Title of the Lesson Plan: Microbes Everywhere

BIORETS Teacher's Name: Katie McAnarney

Intended School Year and Marking Period: 2025-26 first semester, second quarter

Subject and Grade Level: High school biology

Overview: Microbial diversity is truly staggering, yet all these microbes can be grouped into five major types: Viruses, Bacteria, Archaea, Fungi, and Protists. In addition, it incorporates education on the experimental design process, aseptic technique, introduction to microscopes,and identification/classification of microbes collected in the school environment.

Essential Standards:

- HS-LS1-2
  - Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
    - Connection: Comparing cell structures in bacteria, archaea, protists, fungi, and viruses highlights structural and functional differences.
- HS-LS2-6
  - Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms.
    - Connection: Microbial interactions, niches, and roles in ecosystems (e.g., decomposers, pathogens).

Science and Engineering Practices (SEPs):

- Planning and carrying out investigations
- Analyzing and interpreting data
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Using models
  - This lab activity uses scientific practices directly — sample collection, culturing, microscope work, data analysis, and classification.

Crosscutting Concepts (CCCs):

- Structure and Function
- Systems and System Models
- Stability and Change
- Patterns

Disciplinary Core Ideas (DCIs):

- LS1.A: Structure and Function
  - All living things are made of cells. In organisms, cells work together as part of systems...

Learning Objectives:

- Students will be able to identify key differences between the five major types of microbes: Viruses, Bacteria, Archaea, Fungi, and Protists.
- Students will use microscopes and prepared slides to classify different microbes.
- Using knowledge of environments and needs of different types of microbes, students will be able to predict locations within the school where they would be able to find evidence of bacteria.
- Students will be able to use aseptic technique to collect environmental samples and streak plates.
- Students will compare results with other groups and collect quantitative data.

- Students will prepare their slides from their plates and identify/classify the bacteria they found.

Length of Lesson: 5 days

Introduction/Background: [Introduce the background of the selected topic.]
Microorganisms—often called microbes—are the most abundant and diverse life forms on Earth. Found in virtually every environment, from deep-sea vents to human skin, microbes play essential roles in ecosystems and human health. Despite their importance, microbes are largely invisible to the naked eye, making hands-on exploration through sampling and microscopy a powerful tool for discovery.

In this lesson, students will step into the role of microbiologists. They will collect environmental samples, culture them using petri dishes, and observe microbial growth using microscopes. As they analyze what they've found, students will explore the diversity of life at the microscopic level, including Bacteria, Archaea, Fungi, Protists, Viruses, and Bacteriophages. By comparing structural features and ecological roles, they will learn how these organisms are classified and how they relate through evolution.

This lesson integrates inquiry-based learning, hands-on lab practices, and scientific reasoning while aligning with NGSS standards. It encourages students to think critically about life's diversity and the definition of life itself—especially when considering viruses and bacteriophages, which challenge conventional ideas about living organisms.

Ultimately, this investigation helps students understand how microorganisms are both distinct and interrelated, and how they influence larger systems such as ecosystems, human health, and biotechnology.

Key Concepts and Terms Covered:

- Environmental sampling, Microbial diversity, Microbiology lab, Microscopy, Petri dish cultures, Streak plating, Aseptic technique, Colony morphology, Microbe classification, Hands-on science activity, Inquiry-based learning, Bacteria, Archaea, Fungi, Protists, Viruses, Bacteriophage, Prokaryotes vs Eukaryotes, Domain classification, Cell structure comparison, Taxonomy of microbes, Lab Equipment & Techniques, Microscope use, Agar plates, Incubation, Sterile technique, Slide preparation, Structure and function, Interconnectedness of life, Pathogens vs beneficial microbes, Microbial ecology, Experimental Design, Hypothesis Testing

Materials:

- Swabs
- Petri Dishes with nutrient agar
- Media
- Slides
- Microscopes
- Sterile cotton swabs
- Prepared slides
- Wet mount slides
- Microbe ID charts or access to a microbiology database
- Gloves
- Disinfectant

- Lab journals

Activities of the Session:

Day 1: Introduction to Microbes
Objective:
Students identify characteristics and differences among bacteria, archaea, viruses, fungi, protists, and bacteriophages.
Activities:
- Interactive slideshow or video intro to microbial domains
  - https://www.youtube.com/watch?v=YSitT0oOoyc
  - https://www.youtube.com/watch?v=ycO-oWYvaQI
- Students complete “Microbe comparison chart” (cell type, structure, reproduction, etc.)

Assessment:
Exit ticket: Which microbes do you think can be found in the human body?

Day 2: Classification and Interrelatedness
Objective: Classify microbes into major groups and explore their evolutionary relationships.

Activities:
- Interactive slideshow or video intro to parts of a microscope and how to use one
  - https://www.youtube.com/watch?v=tVcEEw6qbBQ&t=109s
- “Introduction to microscope” worksheet
- Student activity “Examine Microbes at Higher Magnifications”
- Group research stations: Bacteria, Archaea, Viruses, Fungi, Protists,

Assessment:
- Group “poster share-out” or presentation

Day 3: Environmental Sampling & Lab Prep
Objective: Students collect environmental samples to investigate microbial presence.
Activities:
- Reading “What’s in Your Petri?” https://www.nasa.gov/wp-content/uploads/2018/05/microbeactivitypart2-petri.pdf
- Safety & sterile technique briefing
- Hypothesize where microbes would be found around the school
- Collect samples (e.g., doorknobs, soil, phone screens, water)
- Streak plates on agar (label, date, sample source)
  - https://www.youtube.com/watch?v=fND5I_A7wNM&t=96s

Exit ticket: Predict what may grow

Day 4: Microscopy and Morphology
Objective: Use microscopes to examine sample results and compare microbial morphology**.**
Activities:
- Observe early colony growth from streak plates, collect quantitative data
- Prepare slides (wet mounts or fixed)
- Record colony shape, color, and microscopic features
- Use a dichotomous key or a basic microbe ID guide

Assessment:

- Lab journal sketches & labels

Exit Ticket: What type of microbe do you think you found, and why?

Day 5: Claim-Evidence-Reasoning & Reflection
Objective: Analyze data and defend microbial classification using CER framework.
Activities:

- Comparative analysis of data from different groups
- Reflection on the original hypothesis
- Students write a CER: "What kind of microbe did you find in your sample?"

Assessment:

- Graded CER statement
- Quiz on microbial domains and differences

Engagement:
Asking students to investigate "What's living on the surfaces around us?" This immediately connects the content to their daily lives (e.g., phones, doorknobs, water fountains) and taps into their natural curiosity—and sometimes discomfort—about unseen microbes.

Students will:

- Collect their own samples from familiar environments, giving them ownership of the investigation.
- Use hands-on tools like microscopes, petri dishes, and swabs, which fosters tactile learning and excitement through discovery.
- Make predictions about microbial growth before incubation and then test those predictions with real data, tapping into inquiry-based learning.
- Collaborate in small groups to compare findings, build phylogenetic models, and classify organisms—making the activity social and discussion-driven.

In addition:

- Each day includes visuals, demonstrations, and movement-based tasks (e.g., walking around to collect samples or analyze growth).
- Students are given authentic roles—scientists, classifiers, detectives—to foster intrinsic motivation.
- Choice is built in: students choose sampling sites, focus organisms to research, and formats to present their findings (e.g., diagrams, CER writing, posters).

By integrating hands-on exploration, collaborative learning, and thought-provoking discussion, students stay actively involved and take ownership of both the lab process and the big biological concepts.

Evaluation:
Ongoing/Formative Assessments:

- Microbe Prediction & Observation Journal
    - Students predict what microbes they expect to find
        - Assesses skills in scientific reasoning, observation, and recording data.
- Microscope Sketch & ID Chart
    - Students create labeled diagrams of microorganisms viewed under the microscope and compare features.

        - Assesses attention to detail, morphology recognition, and classification accuracy.
- Teacher prompts like “What makes a virus different from bacteria?” help gauge understanding and promote critical thinking.

Summative Assessments:

- Claim-Evidence-Reasoning (CER) Response
    - Prompt: “What kind of microbe did you most likely observe in your sample? Defend your claim using evidence from the investigation and knowledge of microbe classification.”
        - Assesses ability to draw scientific conclusions, use evidence, and connect observations to biological concepts.

