each cell has a cell membrane, a well-defined nucleus, and organelles. Some have cell walls. Recent classifications assign different protist groups to several separate kingdoms within the domain Eukarya. The following three groups of protists often are recognized informally.

- **Algae** - Plant-like; single-celled or multicellular; contain chloroplasts; autotrophic (able to carry out photosynthesis).
- **Protozoa** - Animal-like; always single-celled; no cell walls; often motile; absorb nourishment from the environment by feeding on prey or surviving as parasites (heterotrophic).
- **Water and Slime Molds** - Fungus-like; single-celled or multicellular; absorb nourishment from the environment (heterotrophic).

Most protists are harmless but a very small percentage cause diseases to humans. Malaria is caused by a parasitic protozoan, which is carried from person to person by certain kinds of mosquitoes. African sleeping sickness, or trypanosomiasis is caused by another type of protozoan called Trypanosoma. Cryptosporidium and giardia infect humans usually from contaminated water and causes stomach disorders.

What's The Question?

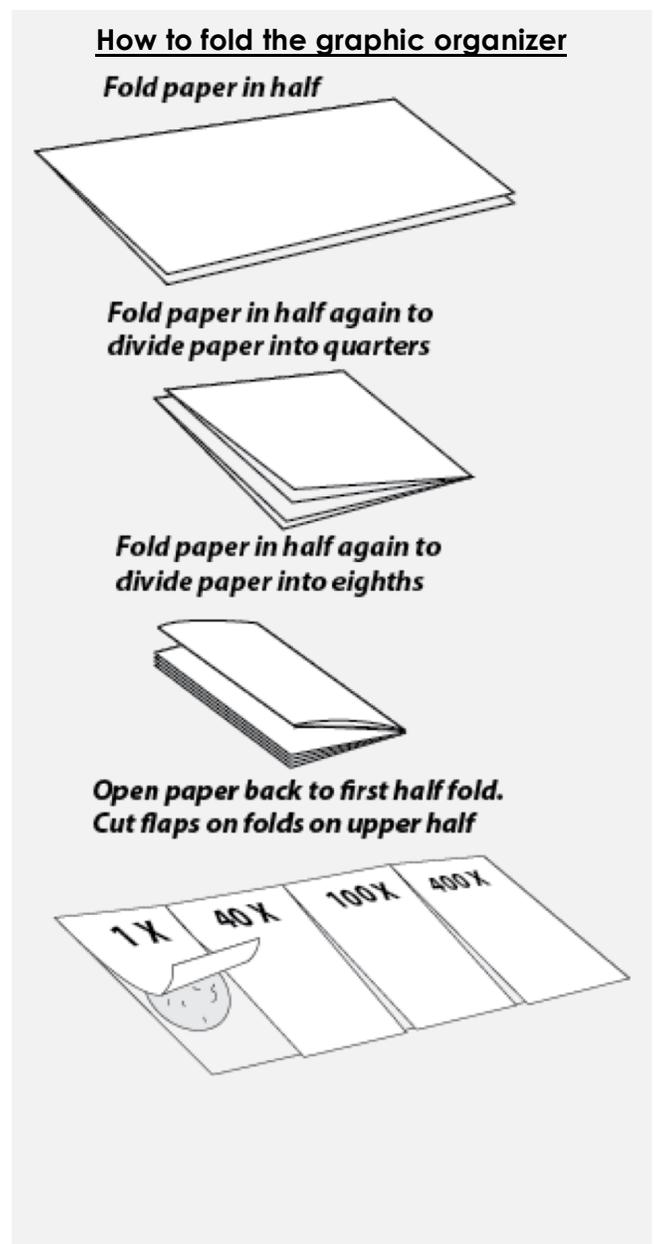
What are some different types of microbes found in pond water and what can you observe about them using a microscope?

Before You Start

Place 50 ml of pond water collected from a pond or drainage area into a container for each group of four. Place materials for each group in a central location.

What To Do

1. First, have students create a graphic organizer using a sheet of 8.5 X 11 paper to record their observations. Tell students to hold a sheet of paper so that the longer side is facing up. Next, have the students fold the sheet in half, creasing the fold. Then fold the paper into fourths horizontally. Open the paper back up to the previous step and you should see three creased lines. Take scissors and cut through the lines only on the top layer. Four flaps will be created. Mark on the first flap, "No Microscope". On the next flap, write "40X Magnification", then "100X Magnification" and on the last flap, write "400X Magnification". Students will draw their observations on the area directly under the flap that corresponds to the magnification used.
2. Give each group of students a clear cup containing 50 ml of pond water and four magnifiers. Ask students to examine it closely. Ask, what do you see? Hopefully there will be tiny moving organisms. Ask, Where do you think this water came from and what might be in the water?
3. Next explain to students that they will be examining the water more closely using a microscope. To prevent contact with any potential disease-causing microbes, provide students with gloves and goggles and have them wash their hands before and after the activity.
4. Show students a slide. If using glass, discuss carefully handling. Explain that it will be used to help them focus on one drop of pond water. Mention that each student in the group should prepare a slide for the whole group to observe. Demonstrate how to make a slide by using a pipette or dropper, and placing a small amount of pond water on the center of the slide. If available, use a document camera. Ask the groups to create their own. Have designated student pick up tray of materials. Then have each student follow your directions.
5. Next instruct students to carefully add one tiny drop of glycerin to the pond water drop on the slide. This will slow the movement of microorganisms so that they are easier to observe.
6. Tell students to observe the slides with their eyes only. Ask, *What do you see in the drop of pond water?* Have the students draw on the graphic organizer under the "No Magnification" flap what they see in the entire drop. Drawing will vary, but some may be able to see small organisms like mosquito larva and other organisms.
7. Have the students place the slide under the microscope using 40X. Remind students that the power is the product of the objective lens times the eyepiece. In this case, the eyepiece is 10X and the objective is 4X, so the total power or magnification is $10 \times 4 = 40X$ magnification. Have students observe using the microscope and draw their observations on the **40X Magnification** flap.
8. Ask students, *If we magnify the pond water even more, what might we observe that we didn't see earlier?* Instruct students to use the 100X



magnification. Have students use color and draw with greater detail under the **100X Magnification** flap.

9. Next have students observe the pond water under 400X magnification and draw under on the **400X Magnification** flap.
10. As students examine all four drawings, discuss some of the similarities and differences among their drawings. The results should include that the greater the magnification the greater the detail that could be observed.

Wrapping Up

Have students share the types of organisms they observed. Have students compare their drawings to the cells of plants (onion and Elodea plant) they observed in the previous lesson. Point out the similarities such as the shape and structures in some of the microbes they see in the pond water to the plant cells. Ask, *Did some microbes seem similar to plants? Were others more animal-like and did some microbes not fit in either category?*

Extension

For more examples of pond life, visit the Microscopy-UK website at www.microscopy-uk.org.uk/.

The Pond Life ID Kit offers a table with pages linked to some common groups of small and microscopic pond life.

The Virtual Pond Dip presents information using graphic interface that is fun for beginners of any age.

4B. The Sizes of Microbes

Time Needed

Setup: 20 minutes
1 session

Before you start

Using the 12-point Arial/Helvetica font, type this line and repeat it 24 times.

“The period at the end of this sentence is larger than a/an _____.”

Print the page and cut the text into strips. Do not photocopy because it will reduce the sharpness of the text. Piece together butcher paper to make a square 2.5 meters across to represent the period enlarged 5,000 times. Place materials for each group on a tray.

You'll need this stuff

Per Class:

- Large paper, (2.5 m) square

Per Group:

- Set of 4 text strips
- 4 hand lenses
- 4 metric rulers marked in millimeters
- Scissors
- Assorted markers or colored pencils
- Meter stick
- Paper or science notebook
- Several sheets of colored or plain paper, or roll of chart or craft paper
- Tape or glue
- Microbe Scaling Chart student sheet

What It's About

Students will create scale models of microorganisms and compare the relative sizes of common bacteria, fungi and protozoa (microscopic members of the protist group) using metric measurements. Students will learn that microbes come in many different sizes and shapes, and frequently are measured in micrometers (μm). 1 meter = 1,000,000 micrometers.

What's the Question

How big are microbes?

What to Do?

