National Aeronautics and Space Administration
Ames Research Center

Educational Product	
Educators	Grades 5-8

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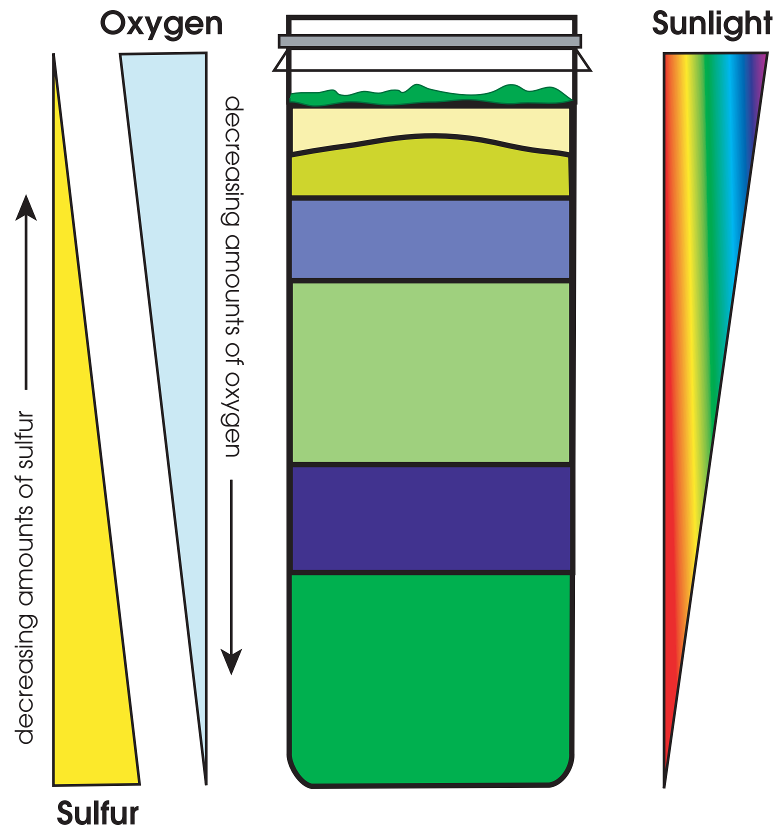
Building a Winogradsky Column

An Educator Guide with Activities in Astrobiology



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NASA Quest

NASA Quest: Building a Winogradsky Column

National Aeronautics and Space Administration
Office of Education

Table of Contents

Building A Winogradsky Column

Students will construct a Winogradsky Column to observe the growth of microbes in a column of mud. During this investigation students will develop a hypothesis, record their observations and results and form conclusions. They will compare and contrast their methods during the investigation with those of the astrobiologists performing research in the field and the laboratory.

Goal: Students will perform an investigation and compare their methods with scientists.

Educational Objectives and Standards

Educational Objectives	National Education Standards/Benchmarks	Evaluation of Objectives
1. Students will conduct their own field investigation that will involve making observations and forming explanations about microbes.	**Meets**: NSES A1 Benchmarks 1B (3-5) 1, 1B (6-8) 1 ISTE 3, 4, 5 **Addresses**: NSES A2 Benchmarks 1B (3-5) 2, 1B (3-5) 3, 1B (6-8) 3 ISTE 6	• Record information for each step of the investigation in the Lab Journal. • Write a paragraph discussing the results of the investigation. • Write a conclusion paragraph summarizing the main points of the investigation and explaining why the hypothesis was or was not correct. See Lesson (need to link)
2. Students will compare and contrast their methods with those of the astrobiologists.	**Meets**: Benchmarks 1B (3-5) 1, 1B (6-8) 1 ISTE 3, 4, 5 **Addresses**: NSES A1, A2 ISTE 6	• Create a Venn diagram comparing and contrasting the methods they used during the investigation with those used by the astrobiologists. See Lesson (need to link)