- Microbial Classification Mini-Project or Poster
    - Students create a visual or written product explaining one microbe group, their defining characteristics, structure, role in ecosystems, and how they compare to others.

- Exit Tickets or Quiz
    - Quick questions targeting objectives: structure/function, domain classification, and microbe comparisons.
        - Assesses individual content retention.

Modifications:

- Provide visual aids (microbe charts, labeled diagrams, life cycle visuals) to reinforce vocabulary and structure differences.
- Offer sentence starters and scaffolds for CER writing (e.g., “I think this is a bacterium because…”).
- Use guided lab worksheets with step-by-step instructions, visuals, and space to record predictions and observations.
- Assign roles in group work (e.g., recorder, slide preparer, observer) to build confidence and ensure participation.
- Pre-label microscope parts or have stations for specific focus (e.g., colony morphology vs. microscope sketching).
- Chunk information—teach a few microbial groups per day if needed instead of all at once.

For English Language Learners (ELLs):

- Provide bilingual word banks or glossaries with visuals.
- Use sentence frames for observations, comparisons, and CERs.
- Pair ELLs with supportive peers or use small-group instruction for vocabulary and discussion support.

Extensions:

- Advanced Research or Projects:
    - Have students research recent discoveries in microbiology or synthetic biology (e.g., bacteriophages in medicine).
    - Have students research a harmful or beneficial microbe and create a mini-report or infographic that includes its structure, host, and real-world impacts.
- Extended Lab Work:
    - Introduce Gram staining to classify bacteria based on cell wall structure.

- Add temperature variation or antibiotic discs to petri dishes to explore microbial resistance and environmental limits.
- Incorporate quantitative colony counts and math integration to measure microbial growth over time.

Application:
This lesson allows students to apply their understanding of microbiology in both real-world contexts and academic frameworks, helping them see how microscopic life connects to health, ecosystems, and biotechnology. It builds skills that extend beyond science content and fosters systems thinking, analysis, and communication.

- Scientific Application:
  - Students apply lab techniques (e.g., streak plating, microscopy, classification) that mirror real microbiological practices used in clinical labs, environmental science, food safety, and pharmaceutical research.
  - They analyze data collected from their own environment, developing the ability to form evidence-based claims—a foundational scientific skill.
- Real-World Relevance:
  - Students connect their findings to current global issues, such as: Infectious diseases and the role of bacteria, viruses, and fungi in outbreaks. Antibiotic resistance and how microbial classification influences treatment. Public health and why hygiene practices (e.g., handwashing, surface cleaning) are effective.
- Cross-Disciplinary Connections:
  - ELA: Through CER writing and poster presentations, students practice scientific writing and argumentation.
  - Math: Quantitative measurement of colony growth or comparison of microbial populations introduces data analysis and graphing.
  - Technology: Optional use of digital microscopes, image analysis, or phylogenetic tree-building software connects students to scientific tools and bioinformatics.

The lesson empowers them to become citizen scientists who can make evidence-based decisions in their own lives about hygiene, health, and the environment.

Resources:
https://bio.libretexts.org/Bookshelves/Microbiology/Microbiology_Laboratory_Manual_(Hartline)/01%3A_Labs/1.05%3A_Get_to_Know_the_Microscope_and_Microbes
https://www.michigan.gov/-/media/Project/Websites/mde/Literacy/Content-Standards/Science_Standards.pdf?rev=a63819680d47402ca6c3858a191f6827
https://www.teachengineering.org/activities/view/nyu_bacteria_activity1
https://www.nasa.gov/wp-content/uploads/2018/05/microbeactivitypart2-petri.pdf
https://www.youtube.com/watch?v=tVcEEw6qbBQ&t=109s
https://www.youtube.com/watch?v=fND5I_A7wNM&t=96s
https://www.youtube.com/watch?v=YSitT0oOoyc

Intro to Microbes

Instructions:

Use today's presentation, your textbook, or classroom resources to fill in the table and answer the questions below. Focus on cell type, structure, reproduction, and key functions. This activity will help you understand how microbes are similar and different from each other.

🧫 Part 1: Microbial Structure & Function Comparison Chart

Feature	Bacteria	Archaea	Protists	Fungi	Viruses
Domain					
Cell Type (Prok/Euk/Neither)					
Nucleus Present?					
Cell Wall Present?					
Cell Wall Material					
Method of Reproduction					
DNA or RNA?					
Can Move? (Motility)					
Size Range (general)					
Living or Nonliving?					

Example Organism					

Part 2: Analysis Questions

1. Which groups are prokaryotic, and which are eukaryotic? What is one key difference in their structure?

2. What makes viruses different from all the other groups listed?

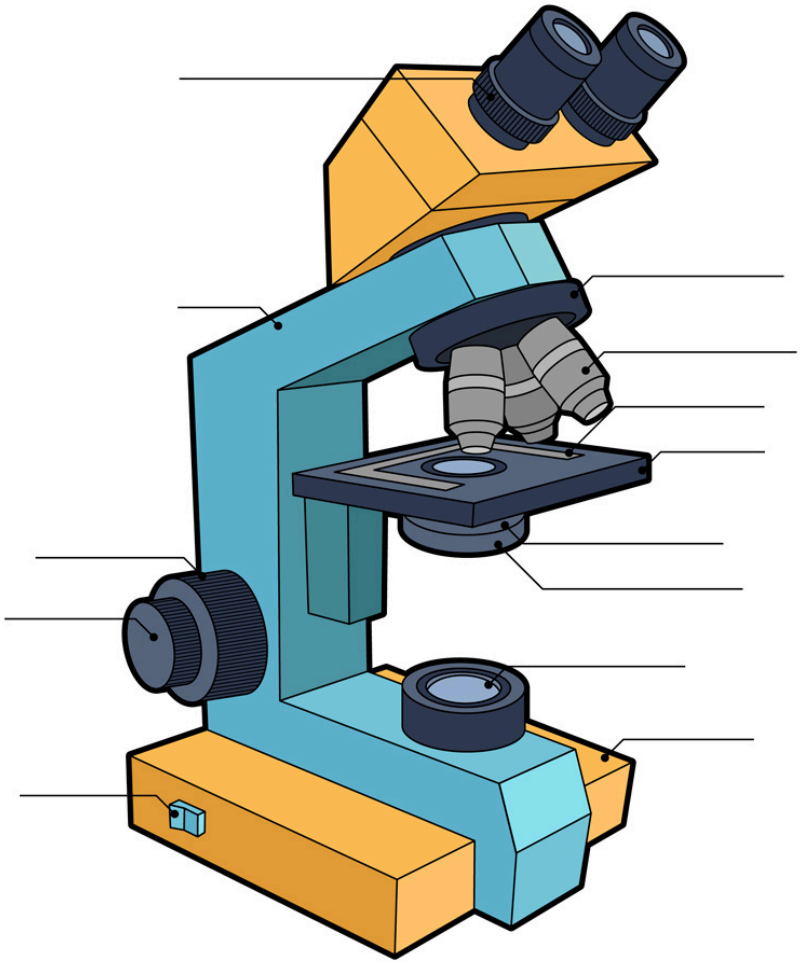
3. Both bacteria and archaea are prokaryotic. What important structural or environmental difference sets them apart?

4. Protists and fungi are both eukaryotic. How can you tell them apart? Give one difference in structure or function.

Microscope Basics Worksheet

Instructions: Use the diagram above to match each numbered part with its name and function. Record your answers in the table provided below.

#	Microscope Part
1	Eyepiece (Ocular Lens)
2	Objective Lenses
3	Stage
4	Stage Clips / Mechanical Stage
5	Coarse Focus Knob
6	Fine Focus Knob
7	Condenser
8	Iris Diaphragm
9	Light Source / Illuminator
10	Arm
11	Base
12	Power Switch



Part 2: Magnification Calculations

Use the formula below (assuming a 10× eyepiece unless stated otherwise):

Total Magnification = Eyepiece × Objective Lens

Scanning objective (4×): 10 × 4 = ____×

Low-power objective (10×): 10 × 10 = ____×

High-power objective (40×): 10 × 40 = ____×

Part 3: Reflection Questions

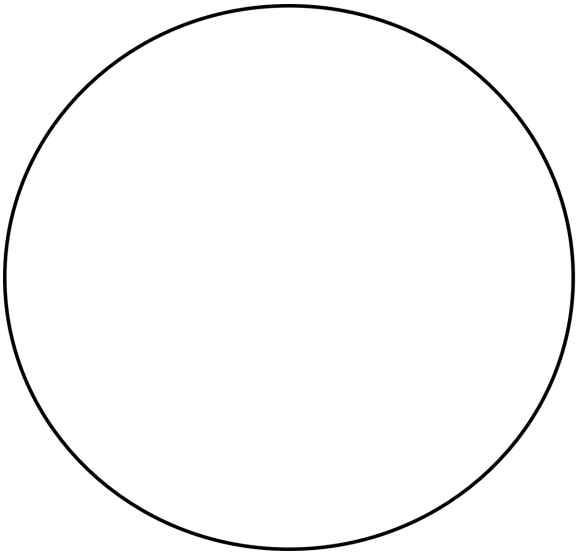
1. Why should you always start viewing a slide with the lowest power objective lens?