1. Ask students to examine the period at the end of the text strips, first with eyes only and then with a hand lens. Tell students to draw in their lab books what the period looks like in each case. Discuss their observations. Ask, “*Did the period appear the same when it was magnified as when observed it with a naked eye?*” (When magnified, the period is a square.)
2. Ask, “*What can you say about the size of the period?*” Tell students the period is about 0.5 millimeters (mm), or 500 micrometers (μm), in length and width. Have students identify the centimeter and millimeter markings on a centimeter ruler. “*How many periods could be lined up, end-to-end, to equal a meter?*” (2,000)
3. At this point you may wish to review the metric system. Explain that the meter is the fundamental unit of length in the metric system. At 39.37 inches, a meter is slightly longer than a yard (36 inches). Ask, “*How many centimeters make a meter?*” (100) The prefix, “centi,” is Latin for one hundred. “*How many millimeters make a meter?*” (1,000) The prefix, “milli,” signifies one thousand. Thus, one centimeter (cm) is equivalent to 10 millimeters (mm).
4. Introduce students to an even smaller measure, the micrometer (μm), or micron, is one millionth (1×10^{-6}) of a meter. A micrometer is too small for to see without special equipment. One centimeter contains 10,000 micrometers. Ask “*What is the size of the period in micrometers?*” (500 μm) Ask, “*Why is the ruler not divided into micrometers?* (Markings would be too small).
5. Ask students, “*What do you know about scale*

models?" Ask, "Why do we make scale models?" (to understand the relative position, size or distance of objects such as road maps and solar system models)

6. Tell students that they are going to make a scale model of microbes, called a "Microbe Mural," using the size of the period as the scale standard. Ask, "If I increased the length and width of the period by 5,000 times, what shape would it have?" (square) "How large do you think it would be?" (Multiply 0.5 mm x 5,000. Answer: 2,500 mm x 2,500 mm, or 2.5 m x 2.5 m.)
7. Bring out the prepared square of paper (period model) and display it on the wall. Again, explain that the sheet represents the size of the period enlarged 5,000 times. Ask, If we enlarged most microbes 5,000 times, do you think they would be larger or smaller than the period? (If enlarged 5,000 times, each microbe models will fit on the period.)
8. Distribute the student sheets and microbe scaling charts. Instruct each student group to make scale drawings or artwork of all microbes, based on the line drawings and sizes provided on the chart. Depending on students' ages and experience, you may want to give them only the information from one or both of the "approximate actual size" columns, and have each group calculate the scale sizes of their organism models.

Note: Make certain every group is assigned at least one microbe large enough to draw (organisms 1–5). The microbe sizes described on the Microbe Scaling Chart represent typical measurements within the normal size range for each kind of organism. Students may find references to different sizes if they are conducting additional research about the organisms. In addition, some organisms named on the chart actually represent relatively large groups of related species or forms. For example, there are approximately 150 different known species of *Euglena*.

9. Have students place their models on the large paper square.
10. Discuss the mural with students. Ask students if they could use the names of the any of the microbes on the mural to complete the sentence on their sentence strips.

Wrap it Up

Ask where does your microbe live. Create poster drawings of a microbial landscape for a microbe you choose. For example: *Bacteroides thetaiotaomicron* in the intestines!

Extensions

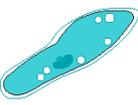
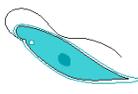
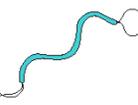
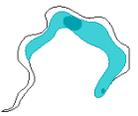
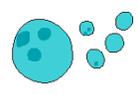
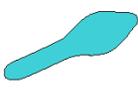
- It can be difficult to imagine the relative sizes of microbes. CELLS alive! has a useful animation to help students visualize and compare the sizes of different microbes on the head of a pin. The animation may be viewed or downloaded for single use or for use in a classroom:

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

- The word "meter" comes from the Greek word for "measure." The meter (m) is the standard unit of length in the International System of Units (SI). Below are definitions of SI units for length. Learn more about the metric system at the following National Institute of Standards and Technology.

website: <http://www.nist.gov/pml/wmd/metric/common-conversion.cfm>

Microbe Scaling Chart

Model Scale Size 0.5 cm = 1 μm		GROUP	ORGANISM	APPROXIMATE ACTUAL SIZE OF A SINGLE UNIT		MODEL SCALE SIZE
				Micrometers (μm)	Millimeters (mm)	Centimeters (cm)
	.		"Period" character - Helvetica type, 12-point size.	500	0.5	250
1		Protists	Amoeba - Group of single-celled organisms known for their constantly changing shape. Some cause human disease.	300	0.3	150
2		Protists	Paramecia - Group of slipper-shaped single-celled organisms that are a key link in freshwater food webs.	250	0.25	125
3		Protists	Euglena - Group of single-celled freshwater organisms that perform photosynthesis.	130	0.13	65
4		Bacteria	Spirillum - Bacteria with a twisted spiral shape. One species causes dental plaque.	60	0.06	30
5		Protists	Trypanosoma - Causes African trypanosomiasis, or "sleeping sickness," and is transmitted by a biting fly.	50	0.05	25
6		Fungi	Saccharomyces - Baker's yeast, a single-celled organism used to make bread rise.	10	0.01	5
7		Bacteria	Clostridium - One type of this bacteria can cause tetanus and another can cause food poisoning.	6	0.006	3
8		Fungi	Cryptococcus - Some members of this group of fungi can cause lung infections.	5	0.005	2.5
9		Bacteria	Bifidobacterium - Type of bacteria that is found in the intestines of many mammals and aids in digestion.	5	0.005	2.5

Actual size: 1 millimeter (mm) = 1,000 micrometers (μm). Drawings not to scale.
Micrometers also are referred to as "microns."

5. Bacteria, Fungi, Protists and Viruses

Time Needed

Setup: 1 session

Before you start

- Copy the *Microbe Groups* and *Microbe Examples* pages on cardstock. Cut out and make six sets of cards (4 large, 20 small cards per set). Place each card set in a re-sealable plastic bag (see Answer Key).
- Have students work in groups of four.

Optional: Change the enlargement setting on a photocopier to 129% and copy pages onto 11-in. x 17-in. paper.

You'll need this stuff

Per Class:

- 12 sheets of cardstock (to prepare cards)
- 6 re-sealable plastic bags

Per Group:

- Set of 4 *Microbe Groups* cards and 20 *Microbe Examples* cards

them to a kingdom or domain.

What's the Question?

What are some major groups of microbes? Are all microbes harmful or beneficial?

What to Do

1. Ask students, *What are some different kinds of microorganisms? Do microorganisms have different kinds of roles? What are some examples?* Discuss students' ideas. Tell students they will be looking at specific examples of materials and resources that involve microbes.

What It's About

Microbes live almost everywhere on Earth—including within and on other living organisms. They can be found in almost all climates, from extreme heat to freezing cold. Some microbes can make us sick, but only a very small percentage actually cause disease. In fact, many microbes—including most bacteria—are helpful. Much of the oxygen released into the atmosphere through photosynthesis comes from algae and blue-green bacteria. Many fungi and bacteria are essential for cycling nutrients in ecosystems and for acting as decomposers, breaking down dead organisms and the waste of living things.

We depend on microbes for food. What would a hamburger be without a bun, cheese and pickles (all of which are produced with direct assistance from microbes)? The cattle used for beef also rely on microbes to digest the tough grasses they eat. In our own intestines, microbes aid in digestion, make several essential vitamins and help prevent disease.

This activity focuses on the diverse array of microbes and the functions they perform. Three kingdoms within the five kingdoms system of classification are included here: Monera (bacteria), Protista and Fungi. The two kingdoms not considered to have single-celled, free-living individuals are plants (Plantae) and animals (Animalia). Many scientists now favor a three-domain classification system: Bacteria, Archaea and Eukarya.

Viruses represent a special case within the groups of microbes. They do not have all of the structures necessary for independent life. They must invade and use living cells to reproduce. For this reason, many biologists do not consider viruses to be "living" organisms, and do not assign

2. Give each student group one bag of cards. Have students remove the set of 20 smaller cards, which describe roles performed by certain microbes. Instruct student groups to read, discuss and decide the best way to sort the cards into categories. Have groups make notes about how they made their decisions. Then, have a spokes-person from each group explain its rationale for sorting and discuss as a class.
3. If students did not organize the cards by "role in food production," "role in causing disease," and "role in ecosystem/environment," have them sort the cards into these new categories.
4. Tell students that the cards also may be sorted by "kind of microbe" involved in each process. Instruct groups to take the four large cards ("Viruses," "Fungi," "Protists," "Bacteria") from the bag and read each card. Discuss the information and ask questions, such as, *Which microbe group does not have members with cells?* (viruses) *Which groups have multi-celled members?* (protists, fungi) Mention that all roles described on the small Microbe Examples cards are carried out by one or more members of the four groups that are described on the large cards.
5. Have students place their large Microbe Group cards on the table. Starting with the cards related to food production, have students use the clues on each small card to assign it to one or more Microbe Group cards. Students may notice that some roles are fulfilled by microbes belonging to more than one group (e.g., cacao seeds are fermented by bacteria and fungi).
6. Discuss as a class. Point out that microbes related to food production are found in either the bacteria or fungi group. Ask, *Are you surprised by this? What can we now say about microbes?* Explain that most microbes are not harmful, and many are helpful. But some microbes, called pathogens, cause diseases in humans, animals, plants and other organisms. Ask, *What do you know about disease?* Instruct groups to select the small cards related to disease and place each one by the appropriate Microbe Group card.
7. Ask students, *What are the differences and similarities between the microbes involved in food production and the microbes that cause disease? What general statement could we make about microbes?* (Microbes have many roles. Some are helpful; some are harmful.) *Is it possible for the same microbe to be both helpful and harmful to humans or to another organism?* (yes)
8. Repeat the sorting activity with the last group of small Microbe Examples cards: ecosystems. Discuss students' groupings. Mention that while microbes often are invisible members of ecosystems, they play important roles in decomposition and in soils, and are important members of food webs.
9. Ask, *Why should we care about microbes?* Discuss as a group. Have students add any new ideas to their concept maps.
10. Have students sort and place the cards back in the plastic bags.