Prerequisite Knowledge

Prerequisite Conceptss	Resource
Living thing: A living thing requires materials such as energy and nutrients, grows, and makes more of itself.	**Activity**: Point out or show students ten items. Include some living and some non-living things, such as a classmate, computer, pencil, plant, mushroom, or class pet. Ask the students to decide whether each item shown is living or non-living. Once all items have been discussed with the students, ask them to think about the qualities that they can use in the future to determine if something is living.
Light as source of energy: Light provides the energy needed for living things such as plants to grow.	**Activity**: Have two plants available that are the same type and approximate size. Ask the students what a plant needs to grow. Student responses may include water and light. Ask the students to describe what would happen if a plant was not watered. Then ask the students to describe what would happen if a plant did not get any light. Explain to the students that you are going to place one plant in an area where it can get light (such as a windowsill) and another plant in an area where it will not receive any light (such as a closet). Explain that the plants will be watered on a regular basis. Check on the plants every 3 days for a period of approximately two weeks. Have the students make observations about both plants. Discuss with students the need for light as a source of energy for the plants.
Opinion: An idea one thinks to be true, but that is not based on evidence. **Vs. Fact**: Information that is true, based on evidence.	**Activity**: Show students a book that they have recently read. Ask them to describe what they thought of the book. Explain that these thoughts are opinions because they are not based on measurable evidence, and one student’s thought on the book may differ from another student’s. Next have a student volunteer measure the length of the book and have a second volunteer measure the length of the same book. The measurements should be exactly the same, although human error may make them slightly differ. Explain to the students that the length of the book is a fact because it can be proven or measured with consistent results.
Observation: Using the five senses to make a factual and detailed description.	**Activity**: Show students an object. Ask them to describe the object using their five senses. Explain to them that their descriptions must be factual and detailed. Repeat this activity with numerous objects.
Interpretation: To present an explanation using facts and evidence to support the reasoning. Different explanations can be given using the same facts (depending on the strength of logic and use of evidence).	**Activity**: Have students take sides on an issue. Then have the students prepare for a debate by gathering facts about the side they have chosen. Have the students participate in a debate using only facts. After the debate, discuss which explanations were most confusing. Help students to identify explanations that aren’t logical or that go beyond evidence. Have students identify the strongest arguments and explain why.

Suggested Schedule

(see calendar)

Materials

For Engage Activities:
- Mushroom or bread with mold to use as an example of a microbe
- Magnifying glasses to use on nature walk (optional)
- Class set of paper and pen/pencil

For 1 Winogradsky Column: (materials needed for each group)
- 2-liter plastic soda bottle
- 5 cups of mud/sand from a forest, garden, lake, pond, marsh, or ocean (can be
- gathered from a saltwater or freshwater area)
- 5 cups of water from each mud/sand location used
- 1 small bucket
- 1 cup (measuring cup if possible)
- 1 paint stirrer or large spoon
- 1 sheet of newspaper
- 1 tablespoon powdered chalk
- Hard boiled egg yolk or calcium sulfate
- 1 spoon (measuring spoons if possible)
- Aluminum foil or plastic wrap and rubber band
- Pencil sharpener (if available, will be helpful for crushing the chalk)
- Mortar and pestle (if available, will be helpful for making the egg yolk into powder)
- Lab Journal without procedures included or
  Lab Journal with procedures included (1 for each student in group)
- 1 lamp with 40- to 60-watt light bulb (optional)

Note to teacher: Depending on grade level, the following information can be used to explain a Winogradsky column and why certain materials are used to make one.

What is a Winogradsky column:
A Winogradsky column is a device based on a more complex one made by Russian scientist Sergei Winogradsky in the 1880's. The column is a translucent container filled with mud, water, and other materials such as shredded newspaper, powdered chalk, and egg yolk mixed together. The column is a self-contained recycling system powered only by light. The purpose of the column is to provide an environment for microbes to grow. The concentration of oxygen, nutrients, and light affect the types and amount of microbes that grow. The column can help students understand the growth of microbial communities and the interdependence of microbes - the activities of one microbe allow another to grow.

Why materials are added:
- 2-liter bottle: A translucent container is needed so that light can get through. This allows photosynthetic microbes to grow.
- Mud/sand: In a small handful of soil, there are billions of microbes. Mud/sand are sources of microbes.
- Water: The water from the mud/sand location is a source of microbes as well.
- Shredded newspaper: Newspaper is a source of carbon. Carbon is the building block of life, and it provides energy to the microbes so they can grow.
- Powdered chalk: Chalk is also carbon source providing energy for microbial growth.
- Egg yolk or calcium sulfate: Egg yolk or calcium sulfate is a source of sulfur. Some microbes use sulfur as their source of energy.