2. What should you avoid doing when using the high-power objective lens?

Examine Microbes at Higher Magnifications

Helminth

Examine an example of a species of helminth. Illustrate the magnified sample in detail, write down the name of the specimen, and indicate the total magnification you made the illustration at. The goal is to distinguish the different categories of microbes based on your illustrations.

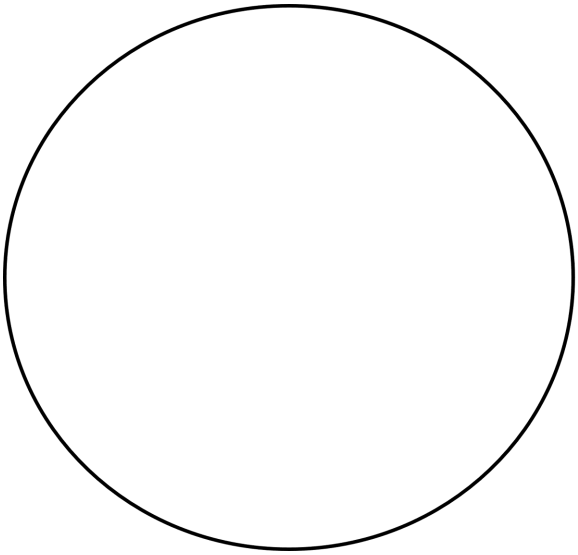


specimen: _____

total magnification: _____

Fungus

Examine an example of a species of fungus. Illustrate the magnified sample in detail, write down the name of the specimen, and indicate the total magnification you made the illustration at. The goal is to distinguish the different categories of microbes based on your illustrations.

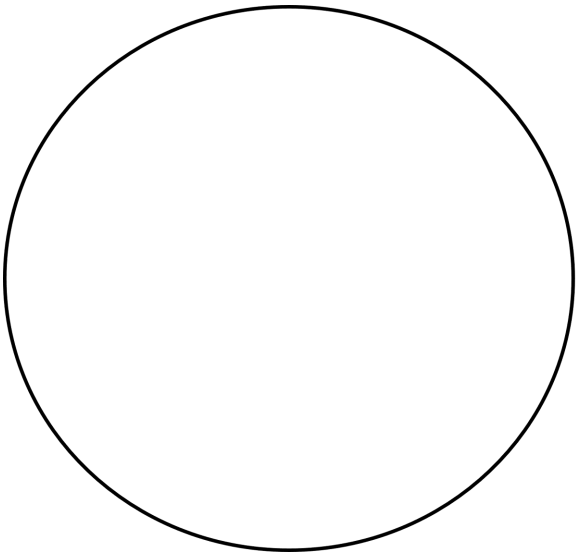


specimen: _____

total magnification: _____

Protozoa

Examine an example of a species of protozoa. Illustrate the magnified sample in detail, write down the name of the specimen, and indicate the total magnification you made the illustration at. The goal is to distinguish the different categories of microbes based on your illustrations.

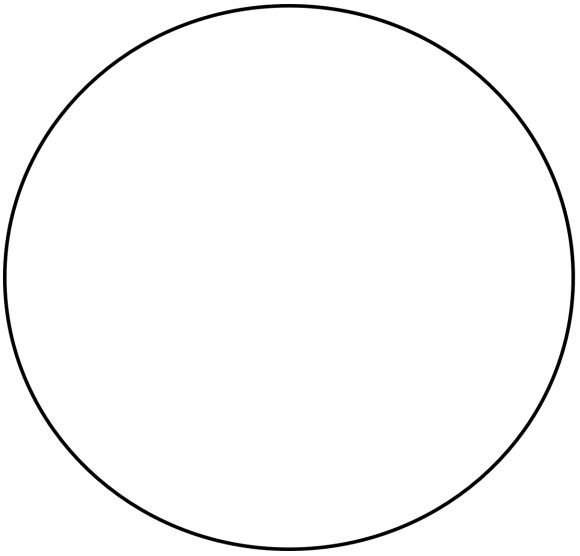


specimen: _____

total magnification: _____

Bacteria

Examine an example of a species of bacteria. Illustrate the magnified sample in detail, write down the name of the specimen, and indicate the total magnification you made the illustration at. The goal is to distinguish the different categories of microbes based on your illustrations.



specimen: _____

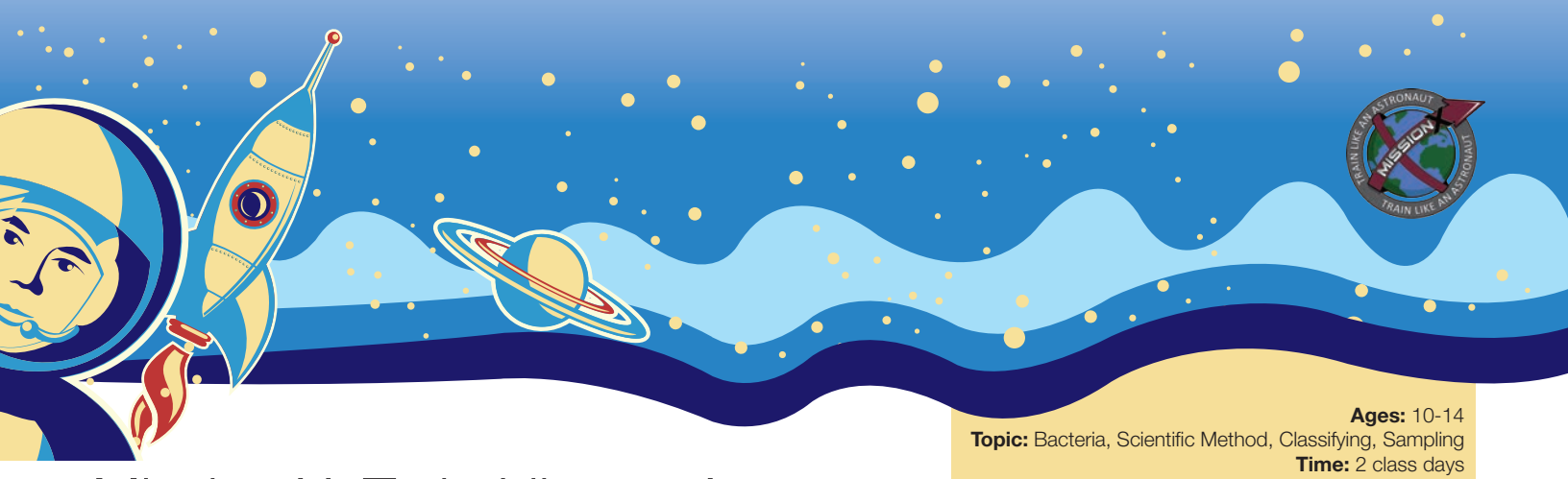
total magnification: _____

Compare and Contrast Different Types of Microbes

1. What were some notable similarities among the different microbe classifications examined with the light microscope?

2. What were some notable differences among the different microbe classifications examined with the light microscope?

3. Do all microbes have the same structure? Explain your answer.



Ages: 10-14
Topic: Bacteria, Scientific Method, Classifying, Sampling
Time: 2 class days

Standards
Next Generation Science Standards:
5-LS2-1 Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment
Common Core State Standards: MP.4 Model with mathematics

Mission X: Train Like an Astronaut

WHAT'S IN YOUR PETRI

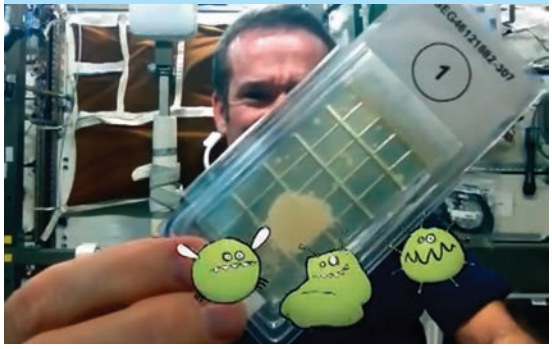
BUGS IN SPACE PART 2

EDUCATOR SECTION (PAGES 1-12)
STUDENT SECTION (PAGES 13-21)

Background

Microbes live everywhere! While many microbes on Earth are harmless, and can even be helpful to humans, some microbes can be unsafe.