Microbe Groups

MICROBE GROUP	MICROBE GROUP
<p>VIRUSES are the tiniest microbes. They must be magnified about 150,000 times to be seen. They are not considered cells, because they do not have a cell wall, cell membrane, or nucleus. They also cannot grow or reproduce on their own. Instead, they invade cells in living organisms and force these cells to produce more viruses. This invasion of healthy cells is how viruses cause disease. Antibiotics cannot destroy viruses.</p>	<p>FUNGI can be made of one or many cells. The main bodies of many-celled fungi are composed of tiny threads and may appear fuzzy (like bread mold) or almost solid (like mushrooms). Fungi do not have chlorophyll (green pigment). They are some of nature's recyclers. Fungi live by absorbing nutrients from other living things or from dead and decaying organisms. Each fungus cell has a defined nucleus, a cell membrane, and a cell wall made of different material than the cell walls of bacteria or plants. Yeasts, which are single-celled fungi, are able to break down food sources through a process called fermentation. Yeast cells must be magnified at least 100 times to be seen.</p>
MICROBE GROUP	MICROBE GROUP
<p>PROTISTS may consist of one or many cells. Some protists (such as paramecia) are microscopic, while others are macroscopic. Cells of all members of the protist group have a defined nucleus and a cell membrane. Some have cell walls. Protists vary greatly in how they obtain food. There are three main groups of protists.</p> <p>ALGAE - Plant-like; able to carry out photosynthesis.</p> <p>PROTOZOA - Animal-like; feed on prey or survive as parasites; always single-celled; sometimes motile (capable of movement).</p> <p>WATER AND SLIME MOLDS - Fungus-like; absorb food from the environment.</p>	<p>BACTERIA are made of only one cell and are much larger than viruses. Bacterial cells usually are shaped like rods, spheres or spirals. They have a cell membrane and usually a cell wall, but they do not have a defined cell nucleus. Some bacteria are motile (capable of movement). They are valuable as recyclers in ecosystems. Some bacteria can break down food sources through a process called fermentation. Others have chlorophyll and carry out photosynthesis. Bacterial infections can be treated with antibiotics, but some bacteria have become resistant to common types of antibiotics. Most bacteria must be magnified 1,000 times to be visible.</p>

Microbe Examples

<p>TUBERCULOSIS</p> <p>is a deadly, contagious disease transmitted through the air. It's also referred to as "TB." Not all antibiotics are effective against the microbe that causes TB.</p>	<p>RINGWORM</p> <p>is a circular, scaly or red rash caused by single-celled or thread-like microbes in the surface layers of skin (not a worm). Animals, people, or contaminated clothing can spread the rash, similar to athlete's foot.</p>	<p>YOGURT</p> <p>is milk or cream fermented by certain kinds of heat-loving microbes that are much smaller than yeast.</p>	<p>RED TIDE</p> <p>is an overgrowth of a microbe that produces a poison. The poison affects the nervous system of fish. The animal-like microbe lives in the ocean.</p>
<p>THRUSH</p> <p>is a disease that causes painful, whitish patches in the mouth and on the tongue. The microbe responsible for this infection is single-celled, has a defined nucleus and must be magnified about 100 times to be visible.</p>	<p>STOMACH ULCER</p> <p>is a sore in the lining of the stomach or small intestine that leads to burning pain. Ulcers usually are not caused by spicy food. Instead, most stomach ulcers are caused by an infection that can be treated with antibiotics.</p>	<p>CHOCOLATE</p> <p>comes from cacao seeds that are broken down and fermented by two kinds of microbes.</p>	<p>NITROGEN</p> <p>is introduced into the food chain by very tiny single-celled microbes that live in water and soil.</p>
<p>HIV</p> <p>is transmitted through the exchange of infected blood or other body fluids. It invades and kills one type of white blood cell needed to fight disease. Once people with HIV become unable to fight infections, they are said to have AIDS.</p>	<p>PEPPERONI SAUSAGE</p> <p>is made of chopped meat that is aged and fermented to improve the flavor. The microbes used to produce this sausage must be magnified around 1,000 times to be clearly visible.</p>	<p>COMPOST</p> <p>results from the breakdown of plant materials by microbes and other organisms, such as earthworms and insects.</p>	<p>MOSAIC DISEASE</p> <p>affects tomatoes, peppers and other food sources. It is caused by a tiny microbe that invades and destroys cells.</p>
<p>MALARIA</p> <p>is caused by a single-celled parasite with a complex life cycle. The animal-like parasite is carried from an infected person to a healthy person by certain kinds of mosquitoes.</p>	<p>SANDWICH BREAD</p> <p>is a baked mixture of ingredients, including flour, water and a single-celled microbe. When the microbe multiplies and releases bubbles of gas, it causes the bread to "rise."</p>	<p>GREEN POND WATER</p> <p>derives its color from tiny photosynthetic microorganisms that are not members of the Plant Kingdom.</p>	<p>PENICILLIN</p> <p>is an antibiotic that kills certain kinds of bacteria. It is a form of natural protection produced by a microbe that forms fuzzy clumps.</p>
<p>ANTHRAX</p> <p>is an infectious disease that spreads from animals to other animals and humans. Anthrax is caused by a single-celled microbe without a defined cell nucleus.</p>	<p>BEER</p> <p>is a mixture of barley, wheat, hops, and sugar that is fermented by a microbe. The microbe is quite large. It must be magnified about 100 times to be visible.</p>	<p>IRISH POTATO BLIGHT</p> <p>is a serious plant disease that killed most Irish potato crops between 1845 and 1851. It is caused by a fungus-like microbe that infected the leaves and stems of potato plants.</p>	<p>MEASLES</p> <p>is a disease spread by coughing, sneezing, or contact with people infected by a microbe that does not have a cell membrane or cell wall.</p>

The Variety and Roles of Microbes – Answer Key

ROLES: (D) = Disease; (E) = Ecosystem; (F) = Food Production

BACTERIA

Anthrax (D) is a disease of the blood that affects humans as well as animals such as cattle, deer and camels. *Bacillus anthracis*, the bacterium that causes anthrax, typically is found in soil. People can catch anthrax by handling products from infected animals or by coming in contact with the dormant (inactive) forms of the bacteria, called spores. Anthrax is treated with antibiotics.

Pepperoni Sausage (F) is a dried meat mixture that is fermented by lactic acid-producing bacteria. The process produces acids that contribute to the flavor.

Nitrogen (E) - Certain bacteria assimilate ("fix") nitrogen from the atmosphere into nitrogen-containing compounds that can be taken up by plants.

Stomach Ulcer (D) is a disease of the stomach and the first part of the small intestine that damages the protective lining of these organs. The most common cause is infection by a bacterium, *Helicobacter pylori*. Infections are treatable with antibiotics.

Tuberculosis (D) is a disease of the lungs caused by the bacterium, *Mycobacterium tuberculosis*. Some strains of the bacterium have developed resistance to the antibiotics once commonly used to treat tuberculosis.

Yogurt (F) is milk or cream fermented by one or more kinds of heat-loving bacteria.

FUNGI

Beer (F) is a mixture of barley, wheat, hops and sugar that is fermented by baker's yeast, a single-celled fungus known formally as *Saccharomyces cerevisiae*.

Penicillin (D) is a chemical substance produced by the fungus *Penicillium* that is toxic to many kinds of bacteria. It is the basis for many modern antibiotics.

Ringworm (D) is a contagious disease of the skin and scalp caused by several different kinds of fungi. Growth of the fungus on the skin often causes a circular, reddish, itchy rash. Ring-worm and related infections, such as athlete's foot, are treatable with antifungal lotions and creams.

Sandwich Bread (F) is a baked mixture of flour, water and baker's yeast that rises when the yeast cells begin to rapidly multiply and emit bubbles of carbon dioxide gas. A small amount of alcohol is produced, but evaporates during baking.

Thrush (D) is a disease of the tongue and mouth caused by a single-celled yeast, called *Candida albicans* (not the same as baker's yeast). Thrush is most common in infants or in adults with weakened immune systems. It may be treated with certain antifungal products.

PROTISTS

Irish Potato Blight (D) is a disease caused by a fungus-like protist which killed most Irish potato crops between 1845 and 1851. Since potatoes were the main food source for most of the population, this led to widespread famine. There were many social consequences of the Irish potato famine—including the immigration of more than one million Irish citizens to the United States.

Malaria (D) is a sometimes fatal, mosquito-borne disease caused by parasitic protozoans of the genus *Plasmodium*. The parasite invades and destroys red blood cells. Malaria is spread by certain mosquitoes that bite an infected person and then become infected themselves; these mosquitoes transmit the disease by biting other people. Worldwide, more than 350 million cases of malaria are reported each year.

Red Tide (D) is a rapid overgrowth of dinoflagellates, a type of protist found in marine plankton, which gives a reddish hue to water. Dinoflagellates produce a neuro-toxin (poison that affects the nervous system) that can be concentrated enough to kill fish.