For Evaluation:
- Class set of paper or poster board for Venn diagram
- Class set of Scientific Inquiry Evaluation Rubric (for lab journals)
- Class set of Scientific Inquiry Evaluation Rubric (for student-designed experiments)
- Class set of Generic Rubric (for Compare/Contrast activity)

Equipment

- Overhead projector, blackboard, or chart paper
- Computers with Internet browser and connection
- Optional Equipment:
- LCD panel or TV monitor connected to a computer with a video card
- E-mail account

Facilities

- Classroom
- Computer lab (optional)

Preparation

- Run a class set of ChatQuestion Generator.

- Preview NASA Web sites to make sure they work and are appropriate for your students.

- Locate the resources relevant to this event. These resources can include career fact sheets, biographies, and journals on the scientists participating in the webcast. If students won't be able to access these resources on the computer, print out copies of them.
  Link to webcast bios:
  http://quest.arc.nasa.gov/astrobiology/events/fieldwork/ed.html#profiles

- If you are participating in a webcast, chat, or forum, follow the directions for Participating in a Webcast, Downloading RealPlayer, or Participating in a Chat.

- **Note**: Many districts have blocks to all chat lines on the Internet. Exploration of the Web site will help determine unexpected blocks of NASA Quest sites because of supposed access to online chatting that does not adequately screen out offensive language. If a block is found, it is up to you to attempt to get the site(s) unblocked. Follow your district's guidelines for unblocking a Web site. NASA Quest chats are moderated by an adult, so no inappropriate language is posted. Also, no personally identifying information is posted (i.e., e-mail, phone number).

- Check the Schedule to determine when the webcast is scheduled and if your class can attend at that time.

Common Misconceptions	Suggestions to help challenge these
A common misconception that students have is that microbes are not living things.	Discuss with students the needs of microbes and the needs of humans. The basic needs for both are the same: water, nutrients, and energy.
Students tend to look for or accept evidence that is consistent with their own ideas. (Benchmarks for Science Literacy, page 332	It is important for students to have many experiences with a concept which will provide evidence that challenges their ideas. They must reach these conclusions on their own through experiences.

Engage

What is a microbe?

1. Ask students to name different types of things that scientists study. List their answers on the board.
   Note to teacher: Student answers may include plants, animals, stars, space, chemicals, humans, and diseases.

2. Ask the students how scientists study the things that are listed on the board. Write their answers in a separate column.
   Note to teacher: Student answers may include using a microscope, magnifying glass, telescope, and going up in the space shuttle.

3. Explain to the students that some scientists specialize in studying living things.

4. Ask the students how scientists study living things. Write their answers in a third column on the board.
   Note to teacher: Students may repeat many of their answers from step 2.

5. Explain to the students that they will be conducting an investigation involving living things and will be comparing their methods with the methods NASA scientists use.
   Note to teacher: This is the goal of the lesson.

6. Ask the students to name some of the living things that they know.
   Note to teacher: All of the living things that students mention will most likely be animals and may be plants.

7. Once the students have had time to share living things that they know, show the students a mushroom or bread mold. Ask students if the example you are showing is a living thing. Have them explain the characteristics of a living thing.
   Note to teacher: The students should include in their explanation that the mushroom or bread mold requires energy and nutrients, grows, and makes more of itself. If the students struggle with this concept, refer to the activity suggested under the Prerequisite Concepts for a living thing.

8. Explain to the students that the example (mushroom or bread mold) is called a microbe. If the students have not heard of microbes before, it would be beneficial to explain that if they eat mushrooms on their pizza, they are eating microbes. If they eat yogurt, they are eating microbes because microbes turn milk into yogurt. If they leave food in the refrigerator too long, microbes will grow on it.

9. Explain that microbes are tiny living things that are too small to be seen with just the eyes.
   Note to the teacher: Students often have difficulty understanding that there are creatures so small a magnifying glass or microscope is needed to look at them.

10. Using the links provided, have students look at information on microbes. If this is not possible, check out a book on microbes from the library. It is very helpful for the students to look at images of microbes so they can begin to understand what they look like.

    Links to microbe information:
    - http://www.microbe.org
    - http://commtechlab.msu.edu/sites/dlc-me/
    - http://www.pfizer.com/rd/microbes/

Note to the teacher: Depending on time and grade level, the extra information below can be included in the lesson. However, students, do not have to understand this information for the lesson.