Microbes belong to a group all by themselves because they are neither plants nor animals. Because they can multiply extremely quickly, it is normal to find millions of them in the same location. Some microbes or "germs", such as bacteria and mold, can grow on food, dirty clothes, and garbage that people produce. Microbes live on your skin, in your mouth, nose, hair, and inside your body.



Astronaut Chris Hadfield taking microbe samples on the ISS.

Microbes can also be found aboard the International Space Station (ISS). NASA scientists have reported that some germs on the ISS have different characteristics when grown in space compared to when they grow on Earth. The safety of the crew is of utmost importance. Therefore, cleanliness and proper disposal of garbage is an important part of living on the ISS.

Scientists who study microbes are called microbiologists and microbiology is the study of microorganisms or microbes. The root word "micro" comes from Greek and means "small". These microbes are so small that powerful microscopes are needed to be able to see them. At the Johnson Space Center in Houston, Texas, NASA microbiologists study the small microbes in the air, water, food, and surfaces of the ISS. Controlling the microbes inside your body is an important part of staying healthy. So, where can you find microbes?

Lesson Objectives. Students will:

- formulate and prepare an inquiry-based investigation.
- grow and study microbial life.
- categorize microbes based on different properties.
- think critically.
- investigate the relationship of everyday products to microorganisms.
- examine the impact of microorganisms on daily life.
- discover that microorganisms have the greatest diversity of all living organisms.
- explain how microorganisms are beneficial to humans and the environment.
- connect healthy living habits from living in space to their schools and homes.

Teacher Notes / suggestions for implementation:

*This activity is designed to accompany **A Microbial Box**, so completing both activities will give the students both a research and a laboratory experience. It is possible to do the activities in different years or separated by a significant amount of time. Thus, the student reading sections and background information are the same as they are appropriate for either activity.*

*To help your discussion with the students, information from the activity **A Microbial Box** can be found here http://trainlikeanastronaut.org/mission-data.*

QUESTION: WHAT IS GROWING ON YOUR SKIN, YOUR DESK, THE COMPUTER KEYBOARDS ON THE ISS AND YOUR SCHOOL?

While on the International Space Station, astronauts take samples to monitor microbial growth and ensure a safe and healthy environment. They take the samples much like you will do in this activity, and while in space they sample the air, surfaces, and water of the ISS.

Microbiologists have found that microbes can live just about everywhere, even on us! We have trillions of microbes inside and outside of our bodies. Run your tongue over your teeth—you are licking thousands of microbes that normally live on your teeth. Millions of them live on your tongue, too. A large part of the mass of your body is actually something else: bacteria, viruses, and fungi.

Microbes are in the world around you, too. If you pick up a fistful of garden soil, you are holding hundreds (if not thousands) of different kinds of microbes in your hand. A single teaspoon of that soil contains over 1 billion microbes of bacteria, about 120,000 microbes of fungi and 25,000 microbes of algae.

Microbes have been around for billions of years because they are able to adapt to the ever-changing environment. They can find a home anywhere, and some of them live in places where we once thought nothing could survive.

For example, scientists have discovered microbes living in the boiling waters of hot springs in Yellowstone National Park. Other heat-loving microbes live in volcanic cracks—miles under the ocean surface, where there is no light and the water is a mixture of poisonous chemicals. Other microbes live in the permanently frozen ice of Antarctica. Microbes have also been found living inside the stones that make up the walls of old cathedrals in Europe.

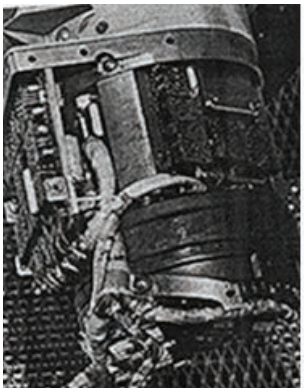


Figure 2: Television camera from Surveyor 3.

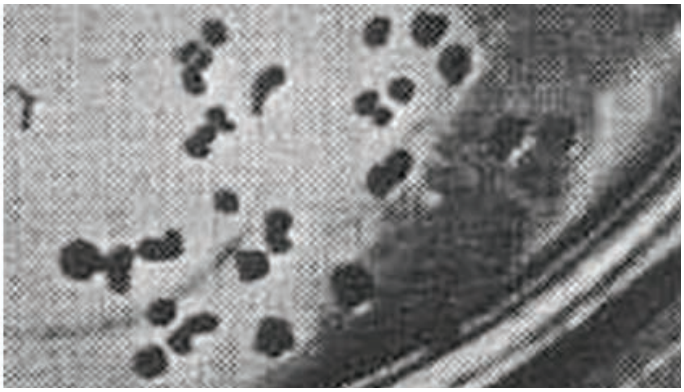


Figure 3: Bacteria found on the television camera of Surveyor 3.

Microbes can even survive in space. On April 20, 1967, the unmanned lunar lander Surveyor 3 landed near Oceanus Procellarum on the surface of the Moon. One of the onboard items included a television camera. Two-and-a-half years later, on November 20, 1969, Apollo 12 astronauts Pete Conrad and Alan L. Bean recovered the camera. When NASA scientists examined it back on Earth, they were surprised to find some bacteria called *Streptococcus mitis* were still alive. Because of the precautions the astronauts had taken, NASA was sure that the germs found inside the camera had been in the camera since before Surveyor 3 launched to space. These bacteria had survived for 31 months in the vacuum of the Moon's atmosphere. They may have frozen or dried inside the camera, which are two ways normal bacteria can enter a state of deep sleep.

Some scientists even believe there is a possibility that bacteria may have once lived on Mars. The photograph below (taken through a microscope) shows what some scientists believe may be the fossils of tiny bacteria in a rock that formed on Mars about 4.5 billion years ago. The rock crash-landed on Earth as a meteorite thousands of years ago.

Figure 4: Close-up of bacteria that survived for almost 3 years on the moon.

Problem: Can I observe life around me that cannot be seen?

SAFETY!!

- Remind students about the importance of classroom and lab safety.
- Students should wear eye and hand protection during this activity.
- Safety Data Sheets (SDS) are required for part 2 of this activity. http://www.3m.com/3M/en_US/company-us/SDS-search/ https://www.osha.gov/dsg/hazcom/ghs.html#4.8
- If a chemical spill occurs, have the students move quickly from the site. Wash off chemicals that have splashed onto the skin or clothing for 15 minutes using large amounts of water in the safety shower, eye/face wash station, or sink.
- This activity requires proper clean up.

Teacher Notes / suggestions for student engagement:

To help with the student engage section, ask some questions such as: If you can't see something, how do you know it exists? If you drop a piece of candy on the gym floor, would you still eat it? What are some cleaning products you use at home? What are some ways to clean a wound if you get a cut in your skin? What are some ways to prevent getting sick? Which surfaces in the school do they think might have the most bacteria and microbial growth?

Part 1 - Explore

Observing life around us that is too small to be seen!

SAFETY SECTION

Remind students about the importance of classroom and lab safety.

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- Safety Data Sheets (SDS) are required for part 2 of this activity. Examples of SDS can be found here: http://www.3m.com/3M/en_US/company-us/SDS-search/ https://www.osha.gov/dsg/hazcom/ghs.html#4.8

- If a chemical spill occurs, have the students move quickly from the site. Wash off chemicals that have splashed onto the skin or clothing for 15 minutes using large amounts of water in the safety shower, eye/face wash station, or sink.
- This activity requires proper clean up.

Pre-lesson Preparation:

Students should work in groups of four. Group size can be adapted for your needs. Students can complete the Analysis Sheet (Appendix A) together or individually.