VIRUSES

HIV/AIDS (D) is a disease caused by human immunodeficiency virus (HIV). This virus attacks a specific type of white blood cell (CD4+ T cells), thereby weakening the immune system and placing a person at greater risk for other infectious diseases and cancer. A person is considered to have Acquired Immunodeficiency Syndrome (AIDS) when the number of CD4+ T cells drops below a defined level, or when he or she develops an HIV-related illness. There is no cure for HIV/AIDS infection, which is fatal.

Measles (D) is a highly contagious disease caused by a virus. Typical symptoms include fever, cough, rash, and inflamed eyes. Persons who have had a case of active measles or who have received a measles vaccination have immunity (biological defenses) against the virus.

Mosaic Disease (D) is a crop disease caused by tobacco mosaic virus that affects tomatoes, peppers and other food sources.

BACTERIA & FUNGI

Chocolate (F) - Cacao seeds must be fermented by yeast (fungi) and bacteria in order for the complex flavors of chocolate to develop.

Compost (E) - Bacteria and fungi help to decompose leaves and other decaying organic materials found in compost piles. Some protists, such as slime molds, also may participate. Compost is used to enrich soil.

BACTERIA & PROTISTS

Green Pond Water (E) - When fresh water appears greenish, many forms of algae, protists, and blue-green bacteria (cyanobacteria) may be present.

6A. The Ghost Map

Time Needed:

1 session

Before You Start

Download the introductory PowerPoint® Presentation on the 1854 London epidemic from BioEdOnline.org. Make copies of the four quadrant maps of the London Soho district and copies of the coordinate codes for each team.

You'll Need This Stuff

Part 1

Per Group:

- Four-part London Soho district map copies
- Victim list copies
- Overhead projector transparency sheets for printers
- Clear tape
- Scissors

Part 2

Per Student:

- Information on Dr. Snow copies

What It's About

The 1854 London cholera epidemic helped establish the branch of medical science called epidemiology and built the foundation for modern public health and hygiene. Epidemiologists track the patterns of health and illness in relation to the population. The Greek physician Hippocrates is thought to have been the first to investigate the occurrence of disease in relation to environment. Dr. John Snow, of London, England, used this approach to track a cholera outbreak to a single public water pump contaminated with infected human waste.

In this activity, students will use Dr. Snow's data to create a map (Ghost Map) of the London Soho district where the first victims fell on August 31, 1854. The data has been recast into a geographic grid to make plotting victims easier. The two previous activities (*Population Density and Disease* and *Spreading Infectious Disease*) have prepared the students to understand relationship between dense populations and the spread of disease.

What's the Question?

"Epidemic" is the name given to any disease that strikes a given population at an occurrence rate greater is normally expected. For example, a few cases of flu, across a large city, are not uncommon and not much cause for concern. However, hundreds or thousands of cases of flu appearing in a short time and close together is cause for concern – an epidemic. The 1854 cholera epidemic in London, England struck hundreds of people in a small area in a frighteningly short time. Using epidemiology techniques, Dr. John Snow determined the source of the epidemic and suggested a microbe origin (though not the particular microbe responsible).

How did Dr. Snow determine the source of the 1854 London cholera epidemic?

What to Do

1. Introduce the 1854 London cholera epidemic with the Cholera Unit Introduction PowerPoint presentation. Download this presentation from <http://goo.gl/CE0zh7>.
2. Read aloud the story *Summer of Death*. Talk about what it must have been like to live in Soho in 1854. Remind students about their classroom maps and short stories they created in the

Population Density and Disease activity. Compare their made-up stories with what it was really like to live in Soho London in 1854.

3. Divide the students into teams of 4. Give each team the four quadrant maps that, when combined, make up the complete map of the London Soho district. Also give each team copies of the victim list with coordinates. Have teams divide up the quadrants between themselves and work on two at a time. Tip: Plotting is easiest if one team member reads the coordinates and another does the map plotting. After finishing one quadrant, reverse reading and plotting roles on the next quadrant.
4. Demonstrate how to plot victims on the map. Instructions on how to do this are included with the victim list. When teams locate the appropriate square for a particular location, the number of victims is written on the map. The numbers should be written over the gray-shaded blocks and not the white streets. Relate the plotting grid on the Soho maps to how cities and towns are located with grid coordinates on standard state highway maps.

Tip: If your students are unfamiliar with highway maps, bring a few maps and have students explore them. Point out the grid system. Challenge students to find out of the way towns by giving them only the grid coordinates.
5. Tell student teams that each quadrant map covers only some of the victims of the epidemic. They will have to search the entire coordinate list to find those that fall on a particular coordinate.
6. When teams complete their victim maps, trim the maps with a scissors along the dashed lines. Carefully align the four quadrants to match up streets and hold them together with transparent tape.
7. Provide teams with the polar chart and map scale printed on overhead projector transparencies. Copy the chart and scale with a printer or make tracings of the polar chart with a fine point permanent marker on write-on transparencies.
8. Have teams slide the polar chart over the map and try to encircle as many of the victims as possible within the 500-yard circle on the chart. When done properly, the center of the polar chart will lie close to the intersection of Broad and Cambridge streets. Students may ask what the black dots that appear across the map are. The dots represent the location of public water pumps that raise water from the underground water distribution pipes. The water in the pipes is drawn from the Thames River that winds through London.
9. Ask students to speculate on what the source of the cholera infection might be. Where or how did the Soho residents catch the disease? List ideas on a board. Also list information that will be needed to determine the answer. The dossier on cholera will provide valuable clues towards answering this question.

Wrap It Up

Read aloud the “Dr. John Snow” article to your students or make copies for them to read and discuss.

Extensions

Challenge students to find pictures of the Broad Street Pump on Google Earth. Google Earth features detailed maps of the world and street views from their roaming cameras. Street view pictures of the Broad Street Pump show what the pump and the surrounding buildings and streets look like today. Use the search function to travel around the Google Earth site. Let students find out for themselves that the name of Broad Street in London has been changed to Broadwick Street.

Google Earth can be downloaded from the following site: earth.google.com

Summer of Death

The Soho district in nineteenth century London, like many other London districts, was a mass of tightly packed humanity. Cobble stone streets were crowded on either side with dingy, smoke-stained shops, wood and brick apartment buildings, cow sheds, pigsties, slaughterhouses, and grease-boiling dens. Narrow alleys intersected the main streets and opened to hidden courtyards providing access to still more apartments, sheds, and animal pens. Sooty air hung over the district. The air was filled with smoke mingled with the smells of human and animal wastes, decaying animal carcasses, and rendered grease (grease left over from animal processing that is boiled and used in soap and candle making). At the end of August in 1854, the conditions were ripe for a medical disaster.

There were few public services in the district. Drinking water was drawn from the Thames River and distributed by a system of pipes running beneath the streets. At scattered locations, water lines were tapped with hand pumps that all citizens shared. Running next to and over and under the water lines were other pipes for sewage. Many of these pipes were old and cracked or broken. The pipes were generally overwhelmed by the quantity of waste attempting to run through them. What waste that did make it through, poured directly into the Thames River, in some cases up stream from the water intake pipes. On every street human and animal waste ran freely along the curbs.

A typical Soho district apartment consisted of a single room in which one or more families lived. Children, parents, aunts, uncles, and grandparents shared the cramped spaces. Furniture was sparse. Cooking and heating was done with wood, coal, or charcoal in a fireplace or grill. The air was always smoky. Food had to be eaten quickly. There wasn't any refrigeration and leftovers soon became rancid, adding to the smells. Washing was done in tubs with water carried in from the pumps. Wastewater was dumped back on to the streets.

Beneath warped boards in the cellars of most building were cesspits that served as toilets. A typical cesspit was circular, brick-lined hole about 6 feet across and 10 feet deep. Urine and fecal matter collected there until overflowing. Many cesspits had never been emptied since they were first dug. The smell was terrible.

In 1831, a new disease had struck the citizens of London. The disease was named Asiatic cholera because the disease originated in the Ganges delta of the Indian subcontinent (India). Today, we just call the disease cholera. Since ancient times, cholera ravaged the Indian population. Gradually, cholera spread along land and sea trade routes and it was believed that it was brought to London was by one or more infected merchant ship crews.

The symptoms of cholera were as swift as they were horrifying. Victims were quickly debilitated with fast-acting and profuse diarrhea and vomiting. This led to dehydration and imbalances of the electrolytes that control nerve and muscle function. The loss of body fluids caused victims to have sunken eyes and wrinkled hands. Untreated, death usually resulted a day or two later and sometimes within hours.

Between 1831 and 1854, four outbreaks of cholera raged across the densest parts of London and left tens of thousands of people dead. At the time, most medical authorities believed cholera was due to a "miasma in the atmosphere" or bad air. Certainly, the air was putrid but the disease, when it struck, seemed to be confined to the warmer months only. The air in many London districts was bad all year round.

August 31, 1854

The summer of 1854 began uneventfully for the residents of the crowded London Soho district. But everything changed on the night of August 31. Cholera struck again. Over the next three days, 127 people, men, women, and children died. Virtually every family, living near the intersection of Broad Street and Cambridge Street, lost one or more members. Some families were completely wiped out.

The Soho incident was part of a larger outbreak that claimed hundreds of lives but the swiftness and intensity of the Soho outbreak was especially terrifying. Within just a week, nearly three-quarters of the surviving Soho residents fled to other parts of London and to the countryside. Soho became an instant ghost town.