Interesting microbe information:

- Microbes live almost everywhere: in the soil, water, air, plants, and animals, including humans.
- Your mouth is a habitat for millions of microbes. There are also microbes in your intestines to help with digestion. There are microbes all over your body.
- In a handful of soil, there are hundreds to thousands of different types of microbes.
- Some microbes live in hot springs, volcanoes, and glaciers. Some scientists believe there could be microbes on Mars.
- There are four main types of microbes: viruses, bacteria, protists, and fungi.
  - **Viruses:** Examples are those that cause the flu, common cold, chickenpox, HIV, measles, mumps, and rabies. Scientists do not agree on whether to consider viruses as living or non-living organisms.
  - **Bacteria:** Examples are those that cause strep throat, scarlet fever, tetanus (lockjaw), Lyme disease, and meningitis. A small percentage of bacteria cause sickness. Many bacteria are helpful. For example, one type of bacteria causes milk to turn to yogurt. Another type produces an antibiotic that can be used to treat infections.
  - **Protists:** Examples are slime mold, paramecium, volvox, and euglena.
  - **Fungi:** Examples are mold, mildew, mushrooms, and yeast.

11. Discuss with the students why scientists might study microbes.
    Note to the teacher: The students may respond with such answers as to help prevent the spread of infections, to learn which microbes are harmful and which are helpful, to learn how to get rid of mildew in your shower, to learn what mushrooms can be eaten, and to learn what soaps kill bacteria on our hands.

12. Explain to students that there are scientists called astrobiologists who study life in our universe. The NASA Astrobiology Institute is interested in three fundamental questions:
    - How did life begin and evolve?
    - Is there life elsewhere in the universe?
    - What is the future for life on Earth and beyond?

    These scientists study microbes specifically to understand the extreme environments in which microbes live so that they can determine what kinds of environments to study on other planets and moons that might have life. Explain to the students that during the next month the students will get to interact with astrobiologists through webcasts, which is streaming audio and video on the web.

Nature Walk

1. Once students have a general understanding of what a microbe is, explain to them that they are going on a nature walk. On this walk, they are going to make observations about the world around them. They should focus on looking for and thinking about microbial life. If available, take magnifying glasses for students to use.

Variation: If there are no natural areas near your school, bring in samples of nature such as leaves, flowers, soil, part of a compost pile, real or preserved specimens, or bark from a tree.

2. Have students bring paper and pen/pencil on the walk so they can record their observations and any questions.

3. Before leaving, it is important to discuss with students the importance of observing nature without disturbing it.

4. At the beginning of the nature walk, have the students note the time of day, temperature, cloud cover, and wind factor. Discuss with the students that these factors affect the life that will be present on their walk.
   Note to teacher: You can explain to students that scientists record this information when they are in the field in order to help them better understand the data.

5. The nature walk can be conducted in whatever manner is most appropriate for your students. A recommendation is to lead the students on a short walk, asking them questions as you go, and having the students point out things they observe. Next have the students divide into partners or small groups and have them choose a small area to explore in detail. This is a great time for the students to look for signs of microbial life. At this time, magnifying glasses could be passed out. The students should be encouraged to turn over logs, observe small puddles of water, look at soil, and even look at their own hands using their hand lenses.
   Note to teacher: Depending on location of the nature walk, the most common forms of microbial life will be protists swimming in the puddles of water, bacteria on the students' hands (although bacteria will not be visible with just a hand lens), and fungi, such as mushrooms. It is difficult to see most microbes without a microscope, so keep this in mind if the students have trouble finding microbes. Focus their attention on making general observations about nature, if microbial life cannot be seen.

6. After completing the nature walk, discuss with the students what they did on their walk. Make a large chart with two columns. Label the first column "What We Did" and label the second column "What Scientists Did/Would Do."
   Note to teacher: You will add to this chart throughout this lesson, so leave plenty of room. There will be a total of four sections that you can put on the chart now or as you go through the lesson: Nature Walk, Preparation for Investigation, During the Investigation, and After the Investigation.

7. Ask the students to share what methods they used when making observations and looking for microbes on their walk. Write student answers in the first column of the chart.

8. Explain to the students that over the next month they are going to be learning about what scientists do when they perform an investigation. Ask the students to predict what they think a scientist would do on a nature walk. Write their predictions in the second column of the chart.

9. Discuss the similarities and differences between the two columns.

10. Post this chart in the classroom so more can be added to it throughout the lesson.
    Note to teacher: This chart will be referred to as the "Compare/Contrast Chart" throughout the rest of the lesson.