Materials:

Per class

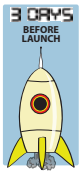
- Clear adhesive tape
- Thermometer
- Small desk lamp or light (15–60 watt)
- Small container (such as medicine cup or cough syrup container)
- Anti-bacterial soap
- Incubator, using a hard-sided cooler OR a 10-gallon glass aquarium with heavy weight plastic (laminating plastic) and packing tape (See how to make a classroom incubator and determine other needed materials in Part 2's pre-lesson instructions section and in Appendix B)

Per group of 4

- 2 plastic cups
- ½-cup distilled water
- 2 permanent markers
- ½-cup weak bleach solution
- One 1-gallon zipper seal bag (to use at 48-hour observation period)
- Color pencils

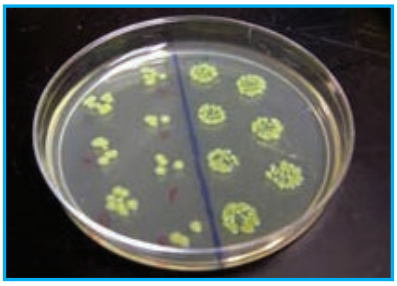
Per student

- 1 Petri dish (with nutrient agar)
- 1 hand lens
- 1 cotton swab
- Eye protection
- Hand protection
- Copy of Bugs in Space Student Section



At least three days prior to the activity

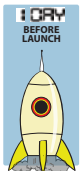
- Purchase Petri dishes
  - It is important to use an agar formulation that does not preferentially grow one kind of bacteria over another. Although other agar formulations might work, it is recommended that you purchase nutrient agar for this activity as it has more nutrients and will grow the widest range of bacteria. You can purchase nutrient agar from any science supply and material company.
  - Prepared Petri dishes should be refrigerated until used and always stored upside down. (i.e., media in upper dish and cover on the bottom). This keeps condensation which forms in the lid from dropping onto (and disrupting) the microbe growing surface.



E.coli cultures in Petri dishes. NASA launched E.coli in the first GeneSat on Nov. 13, 2006. (Image Credit: NASA)

- Construct an incubator (See Appendix B for images of incubators.)
  An incubator is a warm cabinet where you can set the temperature for proper microbe growth to about 35 ºC, or normal body temperature (98.6 ºF). The hard-sided cooler incubator is recommended because it is easy to set-up and easy to regulate temperature.
  - If using a hard-sided cooler:
    - Place a small desk lamp inside a hard-sided cooler, letting the cord come out the top under the cooler lid (see Appendix B, Image 1).
      - It is recommended not to use a halogen lamp. Halogen lamps get hotter than regular, incandescent lamps. Because the halogen lamp operates at very high temperatures, it can pose fire and burn hazards.
      - Try different bulbs (15–25 watts) until you find one that gives you the temperature you need for your incubator.
    - Place a thermometer (0–100 ºC) inside the cooler.
    - Close the lid, leaving a small opening for air flow.
  - If using an aquarium:
    - You will need a 10-gallon aquarium. (It does not need to be watertight.)
    - Turn the aquarium so that the opening faces the front instead of the top (see Appendix B, Images 2 and 3).
    - Cut a heavy-weight plastic (such as laminating film) slightly wider than the aquarium opening and about two inches longer than the height of the opening.
    - Tape the plastic to the top of the aquarium, so that the plastic falls over the opening at the front. This is the “door”.
    - Place a small desk lamp in the aquarium, letting the cord come out the front under the plastic covering.
      - It is recommended not to use a halogen lamp. Halogen lamps get hotter than regular, incandescent lamps. Because the halogen lamp operates at very high temperatures, it can pose fire and burn hazards.
      - Try different bulbs (15–25 watts) until you find one that gives you the temperature you need for your incubator (see box below).
    - Place a thermometer (0–100 ºC) in the aquarium so that you can read it without opening the plastic “door”.
    - Cover the top and back of the aquarium with aluminum foil.
  - If a hard-sided cooler or aquarium is not available, here is an alternative option. Find a warm place behind your refrigerator, next to the radiator, or inside an oven that is off (with the inside light turned on). Please be aware that if using this method, it may take longer than 48 hours to see microbe growth.

Teacher notes: *For whichever option you choose, prepare your incubator in advance and use a thermometer to test it a day before starting your investigation. Temperature should be between 35–39 ºC (98–100 ºF).*



The day prior to the activity:

- Make enough dishes for each group to have four labelled Petri dishes and label them. (See the image to the right of a labelled Petri dish.)
  - Using a permanent marker, divide the Petri dish into two sections by marking a line on the outside of the bottom of the dish.
    - Label one side of the lid with "E" for experimental.
    - Label the other side with "C" for control.

Labeled petri dish for Bugs in Space 1. Courtesy NASA JSC HREC.

The day of the activity:

- With a permanent marker, label two plastic cups per group as follows:
  - WATER
  - BLEACH
- To prepare the cup labeled WATER:
  - Make sterilized water by boiling distilled water and letting cool to room temperature.
  - Partially fill the cup with the sterilized water (one per group for each class).
  - Place cotton swabs in the plastic cup (one cotton swab per student).
- To prepare the cup labelled BLEACH:
  - Make a weak bleach solution by mixing one part bleach with three parts water.
  - Fill half of the cup with this bleach solution. (Use this cup for disposing of used cotton swabs.)

Procedures:

Microbial Life (taken from the *What's in your Petri?* Student Section)

Before beginning, give each group one plastic cup containing cotton swabs in distilled water and one plastic cup containing the weak bleach solution.

Make a list of places and items that microbes live in. Which of these places or items may also be on a spaceflight mission?

Have the students discuss (as a class) the places or items in their environment that contain microbes which might also appear on a spaceflight mission.

Before beginning the activity, students should fill out the sections for the KWHL chart for "WHAT THEY KNOW" and "WHAT THEY WANT TO KNOW". They can use the data from the A Microbial Box activity (http://trainlikeanastronaut.org/mission-data) to assist them.

Direct the discussion towards items that can be swabbed by the students such as:

- Floors
- Trash cans
- Bottom of shoes
- Bathrooms
- Coins
- Sinks
- Erasers
- Insects (an insect can walk across the dish, e.g., a pill bug)

Do not allow students to swab any part of the body such as lips, fingers, mouth, etc. for this activity.

1. With your group, decide what places or items to use to swab the Petri dish. Make sure your teacher approves them.
2. ***Record*** the places or items your group will test on your Microbial Life Analysis Sheet (Appendix A). (Use one Microbial Life Analysis Sheet per place or item tested.)
3. Put on your eye and hand protection.

Teacher notes: *Stress the importance of keeping eye and hand protection on during this section of the lesson. The hand protection is to ensure that students do not transfer microorganisms from their hands to the item. In addition, safety procedures should be followed to ensure that whatever organisms are swabbed does not affect the health of the student.*

4. Watch as your teacher models the correct procedure to swab the Petri dish without tearing the agar surface. *Swab the Petri dish by gently rubbing the sterile cotton swab on the experimental side "E" without tearing the agar surface.*

Teacher notes: *Discuss the control side of the Petri dish with your students. Explain why this side is left untouched: The control side is needed to make the experimental results valid. Leaving the control side untouched allows the student to view the growth difference between the swabbed side (with microbes) and the unswabbed side (without microbes). The two groups are kept in identical conditions and observed in the same way.*

5. Without tearing the agar surface, very gently rub the swab over the agar onto the experimental side "E" in a few strokes, and replace the lid to the dish. *(Each student from the group should collect bacteria from their selected place or item using a swab. Each student will test a different item.)*
6. Dispose of the used cotton swabs in the cup of bleach solution.
7. With a permanent marker, label the edge of your Petri dish with your name and the name of the item to be tested.