Cholera was killing people but what was cholera and how was it spread? No one knew but a London physician, Dr. John Snow had his suspicions. He set out to prove his ideas. His first step was find out who got sick and where.

What Did Dr. John Snow Do?

Dr. John Snow compiled lists of the cholera epidemic victims according to their addresses and marked their numbers on a map. Dr. Snow drew small dashes on his map to indicate individual victims. In doing so, he made an important observation. Virtually all of the initial victims lived within 250 yards of the public water pump on Broad Street. During his investigation of earlier cholera outbreaks, he had begun to suspect that the cholera was related to drinking water. The prevailing hypothesis of the time was that cholera was spread by bad air. Dr. Snow disagreed. Plotting the map of Soho would provide him with the data he needed to confirm his ideas.

Although the Soho map showed a convincing case for cholera being a water-borne infection, there were a few problems. Not all of his data fit the pattern. There were additional victims far removed from the Broad Street pump. How did they get the disease? Dr. Snow decided to find out.

What Dr. Snow Found Out

- Most of the 1854 Soho outbreak deaths occurred within about 250 yards of the intersection of Broad and Cambridge streets.
- The death rate in the Soho district topped 12.8% of the population (double the death rate for cholera in other areas of London at the time).
- A widow living in Hampstead, about three miles the center of Soho, was stricken and died from cholera on September 2nd. Her niece, who lived in Islington, two miles northeast of the center of Soho, died the following day. Dr. Snow was troubled by these two deaths. Their distance from the center of Soho seemed to contradict his ideas about the cause of the epidemic. Dr. Snow visited the widow's home and talked to her son. The son said his mother once lived near Broad Street and liked the taste of the water from the Broad Street pump. She sent a servant with a cart to bring back a large bottle of the water from the pump every day. The widow's niece had visited his mother and had drunk from the bottle that had been fetched on August 31, the first day of the outbreak.
- Five hundred and thirty people lived in the Poland Street workhouse just around the corner from the Broad Street and Cambridge Intersection. Only five of the inmates contracted cholera. Snow observed that the workhouse building had its own water well and most inmates drank from that well.
- None of the 70 workers at the Broad Street brewery contracted cholera. The brewery gave all of its workers an allowance of free beer every day and, consequently, the workers never drank the local water.
- An army officer living in St. John's Wood, about two miles from the Broad Street and Cambridge Street intersection, died from cholera. The night before, he had dinner on Wardour Street, not far from the intersection. During dinner, he drank a glass of water from the Broad Street well.
- Dr. Snow examined water samples from local pumps. Under a microscope, water from the Broad Street well revealed "white flocculent particles." Flocculent particles resemble bits of fluffy wool fibers. While Snow could see the particles, he could not tell what they were. He believed the particles were the source of the disease.

- Dr. Snow learned that in late August a child had taken ill with cholera symptoms. The child's nappies (English term for diapers) had been rinsed in water. The dirty water was dumped into a leaky cesspool located only 3 feet from the Broad Street water pump. The widespread cholera outbreak followed shortly after.

Tip: When going through the bullet points above, place a complete Soho map on the board and mark the location of these incidents. Add labels to the outside of the map and connect them to the locations with lines or strings. The map will resemble the crime maps often portrayed in police detective TV shows.

What Dr. Snow Concluded

Without question, Dr. John Snow concluded that the source of the 1854 cholera outbreak in Soho was due to contaminated water from the Broad Street pump. Cholera microbes had seeped into the water lines from the nearby cesspit and the outbreak began. Dr. Snow's conclusions led to the removal of the pump handle so that no more water could be drawn at that location.

By the end of September 1854, the cholera epidemic had subsided. The Soho death toll stood at 616 residents. It is likely that the epidemic would have subsided on its own without the removal of the pump handle, Dr. Snow's conclusions had a major impact on medical thinking. He helped establish epidemiology as a respected branch of medical research. He also helped establish the relationship between good sanitation and health.

Because of the work Dr. John Snow and many others, cholera is now a very rare infection in developed countries such as the United States. Unfortunately, the cholera microbes are still present in the environment. Recent outbreaks include the country of Haiti that was struck with a devastating earthquake in 2010. The quake wrecked havoc on the country's already minimal sanitation systems. Clean water became difficult to find and cholera followed.



Broad Street Pump, Wanzie Grace

TOP SECRET

Dr. John Snow

John Snow was born in York, England in the year 1813. He was the first child in a family of nine children. His father was a laborer at a coal yard. John spent many of his early years in school and, at age 14, left his home to become a medical apprentice. A medical apprentice was generally a teenage boy who became an assistant to a practicing doctor. The apprentice learned medicine through practical experience by assisting in treating patients, cleaning and other duties. Eventually, John Snow apprenticed with three different doctors across Yorkshire.

When John Snow was 18, the first Asiatic cholera epidemic struck in parts of England. He developed a fascination with the disease and solving the mystery of its cause became a life-long mission.

In 1844, John Snow earned his doctor of medicine degree and became a very successful physician in London. One of his specialties was anesthesiology (the use of chemicals to reduce pain during surgery). He developed a device to improve the delivery ether gas to patients. After assisting in the delivery of a baby for Queen Victoria, Dr. Snow's fame spread across England.

Following the second cholera epidemic in 1848-1849, Dr. Snow and others founded the London Epidemiological Society. Epidemiology is the study of patterns of health and illness. It is an evidence-based practice that seeks to identify diseases and their treatments by collecting data across segments of the population. In other words, who got sick, when did the sickness strike, what do all the victims share in common with each other, and other such questions.

Eventually, Dr. Snow formed a hypothesis about the cause of the cholera but he needed data to confirm or reject his hypothesis. As the Soho death toll mounted, Dr. Snow gathered data. He became more and more confident that he was on the right track. If he were right, cholera could be stopped.



Wikimedia Commons, Public Domain.

TOP SECRET

Dossier: Cholera

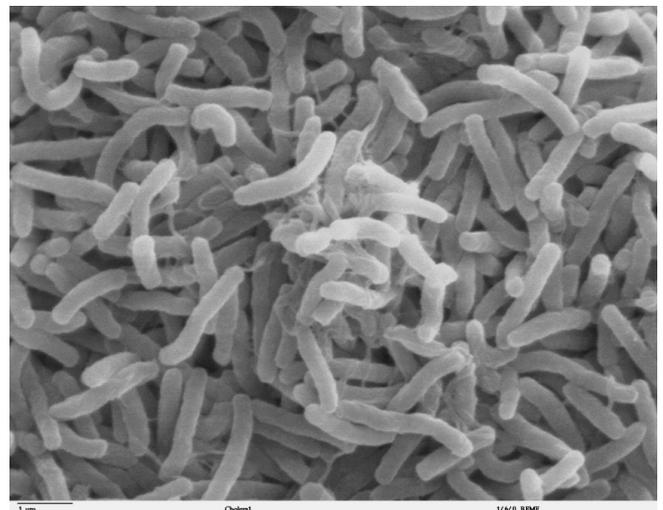
Cholera is an infection of the small intestine by the *Vibrio cholerae* bacterium. The bacterium responsible for cholera was isolated in 1855 by Italian scientist Filippo Pacini but his results were generally not known. Thirty years later, Prussian physician Robert Koch identified the bacterium responsible for cholera.

Transmission or the spread of cholera is primarily accomplished by consuming water or food contaminated by the bacteria. Once infected, a victim experiences rapid diarrhea and vomiting that leads to dehydration (excessive loss of body water) and electrolyte (various salts critical to conducting electric impulses in body cells) imbalances. Untreated, death can result within hours. With poor sanitation, waste from victims further contaminates water and food supplies and the bacterium are passed on.