First Webcast: Before Going into the Field

1. Before participating in the online events, have the students review the biographies (bios) of the scientists they will be talking to.
   Link to webcast bios:
   http://quest.arc.nasa.gov/astrobiology/events/fieldwork/ed.html#profiles

2. Once the students are knowledgeable about the scientists, discuss with the students the main focus for the webcast. During the first webcast, the students will learn what an astrobiologist does, more information about microbes, preparation scientists do before conducting a fieldwork investigation, as well as the materials the students will need for their investigation.

3. After students understand the main focus of the webcast, have the students work in groups of three to four to brainstorm questions for the scientists using the Chat Question Generator. Then have them decide the five best questions for their group.

4. Have the students share the questions their group developed with the class. If possible, combine questions from different groups. This will shorten the list of questions.

5. Post these questions and have the students read them. Determine the top five to ten questions that they want to ask during the webcast.
   Note to teacher: Keep the other questions handy in case there is time during the webcast for more questions to be asked.

6. Attend the first webcast on September 18.
   Note to teacher: During this webcast, students will be introduced to the materials needed to build the Winogradsky column.
      Link to webcast participation:
      http://quest.arc.nasa.gov/astrobiology/events/fieldwork/index.html#participation

Online Forum

1. After the first webcast, an online forum will be available for students to ask astrobiologists questions. This is a great opportunity for students to ask questions they have about astrobiology and microbes as well as the materials needed for the Winogradsky column.

Forming a Hypothesis

1. After attending the webcast, lead a discussion using the following questions:
   - Where were the scientists during the first webcast? *(Baja California, Mexico)*
   - What were they studying while they were at this location? *(microbial mats)*
   - What are microbial mats?
   - Do you think it would be interesting to study microbial mats?

   Note to teacher: Microbial mats are groups of microbes that live in layers of soil and mud. Scientists study microbial mats to understand early life forms and what environments and conditions led to their development, since microbial mats populated the early Earth and are some of the oldest life forms that we know of.
   If you or your students would like to learn more about microbial mats, visit NASA's Astrobiology Institute Web site at http://nai.arc.nasa.gov/index.cfm?page=focus.

2. After this discussion, explain to the students that since we can not travel to Baja where the microbial mats are, we are going to grow microbes here in the classroom. Our investigation will help us understand better the scientists' work.

3. Review with the students the investigation that was discussed by the scientists. Be sure the students understand that the Winogradsky column will be an environment for microbial growth. Review the basic materials for making the column.

4. As a class, discuss what skills scientists need to write a hypothesis from a question. This discussion should include the fact that scientists must know the topic they are investigating well before a hypothesis can be developed. Scientists often do research on the topic before making a hypothesis.
   Note to teacher: Depending on grade level, you may want to replace the word hypothesis with the word prediction. Once the students have completed the next few directions, you can then explain what a hypothesis is.

5. Divide the students into small groups and ask them to discuss the Winogradsky column. What changes do they think will occur in the column? Why do they think these changes will occur? Have the students record all of the ideas that their group members develop.

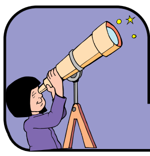
6. Once all groups have brainstormed possible changes in the column, have every student or group choose the idea each thinks is best or most likely to occur.

7. Ask the students to write their best idea in the form of a sentence in their lab journals. Explain to the students that this is what scientists refer to as the hypothesis. A hypothesis is a prediction that uses reasoning or evidence to support it.
Note to teacher: A hypothesis can be developed only if the person doing the research has previous knowledge on the subject matter. This is important to explain to the students.

8. Groups should share their hypotheses verbally with the class and explain their reasoning.
Note to teacher: At this point, the students' hypotheses might be very general. After actually constructing the Winogradsky column, changes may be made.

9. Have the Compare/Contrast Chart ready. Discuss with students what they have done so far to prepare for their investigation. List this information in the chart under the "Preparation for Investigation" section and "What We Did."

10. Discuss with the students what the scientists did to prepare for their investigation. List this information in the chart under "Preparation for Investigation" section and "What Scientists Did."



Explore

Second Webcast: In the Field

1. Before participating in the second webcast, have the students review the bios of the scientists they will be talking to.
   Link to webcast bios:
   http://quest.arc.nasa.gov/astrobiology/events/fieldwork/ed.html#profiles

2. Once the students are knowledgeable about the scientists, discuss with the students the main focus for the webcast. During the second webcast, the students will learn what astrobiologists do in the field, what instruments they use to gather data, and how to prepare the Winogradsky columns.