Teacher notes: *It's important for students to label each dish so they know the source of the bacteria. When labelling, students should use the edges and the control side, "C". This makes it easier to view the culture on the experimental side, "E". (See image to the right of a labeled Petri dish.)*

8. To help prevent condensation from dropping onto and disrupting the microbe growing surface, place the Petri dish upside-down in the incubator.
9. Place a thermometer inside the incubator to monitor the temperature. To encourage culture growth in the incubator, the environmental temperature should be between 35°–39 °C (98–100 ºF).
10. Place the small container (such as a medicine or cough syrup cup) with water in the incubator to keep the environment moist and to prevent the agar from drying. *Be careful not to spill water inside the incubator. Excess water could cause a short circuit with the lamp.*
11. Wash your hands with anti-bacterial soap and water.
12. Predict what will happen in 24–48 hours, and record your predictions on the Microbial Life Analysis Sheet. Include physical properties such as shape, color, etc. *Discuss predicted physical properties (i.e., shape, color, etc.) with students and ensure these properties are included in their recorded predictions. Prior to students recording their observations, explain and discuss the Microbial Life Analysis Sheet. Make sure students understand the words "translucent" and "sketch".*

SUGGESTED PLACE TO PAUSE ACTIVITY TO LET MICROBES GROW – RESUME AT 24 AND 48 HOURS

Students should observe the Petri dishes at 24 and 48 hours.

After two days (or when the cultures are ready for observations), tape the Petri dishes shut, sealing around the outside edges using the following procedure. This will prevent students from opening a Petri dish with microbial growth. Additional suggestions:

- *Close the Petri dish, making sure it is tightly shut.*
- *Using clear adhesive tape, center the tape on the two sides of the edge of the dish.*
- *Tape the outside of the dish all the way around.*

Teacher notes: *Upon removal and observation, make sure students **DO NOT** turn the Petri dish right side up; otherwise condensation will leak out (see Appendix B, Image 4).*

13. Put on your eye and hand protection.
14. With your group, use hand lenses to make observations and record data on the culture-tested bacteria from your selected place or item containing microbes.

Important! Do not open cultures!

You should see growth within a couple of days. The dishes might start to smell, which means the bacteria are growing.

15. **Record your observations** by making sketches using colored pencils on your Microbial Life Analysis Sheet.
16. As a group, present your data to the class.

Teacher notes: *As groups, have students present their data or write their data on chart paper. You can also make a transparency of a blank Microbial Life Analysis Sheet so that the information can be viewed by the whole class. This information will be important when answering the study data questions. If available, you may also consider using a document camera to view the Petri dishes with microbial growth.*

17. If completing the 24-hour observation, allow your teacher to return the Petri dishes to the incubator.

Put on hand protection. Keeping petri dishes with lids facing down, remove the tape from each petri dish and gently replace back into incubator.

If completing the 48-hour observation, properly dispose of the bacterial cultures.

- Place the Petri dishes inside your group's zipper seal bag and close securely.
- Give the sealed bag to your teacher.

Put on hand protection. For each zipper sealed bag: remove tape from the outside of each Petri dish, but make sure each Petri dish is opened inside the bag. Add one tablespoon of household bleach to the bag. Make sure bleach goes inside each Petri dish to kill the microbes. Dispose of the Petri dishes.

Explain:

When students have completed their observations, ask them to study their data and answer the following questions.

1. How is the control side of your Petri dish used? [The control side is to give a baseline for any microbial growth that is independent, or not part, of the experiment.]

2. What is an incubator? [An incubator is something that creates a controlled environment to grow microbes.]

3. How did you choose your sample? [Answers will vary]

4. Does the sample growth lead you to believe that there are few or many microbes in your environment? Why? [Answers will vary]

Evaluate:

Have the students update the HOW DID YOU FIND OUT and LEARNED columns in your KWHL chart and then answer the following questions:

1. Restate your hypothesis. [Answers will vary]

2. Explain how the results do, or do not, support your hypothesis. [Answers will vary, but make sure the answers refer to the students' hypothesis. It is acceptable to have the results not support the hypothesis, but not acceptable for them to change the hypothesis at this stage to match the results. It is better to explain why the results are different than what they expected.]

3. Microbes are too small to see without a microscope. How did you observe and measure microbe growth without seeing each microbe? [Answers will vary, but most likely will relate to not being able to see single microbes, rather seeing many of them.]

4. What was the purpose of using light bulbs to grow the microbes? [The light bulbs increased the temperature to provide optimal temperature.]

5. Where else do you think you would be able to find a large amount of microbes? [Answers will vary]

Elaborate:

1. How can you observe life around you that cannot be seen? [Using tools such as microscopes or telescopes, or letting things grow until they are big enough to see.]

2. Does your data support your hypothesis? Why or why not? Compare your data with your class. [Answers will vary]

3. As a group, develop a plan as to how you help maintain a clean and microbe-free school. How could you do this at home? [Answers will vary]

4. Imagine you are a microbiologist concerned about astronaut safety. Please make recommendations to NASA to reduce the microbial level aboard spaceflight missions. [Answers will vary]

Extend:

1. A company makes cleaning supplies and has asked your group for advice. They would like to investigate which surface might be the most important to clean. Which surface in your school would you suggest they use to test their cleaning supplies? [Answers will vary]

2. Read the "Did you know?" graphic. Why do you think astronauts have their bodies wiped with rubbing alcohol before they fly to the space station? [Answers will vary]

3. Astronauts are kept away from other people for a week before launching into space. How does this keep them from getting sick in space? [Answers will vary]

4. Look at your data again. Where on the ISS would you expect more microbes to be found? Where would you expect the least amount of microbes? [Answers will vary]

5. Pick one of your petri dishes and create a diary or story from the perspective of the microbes inside. For example, if you were one of the microbes in the petri dish, what would be your life story? [Answers will vary]

Educator resources

Useful Websites for Further Information

Microbes living on the ISS before humans ever lived there
http://science.nasa.gov/science-news/science-at-nasa/2000/ast26nov_1/

Preventing "Sick" spaceships
http://science.nasa.gov/science-news/science-at-nasa/2007/11may_locad3/

To read more about the ISS Environmental Control and Life Support System
http://www.nasa.gov/sites/default/files/104840main_eclss.pdf

To learn more about microbes and health
https://www.niaid.nih.gov/topics/microbes/Documents/microbesbook.pdf

NASA eClips about life on other planets
http://www.nasa.gov/audience/foreducators/nasaeclips/search.html?terms=&category=1000

SCIENTIFIC INVESTIGATION RUBRIC

Experiment: BUGS IN SPACE

Student Name _____ **Date** _____

Performance Indicator	0	1	2	3	4
Developed a clear and complete hypothesis.					
Followed all lab safety rules and directions.					
Followed the scientific method.					
Recorded all data and drew a conclusion based on the data.					
Asked engaging questions related to the study.					
Made recommendations to NASA for reducing the microbial level onboard spaceflight missions.					
Point Total					

4 = Excellent/Complete/Always follows directions/Organized
3 = Good/Almost complete/Almost always follows directions/Usually organized
2 = Average/About half done/Sometimes follows directions/Sometimes organized
1= Poor/Incomplete/Rarely follows directions/Disorganized
0 = No work/Didn't follow directions/Interfered with work of others

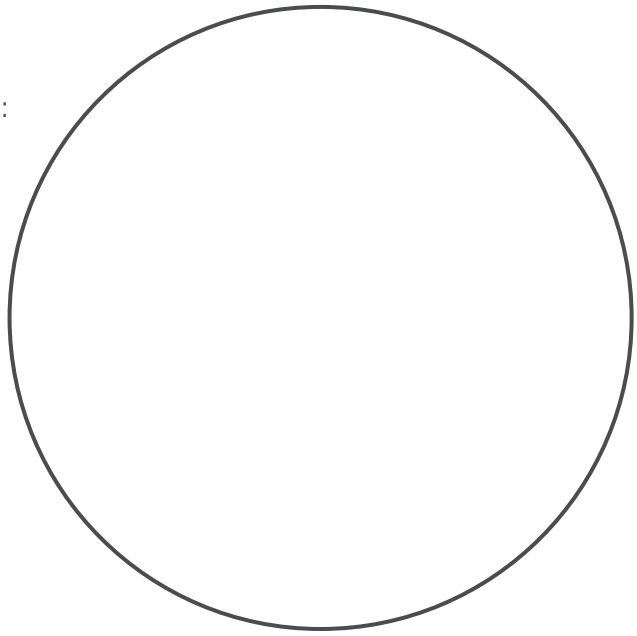
Point total from above: _____ / (24 possible)

Grade for this investigation: _____

Grading Scale:
A = 22–24 points
B = 19–21 points
C = 16–18 points
D = 13–15 points
F = 0–12 points

Appendix A - Sample of Microbial Life Analysis Sheet from Student Section.