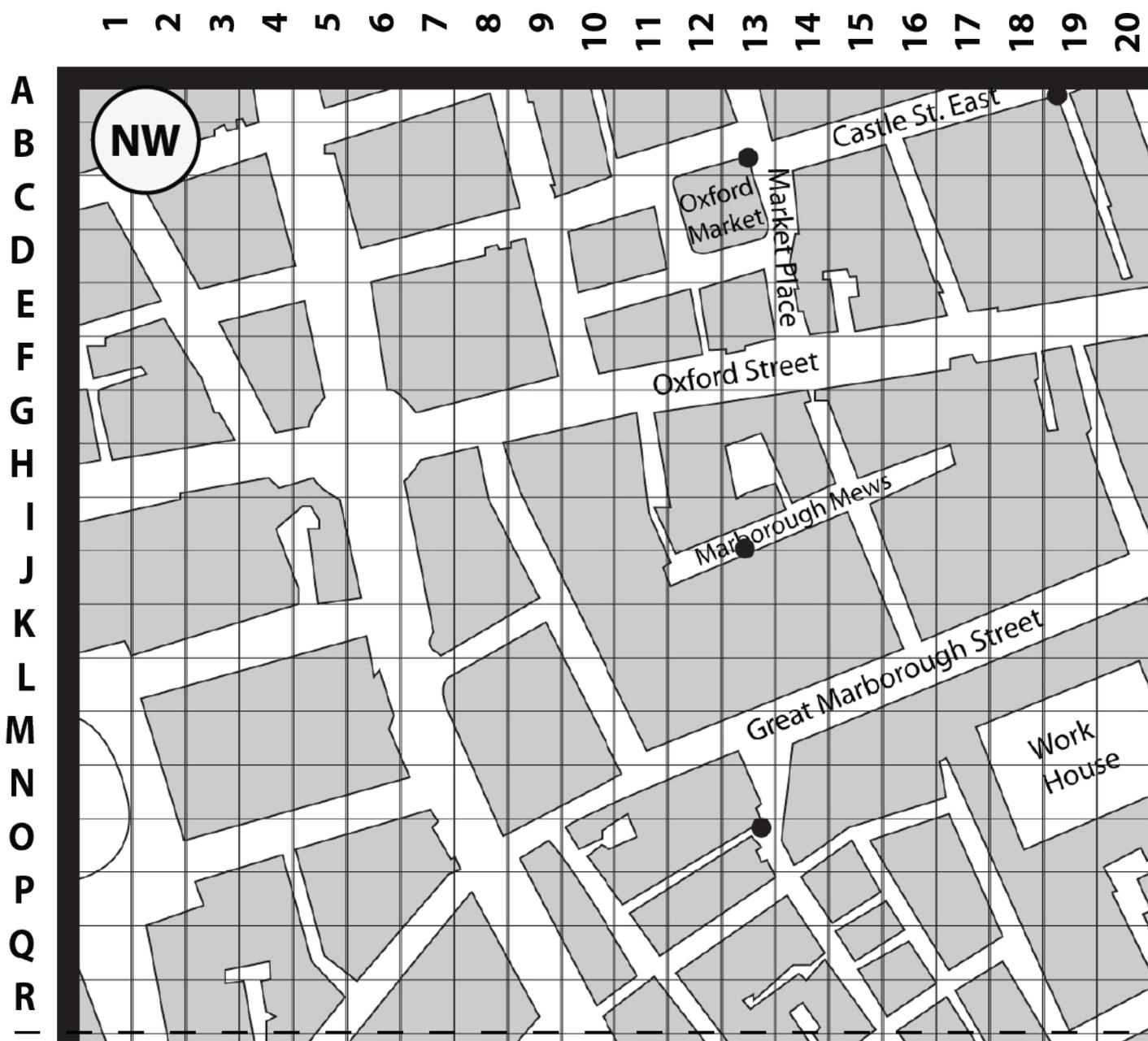
Cholera originated in India and was once referred to as “Asiatic Cholera.” Slowly, the disease traveled to other nations through shipboard and overland trade routes. Cholera arrived in England in 1831. The 1854 epidemic was one of several that struck England, killing tens of thousands of people. The epidemic traveled through Europe and to North America. Though striking heavily in poor area where sanitation was questionable, not all victims were poor. American president James K. Polk died from cholera as did Charles X, king of France. Recently, a cholera epidemic struck the nation of Haiti following the devastating 2010 Earthquake. Worldwide, between 3 and 5 million cases of cholera occur annually and 100,000 deaths occur, mostly in countries where finding clean water is a challenge. Cholera is treatable but treatment must begin quickly to be effective.

Treatment

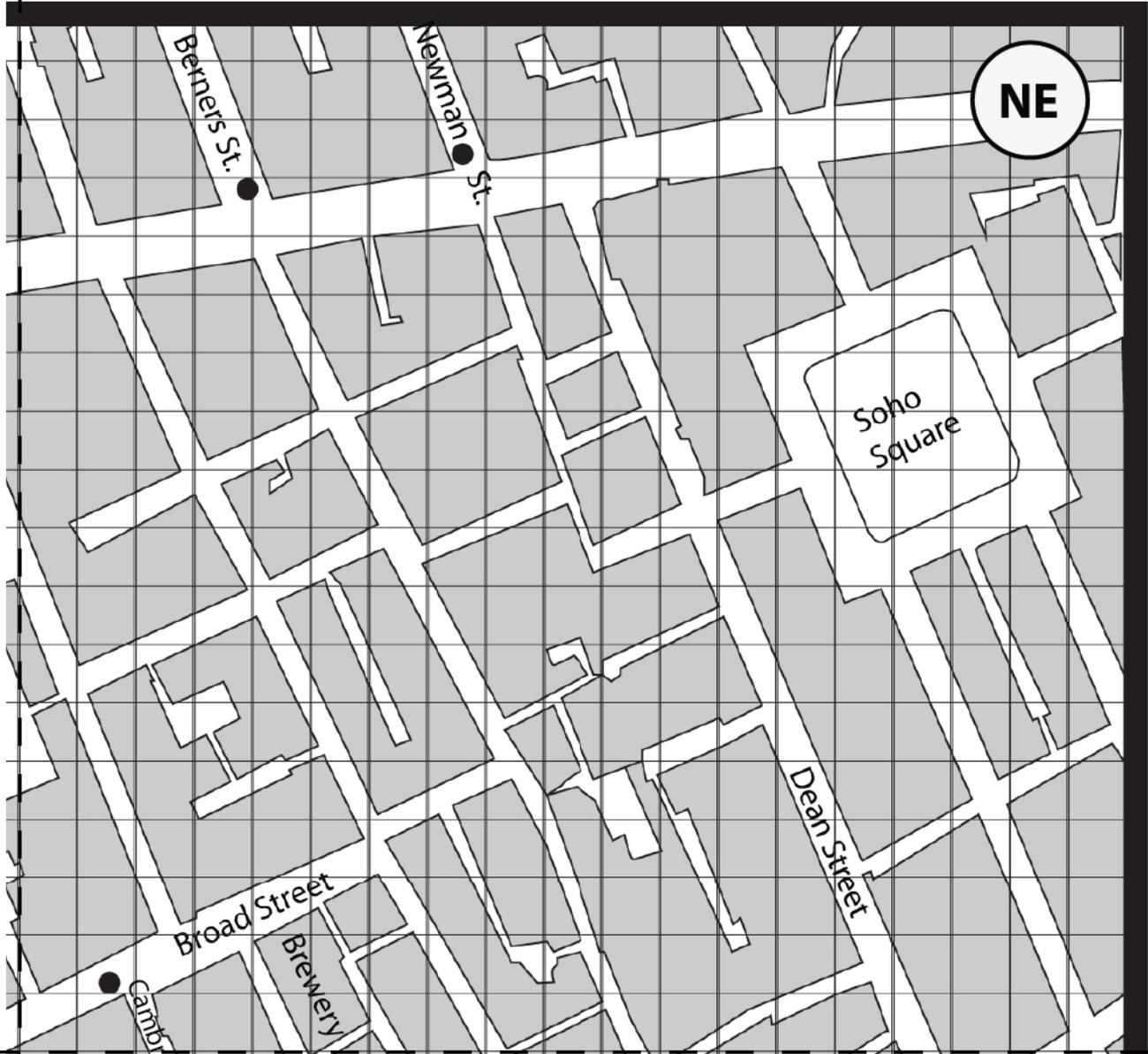
The goal of cholera treatment is to replace lost body fluids and electrolytes as quickly as possible. A simple rehydration (replacing body water) solution, called ORS for Oral Rehydration Salts, starts as a powder that is dissolved in a bottle of water. The victim drinks the solution.



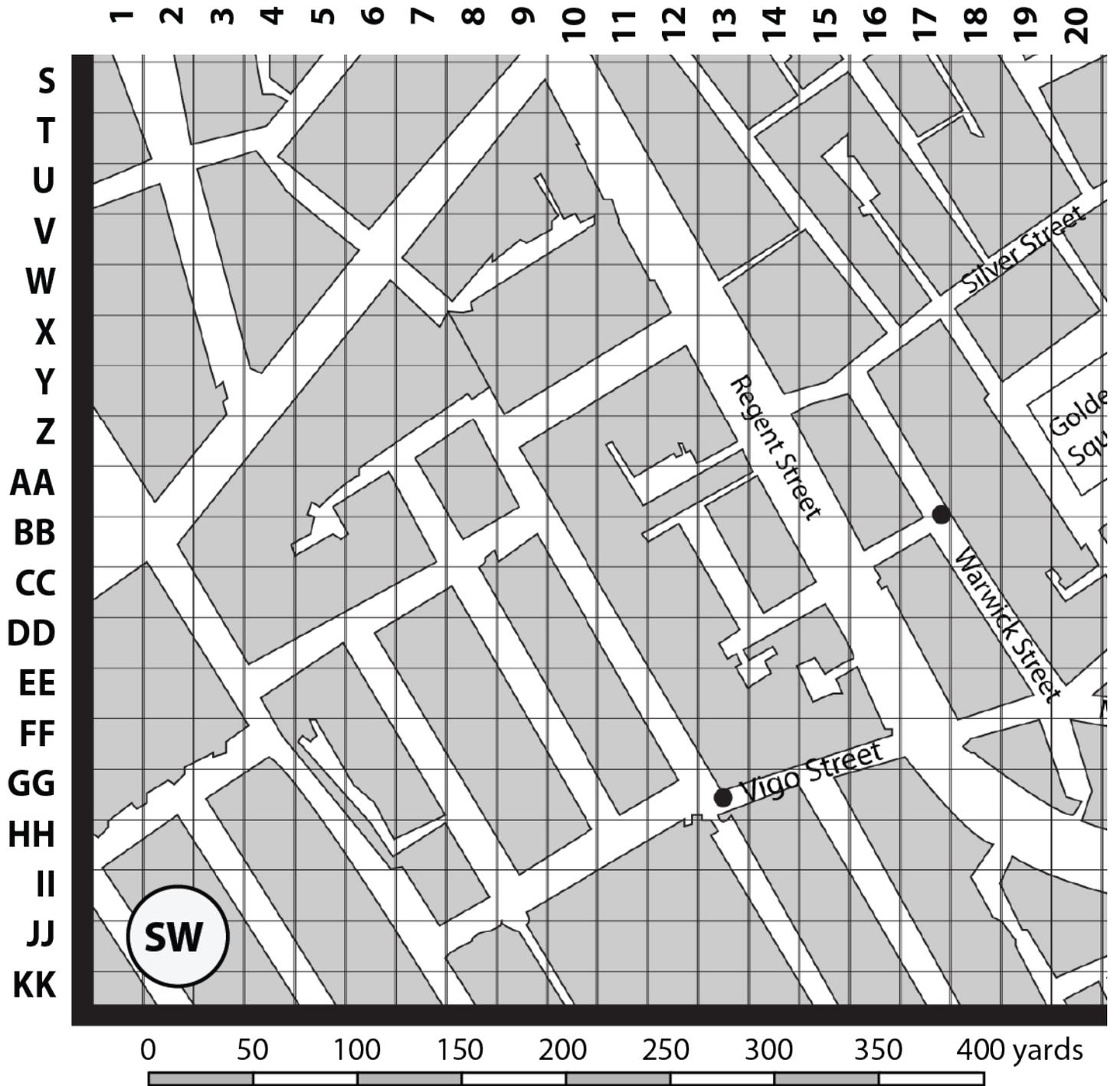
Dartmouth Electron Microscope Facility,
Public Domain