3. After students understand the main focus of the webcast, have the students work in groups of three to four students to brainstorm questions for the scientists. Then have them decide the best five questions for their group.

4. Have the students share the questions their group developed with the class. If possible, combine questions from different groups. This will shorten the list of questions.

5. Post these questions and have the students read them. Determine the top five to ten questions that they want to ask during the webcast.
Note to teacher: Keep the other questions handy in case there is time during the webcast for more questions to be asked.

6. Attend the second webcast on September 20.
   Note to teacher: Have the students take careful notes on how to prepare their experiment and what they will be doing over the course of the next month.
   Link to webcast participation:
   http://quest.arc.nasa.gov/astrobiology/events/fieldwork/index.html#participation

7. After the webcast, have the Compare/Contrast Chart ready. Discuss with the students what the scientists did while they were in the field. List this information in the second column of the chart. The students will record information on what they did during their experiment later in the lesson.

8. Gather the materials for the Winogradsky column. The column may be made as a class activity or small group activity. Breaking students into groups of about four students would allow each student to have greater participation in the activity.

Building the Column

One Day Prior to Building the Column: (for teacher)

1. Gather mud or sand from a forest, garden, lake, pond, marsh, or ocean.

Extension: If possible, gather mud or sand from a variety of places. Columns can be set up representing each place the mud or sand was collected from. This will allow the students to compare the microbial growth from a variety of places. For example, if some of the mud was from a freshwater area while some was from a saltwater area, a comparison could be made about the amount of microbial growth.

2. Gather water from each mud or sand location used.

3. Carefully cut off the top of the 2-liter bottle to use as a funnel.

4. Use a pencil sharpener to powder the chalk. Depending on grade level and resources available, students can do this step while making their column.

5. Use a mortar and pestle to mash the hard-boiled egg yolk. Depending on grade level and resources available, students can do this step while making their column.

6. Set out materials for each group.

Directions for Building the Column: (for students)

1. In a small bucket, add 5 cups of mud or sand. Remove any sticks, leaves, or rocks.

2. Stirring the mud or sand with a large spoon or paint stirrer, slowly add water until the mixture is like thick cream. Be careful not to add too much water.

3. Shred a full sheet of newspaper into very small pieces. Add the newspaper shreddings to the mixture.

4. Then add 1 tablespoon of powdered chalk to the mixture.

5. Add 1 teaspoon of mashed hard-boiled egg yolk or calcium sulfate to the mixture.
   Note to teacher: 1 egg yolk equals approximately 4 teaspoons of egg yolk powder.

6. Stir the mixture gently using a large spoon or paint stirrer. Make sure the mixture is fluid so it will flow through the funnel.

7. Remove any labels from your bottle. Make a new label with the names of the students in your group as well as the source of the mud or sand.

8. Set the funnel into the mouth of the bottle. Secure the funnel with tape or have a group member hold the funnel in place.

9. Pour or scoop a small amount of the mixture into the base of the bottle.

10. Place your hand over the top of the bottle and tap the bottom of the bottle firmly on the table. This helps the mixture settle and removes oxygen that is trapped in the mixture.

11. Repeat the two previous steps of adding a small amount of mixture and settling the mixture until the bottle is about 90 percent full.

12. Stir the mixture in the bottle to remove any air bubbles.

13. Let the bottle sit for 30 minutes. The water that settles on top of the mixture should be about 2 cm deep. Add/remove the water in your bottle as needed.

14. Cover the bottle with foil or plastic wrap and a rubber band.

Extensions:
If multiple columns are made, place half of the columns placed in the dark. This will allow the students to compare microbes that require light with those that do not.
Note to teacher: Depending on grade level, a discussion on photosynthesis could be conducted at this point. Photosynthesis is the process by which living things such as plants make their own food by using energy from the sun. Students in the older grade levels can be introduced to the concept that without the photosynthetic activity of early bacteria, Earth's atmosphere would still be without oxygen.

Links to photosynthesis information:
http://photoscience.la.asu.edu/photosyn/education/colorchange.html
http://www.ed.gov/pubs/parents/Science/plants.html
http://www.pbs.org/ktca/newtons/9/phytosy.html
OR
Materials can be gathered from saltwater or freshwater sources. If you have access to both, half of the columns could be made with materials from freshwater sources while the other half could be made with materials from saltwater areas.