PART 2: Microbial Life Analysis Sheet - sample

Write a description of the bacterial culture	**Sketch the bacterial culture (Use colored pencils when appropriate)**
Date: Time: Temperature: Shape and color: Translucent: Other:	Object tested: Group Members: 

Appendix B - Homemade Incubator Designs and Petri Dish Labelling

Image 1: Incubator made from a hard-side cooler.

Image 2: Incubator made from a 10-gallon aquarium with closed plastic cover.

Image 3: Incubator made from a 10-gallon aquarium with open plastic cover.

Image 4: Labeled petri dish for Bugs in Space, courtesy NASA JSC HREC.

Mission X: Train Like an Astronaut

WHAT'S IN YOUR PETRI

BUGS IN SPACE PART 2

Did you know?

"Less-known astronaut fact: before launch in the Russian Soyuz, our bodies are wiped with rubbing alcohol to kill fungus"

– Commander Chris Hadfield, who flew to space three times

Student Section

Problem: Can I observe life around me that cannot be seen?

Engage:

Which do you think has more bacteria or fungus on it, a student desk in a classroom or the door handles to the front door of a school? Which surfaces in your school do you think have the most microbes? Can you imagine all the microbes floating around your school or the International Space Station?

In this activity, your group will sample, grow, and investigate the microorganisms around us. If your class completes the introductory part 1 of this activity, "A Microbial Box", your group will research and study different types of microbes and discuss which ones are in space.

Explore

How can I observe life that is too small to be seen?

Safety: Classroom and lab safety is important!

- Everyone should wear eye and hand protection during this activity.
- Materials Safety Data Sheets (MSDS) are required for part 2 of this activity. http://www.msdssearch.com/msdssearch.htm.
- If a chemical spill occurs, move quickly from the site. Wash off chemicals that have splashed onto the skin or clothing for 15 minutes using large amounts of water in the safety shower, eye/face wash station, or sink.
- This activity requires proper clean up.

Materials needed Per Group of 4

- 2 plastic cups
- ½-cup distilled water
- 2 permanent markers
- ½-cup weak bleach solution
- One 1-gallon zipper seal bag (to use at 48-hour observation period)
- Color pencils

Materials Needed Per Student

- 1 Petri dish (with nutrient agar)
- 1 hand lens
- 1 cotton swab
- Eye protection
- Hand protection
- Copy of *What's in your Petri?* Student Section (distributed in Part 1)

Procedures

Microbial Life

Use the first column of this KWHL chart to organize what you *already know* about microbial growth. Brainstorm with your group what you *want to know* about microbial growth, then list in the second column of this KWHL chart. Later you will fill in *how you found* out and what you *learned*.

KNOW	WANT TO KNOW	HOW DID YOU FIND OUT	LEARNED

Hypothesis:

Based on your observations, answer the "problem question" with your best guess about what will happen. (How can I observe life around me that cannot be seen?) Your hypothesis should be written as a statement.

My hypothesis: _____

_____

1. With your group, decide what places or items to use to swab the Petri dish. Make sure your teacher approves them.

2. ***Record*** the places or items your group will test on your Microbial Life Analysis Sheet. (Use one Microbial Life Analysis Sheet per place or item tested.)

3. Put on your eye and hand protection.

4. Watch as your teacher models the correct procedure to swab the Petri dish without tearing the agar surface.

5. Without tearing the agar surface, very gently rub the swab over the agar onto the experimental side "E" in a few strokes, and replace the lid to the dish. (Each student from the group should collect bacteria from their selected place or item using a swab. Each student will test a different item.)

6. Dispose of the used cotton swabs in the cup of bleach solution.

7. With a permanent marker, label the edge of your Petri dish with your name and the name of the item to be tested.

8. To help prevent condensation from dropping onto and disrupting the microbe growing surface, place the Petri dish upside-down in the incubator.

9. Place a thermometer inside the incubator to monitor the temperature. To encourage culture growth in the incubator, the environmental temperature should be between 35°–39°C (98–100ºF).

10. Place a medicine cup with water in the incubator to keep the environment moist and to prevent the agar from drying.

11. Wash your hands with anti-bacterial soap and water.

12. Predict what will happen in 24–48 hours, and record your predictions on the Microbial Life Analysis Sheet. Include physical properties such as shape, color, etc.

13. Put on your eye and hand protection.

14. With your group, use hand lenses to make observations, and record data on the culture-tested bacteria from your selected place or item containing microbes.

Important! Do not open cultures!

Note: You should see growth within a couple of days. The dishes might start to smell, which means the bacteria are growing.

15. ***Record your observations*** by making sketches using colored pencils on your Microbial Life Analysis Sheet.

16. As a group, present your data to the class.

17. **If completing the 24-hour observation**, allow your teacher to return the Petri dishes to the incubator.
If completing the 48-hour observation, properly dispose of the bacterial cultures.
    - Place the Petri dishes inside your group's zipper seal bag and close securely.
    - Give the sealed bag to your teacher.

Microbial Life Analysis Sheet

Write a description of the bacterial culture	Sketch the bacterial culture (Use colored pencils when appropriate)
Date: Time: Temperature: Shape and color: Translucent: Other:	Object tested: Group Members:
Date: Time: Temperature: Shape and color: Translucent: Other:	Object tested: Group Members:
Date: Time: Temperature: Shape and color: Translucent: Other:	Object tested: Group Members:
Date: Time: Temperature: Shape and color: Translucent: Other:	Object tested: Group Members:

Student reading section:

Microbes live everywhere! While many microbes on Earth are harmless, and can even be helpful to humans, some microbes can be unsafe.

Microbes belong to a group all by themselves because they are neither plants nor animals. Because they can multiply extremely quickly, it is normal to find millions of them in the same location.

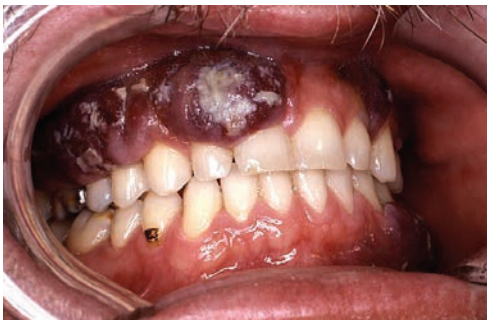


Figure 1: Inside a mouth where microbes cultivate (courtesy of Hardin MD/ University of Iowa and The Centers for Disease Control and Prevention)

Some microbes or "germs", such as bacteria and mold, can grow on food, dirty clothes, and garbage that people produce. Microbes live on your skin, in your mouth, nose, hair, and inside your body.

Microbes can also be found aboard the International Space Station (ISS). NASA scientists have reported that some germs on the ISS can increase to a higher number than they do on Earth. Therefore, cleanliness and proper disposal of garbage is an important part of living on the ISS.

Scientists who study microbes are called microbiologists and microbiology is the study of microorganisms or microbes. The root word "micro" comes from Greek and means "small". These microbes are so small that powerful microscopes are needed to be able to see them. At the Johnson Space Center in Houston, TX, NASA microbiologists study the small microbes in the air, water, food, and surfaces of the ISS. Controlling the microbes inside your body is an important part of staying healthy. So, where can you find microbes?

Microbiologists have found that microbes can live just about everywhere, even on us! We have trillions of microbes inside and outside of our bodies. Run your tongue over your teeth—you are licking thousands of microbes that normally live on your teeth. Millions of them live on your tongue, too. A large part of the mass of your body is actually something else: bacteria, viruses, and fungi.

Microbes are in the world around you, too. If you pick up a fistful of garden soil, you are holding hundreds (if not thousands) of different kinds of microbes in your hand. A single teaspoon of that soil contains over 1 billion microbes of bacteria, about 120,000 microbes of fungi and 25,000 microbes of algae.

Microbes have been around for billions of years because they are able to adapt to the ever-changing environment. They can find a home anywhere, and some of them live in places where we once thought nothing could survive.

For example, scientists have discovered microbes living in the boiling waters of hot springs in Yellowstone National Park. Other heat-loving microbes live in volcanic cracks—miles under the ocean surface, where there is no light and the water is a mixture of poisonous chemicals. Other microbes live in the permanently frozen ice of Antarctica. Microbes have also been found living inside the stones that make up the walls of old cathedrals in Europe.

Geyser in Yellowstone National Park.