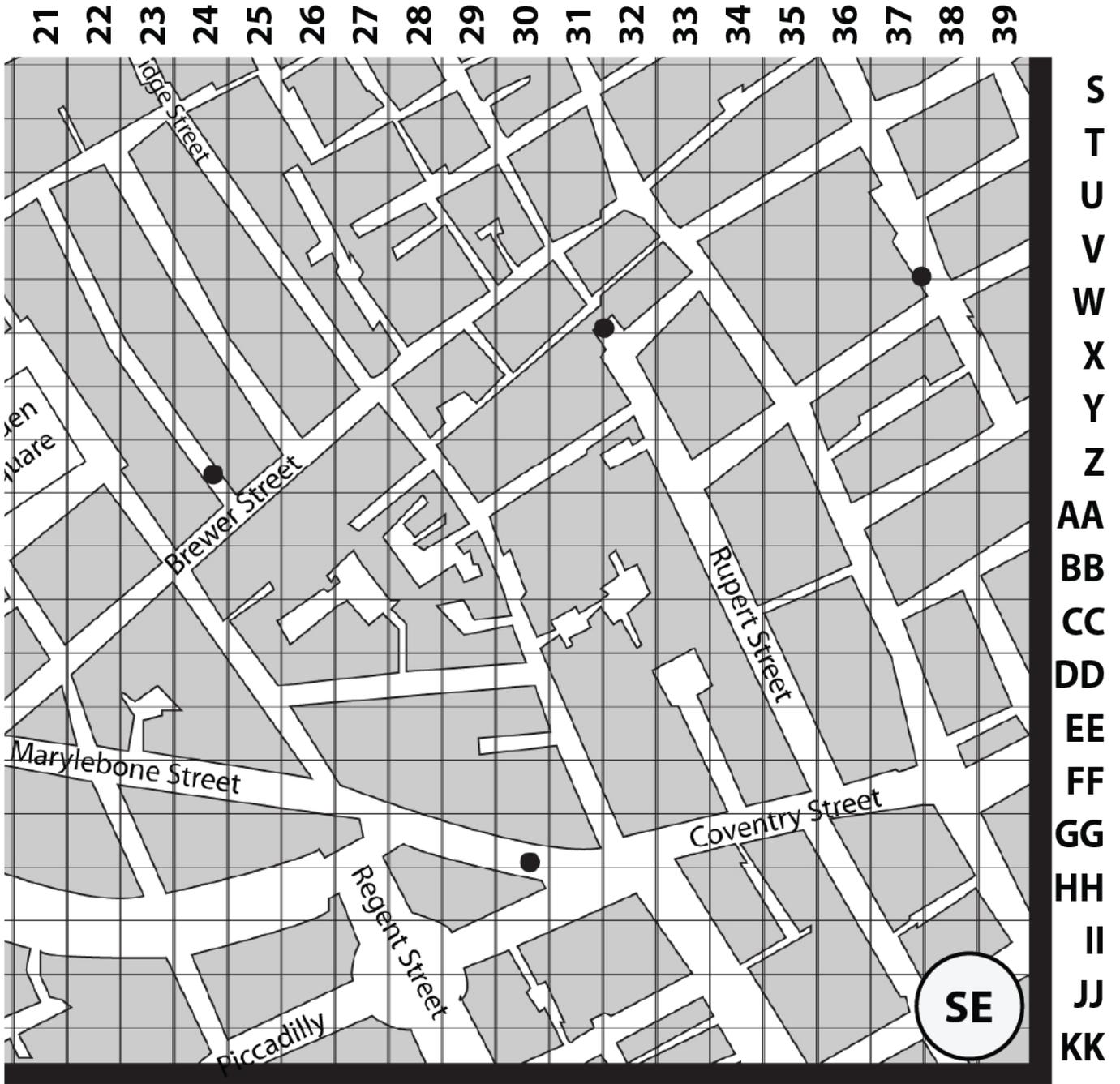


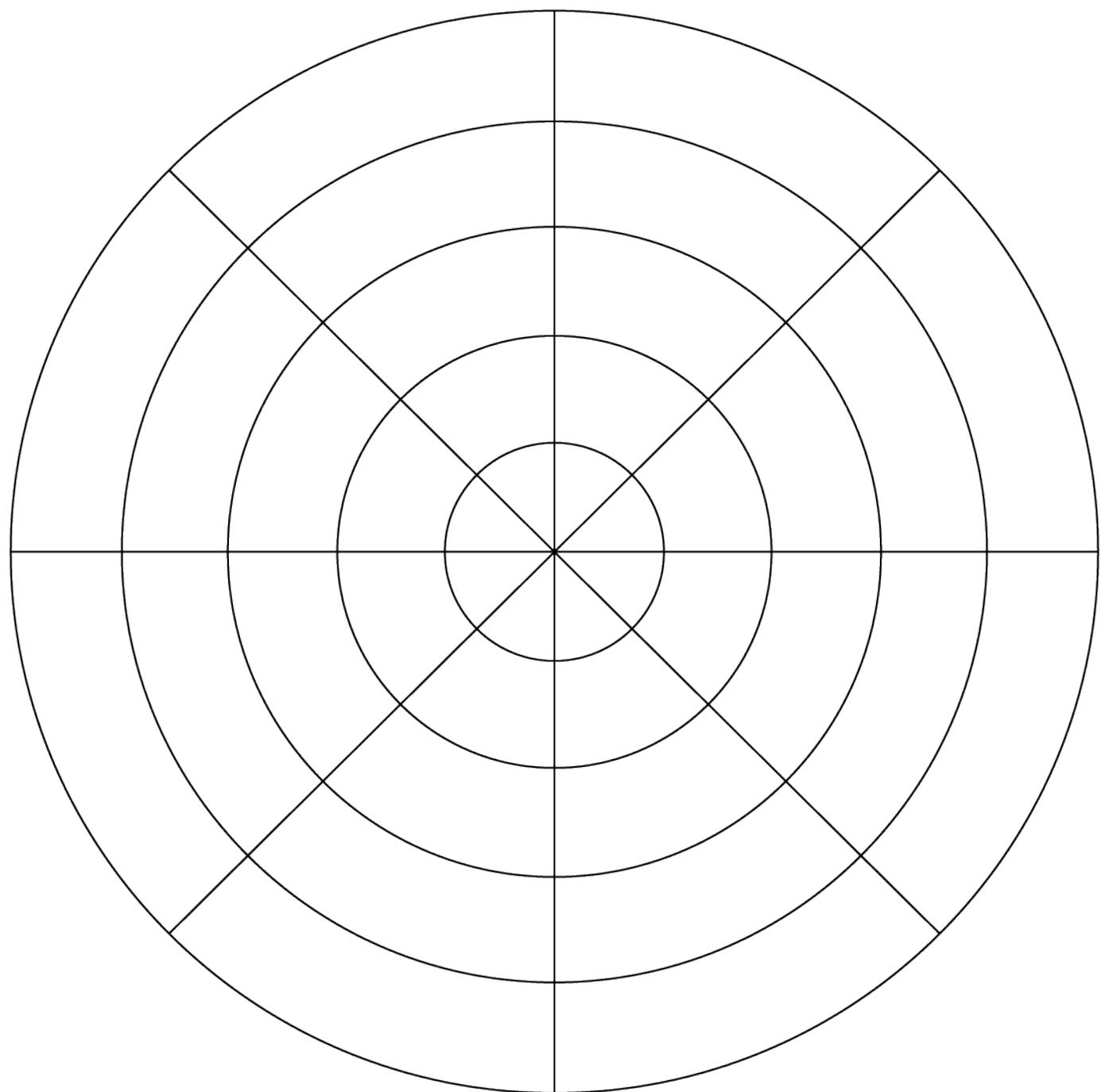
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1854 Soho Cholera Deaths Coordinates

Instructions

Each code on this list provides two pieces of information. The letters and first numbers tell the location of cholera deaths in the 1854 London Soho epidemic. The second number (after the dash) tells how many victims lived at each location. Use these codes to plot the location and number of victims across Soho.