15. Once columns are completed, have students re-read their hypotheses and decide if they want to make any changes to it. Record this modified hypothesis in the lab journal.
Note to teacher: Scientists would not modify their hypothesis after beginning the investigation, but due to the students' limited knowledge on the subject matter, it may be helpful.

Extension:
Depending on time and grade level, the students could be asked to make more specific hypotheses. For example, the students could develop hypotheses to these questions:
- Will sunlight have an effect on the column?
- Will freshwater or saltwater allow more microbial growth?
- Will microbes be able to grow better at the surface of the column or at the bottom of the column?

Encourage students to provide reasoning behind their hypotheses.

16. Have students record in their Lab Journals their first observations about the column, including a picture of their column.

17. Place the completed column in a well-lit place away from direct sunlight. If you do not have a window, place the bottle about 60 cm from a 40- to 60- watt lamp. The column should not be exposed to direct sunlight or intense heat.

18. Have the students keep the bottle in one position. They should not move it.

Recording Data Each Week

1. Each week, have the students record room temperature and make visual observations of the amount of light in the room.

2. Then have the students draw, label, and color a picture of their column as well as record observations about the color and thickness of the layers in their Lab Journal. Students should record data on the same day each week in order to have the same number of days between each recording.
   Note to teacher: Once the layers forms, have the students measure the thickness of the layers (indicated by color change) in centimeters. These measurements can then be compared to the thickness of the layers from the field samples.

3. Have the students share the changes they have observed in their columns each week. Because this experiment occurs over a few weeks, try different methods of sharing data. Some ideas are verbally sharing, drawing accurate pictures of the columns and sharing these pictures with the class, and writing about the changes the students have observed. This allows students to begin to understand that scientists use many different methods when gathering data for an experiment.

Note to teacher: Depending on grade level, use the following information to help students in analyzing the data.

- *The initial changes that the students should see are green or purple spots inside the column. The spots will first appear on the side facing the light source. These spots are photosynthetic microbes.*
- *Photosynthetic microbes use different wavelengths of visible light to make food. If there is too much light or not enough light, these microbes will not grow.*
- *Columns that are placed in the dark will not grow photosynthetic microbes because there is no light to provide energy to make food. Other types of microbes that are not photosynthetic will grow.*
- *Layers of microbes will grow in the columns. At the top of the column, the oxygen concentration is high. Microbes that require oxygen are called aerobic and live close to the surface. From the top of the column to the bottom of the column, the oxygen concentration decreases greatly. Microbes that do not require oxygen live at the bottom of the column. These microbes are called anaerobic. This decrease in oxygen from the top of the column to the bottom is called a downward oxygen gradient.*
- *The concentration of sulfur is also important in the column. The columns have an upward sulfur gradient. Microbes that can survive without oxygen and instead use sulfur grow at the bottom of the column. Microbes that use oxygen and not sulfur grow at the top of the column.*
- *Possible results: In the top few centimeters of the column, cyanobacteria and algae may grow. This will appear as green patches. The next layer may be reddish purple or rust-colored regions. This is purple non-sulfur bacteria. Purple sulfur bacteria will appear as purple and violet regions. At the bottom of the column, green sulfur bacteria may grow, and it will be olive-green patches.*

Links that provide further discussion of results from a Winogradsky column:

- http://www.microbeworld.org/mlc/pages/activities.asp
- http://www.bsu.edu/teachers/academy/ecosystems/activity2.html
- http://helios.bto.ed.ac.uk/bto/microbes/winograd.htm
- http://www.pfrr.alaska.edu/~ddr/ASGP/HANDSON/OOZECITY/SCIENCE2.HTM

4. Discuss why there are differences in the changes in each column although all the columns were made out of the same materials.
Note to teacher: Include in this discussion the fact that the amounts of each material added, how closely the procedures were followed for setting up the columns, and location of the column may affect the growth of microbes. Discuss that one small change can have a major effect on an experiment. Depending on grade level, a discussion about the fact that each investigation needs a control and a variable would be appropriate here.

5. Once all of the data has been collected, have the Compare/Contrast Chart ready. Discuss with the students what they did during the investigation. Add this information to the section "During the Investigation" and "What We Did."

Online Forum

1. Students can post their data as well as any questions in the online forum. Astrobiologists will answer their questions.