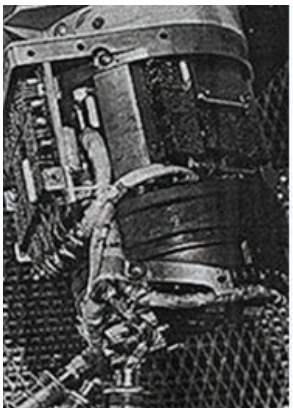


Figure 2: Television camera from Surveyor 3.

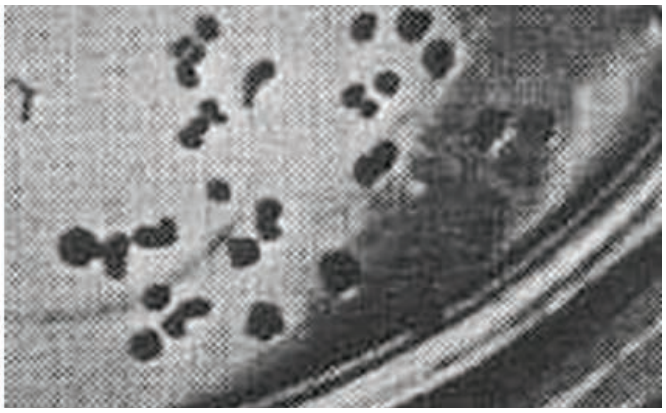
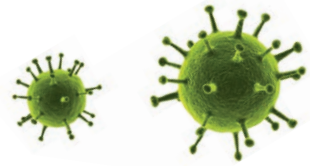


Figure 3: Bacteria found on the television camera of Surveyor 3.

Microbes can even survive in space. On April 20, 1967, the unmanned lunar lander Surveyor 3 landed near Oceanus Procellarum on the surface of the Moon. One of the onboard items included a television camera. Two-and-a-half years later, on November 20, 1969, Apollo 12 astronauts Pete Conrad and Alan L. Bean recovered the camera. When NASA scientists examined it back on Earth, they were surprised to find some bacteria called *Streptococcus mitis* were still alive. Because of the precautions the astronauts had taken, NASA could be sure that the germs were inside the camera when it was retrieved, so they must have been in the camera before the Surveyor 3 was launched. These bacteria had survived for 31 months in the vacuum of the Moon's atmosphere. They may have frozen or dried inside the camera, which are two ways normal bacteria can enter a state of deep sleep.

Figure 4: Close-up of bacteria that survived for almost 3 years on the moon.

Some scientists even believe there is a possibility that bacteria may have once lived on Mars. The photograph below (taken through a microscope) shows what some scientists believe may be the fossils of tiny bacteria in a rock that formed on Mars about 4.5 billion years ago. The rock crash-landed on Earth as a meteorite thousands of years ago.



Explain

When you have completed your observations, study your data and answer the following questions.

1. How is the control side of your Petri dish used?

2. What is an incubator?

3. How did you choose your sample?

4. Does the sample growth lead you to believe that there are few or many microbes in your environment? Why?

Evaluate:

Update the HOW DID YOU FIND OUT and LEARNED columns in your KWHL chart. Then answer the following questions:

1. Restate your hypothesis

2. Explain how your results do, or do not, support your hypothesis.

3. Microbes are too small to see without a microscope. How did you observe and measure microbe growth without seeing each microbe?

4. What was the purpose of using light bulbs to grow the microbes?

5. Where else do you think you would be able to find a large amount of microbes?

Elaborate

1. How can you observe life around you that cannot be seen?

2. Does your data support your hypothesis? Why or why not? Compare your data with your class.

3. As a group, develop a plan as to how you help maintain a clean and microbe-free school. How could you do this at home?

4. Imagine you are a microbiologist concerned about astronaut safety. What would be your top three recommendations to NASA to reduce the microbial level aboard spaceflight missions?

Extend

1. A company makes cleaning supplies and has asked your group for advice. They would like to investigate which surface might be the most important to clean. Which surface in your school would you suggest they use to test their cleaning supplies?

2. Read the “Did you know?” graphic. Why do you think astronauts have their bodies wiped with rubbing alcohol before they fly to the space station?

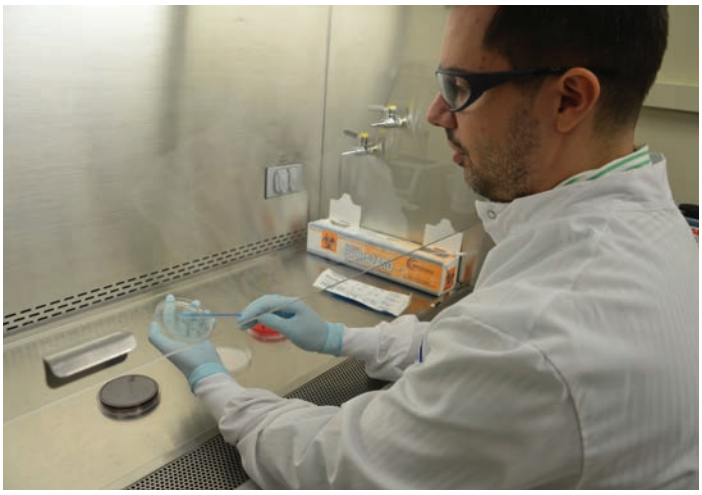
3. Astronauts are kept away from other people for a week before launching into space. How does this keep them from getting sick in space?

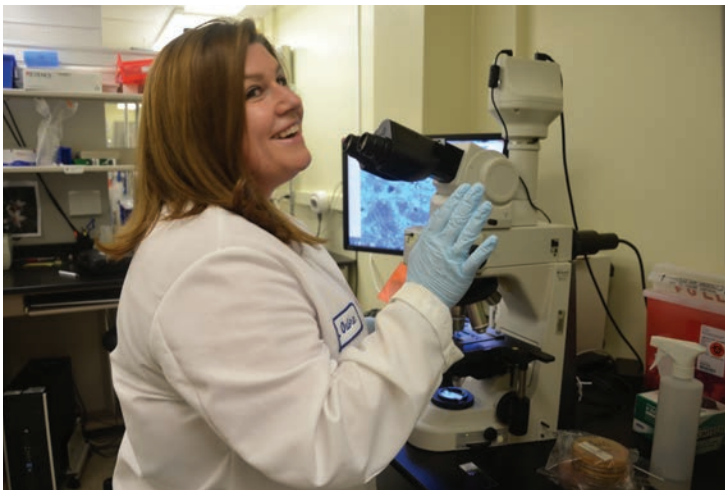
4. Look at your data again. Where on the ISS would you expect more microbes to be found? Where would you expect the least amount of microbes?

5. Pick one of your petri dishes and create a diary or story from the perspective of the microbes inside. For example, if you were one of the microbes in the petri dish, what would be your life story?

Thank you to our Contributors:

Thanks to subject matter experts Dr. Cherie Oubre, Rebekah Bruce, and Dr. Mark Ott for their contributions to the development of this education material. These scientists work in the Microbiology Laboratory at the NASA Johnson Space Center (JSC) in Houston, Texas.





Are you interested in working with microbes that are too small to see, yet are critical in the health and well-being of others? You, too, can continue to study microbiology and maybe one day you can work in the NASA Microbiology Laboratory with the highly skilled interdisciplinary team at the Johnson Space Center!

The Microbiology Laboratory serves as a NASA-wide resource for microbial issues associated with living and working in closed environments specializing in spaceflight operations, including requirements development, environmental monitoring (including enumeration, microbial characterization and identification), potable water analysis, crew diagnostics, food analysis, crew training, biosafety review of payloads, and flight hardware and technology development. When a microbe is sampled on the ISS, chances are very good that the JSC Microbiology Laboratory has already studied it. The wonderful scientists in this lab devote their careers to studying these very small organisms that are too small to see, but are necessary to maintain a healthy life in space as well as on Earth.

This lesson was developed with the support of Sylvia Sáenz, a Bilingual Educator at Tinsley Elementary in Houston ISD. She has been teaching for nine years and currently works as a 3rd grade bilingual educator.

This lesson was beta-tested with the support of the following teachers: ***Ellen Hutto*** *has taught 6th, 7th, and 8th grade and has a true passion for space science. She is also the founder and director of Saltgrass Science Programs.* ***Jami Temple*** *has taught 5th grade and, at the time of this activity being developed, taught math and science, and spent any spare time she had reading and spending time with her 19-month old son, Travis.*

Both teachers were proud to be Ross Roadrunners at James H. Ross Elementary in League City, Texas.

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