The Soho district map has been divided into four quadrants so that four teams can work together to rapidly plot all the cholera victims. As in all epidemics, determining where the disease started and how it spreads is key to establishing a treatment program. The sooner the better.

How to Plot Location

The letters and first number refer to a grid on the map quadrant provided to your team.

Look at the letters and numbers along two sides of your quadrant map. Next, look at the code table and find a code that falls on your quadrant. For example, if you have quadrant SW (southwest), code AA12-1 falls on your map.

Locate the AA row and start on the left. Slide your finger to the right until you reach column 12. This is the code location.

Plot the Victims

According to the AA12-1 code, one person fell victim to cholera at that location. Write in the number 1 in that square. Do the same for all the other codes that apply to your map. Find the location and write in the victim numbers.

AA12-1	K32-6	O16-4	Q20-1	S23-3	U24-4
BB12-3	L21-1	O18-2	Q21-5	S24-7	U25-2
BB29-2	L23-1	O20-3	Q24-8	S25-7	U29-1
BB34-1	L24-2	O22-2	Q26-1	S27-5	U31-1
CC35-1	L25-3	O24-12	Q27-5	S29-11	V18-6
DD14-1	L26-2	O25-7	Q28-5	S30-1	V19-2
E29-2	L28-1	O26-5	Q29-1	S32-2	V20-2
F27-1	L31-3	O27-1	R14-2	S34-2	V23-2
G19-1	L32-2	O29-2	R17-8	T14-2	V24-2
G23-1	M20-5	O30-6	R18-2	T15-3	V25-1
H26-1	M21-3	P14-1	R19-5	T19-1	V27-1
H27-1	M22-4	P15-4	R20-2	T20-5	W16-1
I13-1	M25-3	P16-1	R21-23	T21-3	W20-1
I21-1	M26-3	P17-3	R22-13	T22-4	W22-1
I25-1	M28-1	P18-4	R23-4	T23-6	W24-2
J18-3	M29-4	P19-2	R25-3	T24-1	W26-1
J19-2	M30-1	P22-4	R26-2	T25-1	W30-2
J21-2	N14-4	P23-4	R27-2	T26-9	X18-1
J22-3	N17-2	P24-6	R29-3	T31-1	X19-2
J23-1	N22-1	P27-2	R30-1	T34-2	X25-3
J24-1	N23-2	P28-1	R32-2	T35-1	X26-1
J28-1	N24-3	P30-6	S13-1	U17-1	X27-2
K22-3	N25-2	Q12-1	S15-4	U18-1	X31-1
K23-3	N26-8	Q13-4	S16-1	U19-4	Y32-1
K24-1	N27-2	Q15-2	S17-7	U20-2	Z23-4
K25-1	N28-1	Q17-4	S18-5	U21-2	
K27-1	N29-1	Q18-5	S19-6	U22-2	
K31-7	N30-1	Q19-1	S20-9	U23-1	

PowerPoint Presentation Script for The Ghost Map Activity

- Slide 1 The Ghost Map
- Slide 2 By the mid nineteenth century, London became the world's largest city. It was the capital of the British Empire and the world center for trade, money, and power.
- By 1854, two and a half million Londoners lived within 9 miles of each other. London was a busy, crowded city packed with homes, businesses, and industries. Crisscrossing London were railroads, streets, and bridges.
- Travel in the city was accomplished by walking, on horse-drawn vehicles, and by train. Coal fuel fueled the industry and homes of London, making the air foggy and sooty
- Slide 3 There were really two Londons – London for the rich and London for the poor.
- The rich lived in fine homes tended by small armies of servants. Life was safe and good.
- The poor, millions of them, lived in overcrowded and unsanitary slums. For them, life was dangerous and always a struggle.
- Slide 4 As the month of August 1854 drew to a close, and old fear made itself known again. It began in the Soho District in the heart of London.
- Slide 5 The Soho District was a quarter square mile tract of London where more than 10,000 people lived in poverty.
- Its many narrow streets were covered with cobblestones, making walking difficult. On either side of the streets were dingy, smoke-stained shops, wood and brick apartment buildings, cowsheds, pig-stys, and slaughterhouses.
- (FYI: Cobble stones are rounded stones set into the street. The bumps in the stones helped horses find traction as they clopped along with carriages or wagons in tow.)
- Slide 6 Narrow alleys intersected the main Soho streets and opened to hidden courtyards where there were still more apartments, sheds, and animal pens stuffed into every space possible.
- The air was filled with smoke mingled with the smells of human and animal wastes and rendered grease.
- (FYI: Rendered grease comes from animal scraps that are boiled down into fat for making lard for cooking and tallow for candle making.)

- Slide 7 There were few public services in the district. Drinking water was drawn from the Thames River and distributed by a system of pipes running beneath the streets. At scattered locations, water lines were tapped with hand pumps that all citizens shared. Running next to the water lines were other pipes for sewage. Many of these pipes were cracked or broken and waste flowed out on to the streets.
- What waste water that made it through the sewer lines poured directly into the Thames River, in some cases up stream from the drinking water intake pipes. On every street, human and animal waste ran freely along the curbs.
- Slide 8 A typical home consisted of a single room in which one or more families lived. Cooking and heating was done with wood or coal in a fireplace or grill. The air was smoky. Windows provided light during the day and candles were used at night.
- Food had to be eaten quickly because leftovers soon became rancid. Washing was done in tubs with water carried in from the pumps. Wastewater was dumped back on to the streets.
- Beneath warped boards in the cellars were cesspits that served as toilets. Cesspits were circular, brick-lined holes about 6 feet across and 10 feet deep. Urine and fecal matter collected there until overflowing. The smell was terrible.
- Slide 9 The night of August 31, the Asiatic Cholera returned. It was called Asiatic because the disease originated in the Ganges delta of the Indian subcontinent (India).
- Since ancient times, cholera ravaged the Indian population. Gradually, cholera spread along land and sea trade routes. It was believed that cholera was brought to London by one or more infected merchant ship crews.
- The return of the disease to London, the fourth time since 1831, made the headlines of all the newspapers. Panic ensued.
- Slide 10 (Read the newspaper story on the screen.)
- Slide 11 The symptoms of cholera were as swift as they were horrifying. Victims were quickly debilitated with fast-acting and profuse diarrhea and vomiting. This led to dehydration and imbalances of the electrolytes that control nerve and muscle function.
- The loss of body fluids caused victims to have sunken eyes and wrinkled hands. Death usually resulted a day or two later and sometimes within hours. (FYI: Electrolytes are chemicals that can conduct electricity. They are important for many body functions. After exercising, athletes may drink solutions containing electrolytes to replenish body supplies.)

- Slide 12 The Soho cholera outbreak was part of a larger epidemic across London that claimed hundreds of lives. But the swiftness of the Soho outbreak was terrifying. Over three days, 127 people – men, women, and children – died. Entire families were wiped out. Soho became an instant ghost town as residents fled the area.
- Slide 13 Cholera was killing people but what was cholera and how was it spread? No one knew but a London physician, Dr. John Snow, had his suspicions.
- Dr. Snow was born in 1813. At age 14, he became an apprentice to a surgeon and began his study of medicine. Years later, Dr. Snow became an expert in the use of anesthetics during childbirth. He helped deliver Queen Victoria's last two children and became famous for doing so.
- (FYI: Anesthetics are drugs or gases administered to patients to prevent pain during surgery.)
- Slide 14 This is a map of the Soho District of London. It covers an area of approximately one-quarter square mile. Shown on the map are streets (white), clusters of buildings (gray), and public water pumps (black dots).
- Dr. Snow collected data on the cholera deaths. He plotted the numbers of deaths by the locations where the people died. The distribution of the deaths provides what Dr. Snow thought were valuable clues as to the probable cause of the cholera epidemic.
- Slide 15 Our task will be to recreate Dr. Snow's work. We will construct our own maps and see if any patterns appear. If there are patterns, they will go a long way to confirming Dr. Snow's ideas about the cause of cholera.
- Slide 16 We will organize into four survey teams. The Soho map has been divided into four parts. Your team will receive one-quarter of the map. You will also receive a table of coordinates for all of the Soho deaths.
- Team Tasks
1. You will identify the coordinates on the table that fall on your team's map.
 2. You will write the number of deaths that occurred in the coordinate squares on your map.
 3. When finished plotting deaths, the four map quarters will be reunited to make the complete Soho map
- Slide 17 (Read the text on the slide.)
- Slide 18 End of Part One
- Slides 19-24 (Read the text on the slides.)