2. Have students view data entered by other students. Discuss in small groups the similarities and differences in the data posted by other students.
Note to teacher: Depending on grade level, consider including in the discussion the following questions: Do scientists in different parts of the world get the same data when running the same experiment? Why or why not? What do scientists do to ensure that the data they have is accurate?

3. Have a different group each week respond to a question/information posted in the online forum. Encourage the students to add their own questions to the forum.

Explain

Summary of Results

- In small groups, have students look at all of the data obtained for their column (or for the class column). Ask the students to look for major observations and changes that occurred during the last few weeks. If the students bring up that the microbes grew in layers, discuss this observation using the following questions:
- What might have caused the layers?
- Why are the layers different?
- Why might different microbes grow in different places?

- Once the students have had time to discuss the results in small groups, bring the class back together and have each group share one important observation about their column. If multiple columns were made, remind the students that different groups will have different results. Explain that no group is wrong. Have the students discuss what might have caused the differences.

- Have the students write in paragraph form in their Lab Journals the most important observations and changes that occurred in their Winogradsky column. This activity can be done in small groups or individually. It is important to explain to the students that their paragraphs should only discuss the data and not explain why.

Variation: Instead of writing a results paragraph, students can create pictures with captions that explain the major observations and changes of the experiment.

Conclusions

1. Have students check to see if the hypothesis they recorded at the beginning of the experiment was correct based on the data they obtained. As a class or in small groups, discuss possible reasons for any differences between the hypothesis and the results.

2. Have the students write a conclusion paragraph. In this paragraph they should summarize the main points of the investigation, whether their hypothesis was or was not correct, why they think their hypothesis was or was not correct, and how the investigation could be improved if it were run again.

Third Webcast: After the Field

1. Prepare students to attend the third webcast by reviewing the bios of the scientists.

2. Have students brainstorm questions about what the astrobiologists do when they return from the field, what data the scientists collected, how they analyzed the data, and any problems that the students had during the investigation or while writing the results and conclusions.

3. Attend the third webcast on October 25.
   Link to webcast participation:
   http://quest.arc.nasa.gov/astrobiology/events/fieldwork/index.html#participation

4. After attending the webcast, ask the students how their experiment was like the microbial mats fieldwork and how it was different.
   Note to teacher: Students should understand that microbes grow in layers because different microbes need different things to survive.

5. Have the students review and finalize their results and conclusions. When they are finished, have the students turn in their Lab Journals to be evaluated.

6. Once the students have attended all three webcasts and turned in their lab journals, have the Compare/Contrast Chart ready. Discuss with the students what they did after the investigation. Add this information to the chart under the section "After the Investigation" and "What We Did."

7. Discuss with the students what the scientists did after the investigation. Add this information to the section "After the Investigation" and "What Scientists Did."

Extend/Apply

Design Experiment

1. Ask the students to share the basic steps they followed over the past few months to complete this investigation.
   Note to teacher: It would be helpful to write these steps on the board or chart paper so the students can refer back to them. These steps should include: 1. Develop a question; 2. Form a hypothesis; 3. List the materials; 4. Write the procedures; 5. Make observations/record data; 6. Write the results; 7. Write the conclusion. Discuss with the students that some of the above steps were done for them in this investigation.

2. Once all of the basic steps have been reviewed, explain to the students that they are going to design their own experiment about a living thing, following the scientific inquiry process that was modeled/practiced in this lesson.
   Note to teacher: You may want to have all of the students design an experiment about plants, depending on time and grade level.

3. It is recommended that the students share their question before going through the rest of the steps. Some students will struggle to come up with ideas while other students will have ideas that are not possible. Explain to the students that the questions should not be yes or no questions.

4. The students should develop a question, hypothesis, list of materials, procedures to follow for the experiment, and a table or chart to record data. The students will not write their results or a conclusion paragraph since they are not running the experiment.

Extension:

- Depending on time and grade level, the students could do research to learn more about their question before developing a hypothesis. This is what a scientist would do.
- For students who have a good understanding of the scientific inquiry process, encourage them to identify a control as well as only one variable in their experiment.
  Note to teacher: A control is the part of the experiment that is kept constant and is used as a comparison. A variable is the part of the experiment that is changed in order to test the effect of that change. For example, if two identical columns are made and one is placed in a window while the other is placed in a closet, the variable in the experiment would be light.
- If time allows, the student-designed experiments could be tested. The students could then go through all of the steps of the inquiry process.

Evaluate

1. Use the Science Inquiry Evaluation Rubric to evaluate students' lab journals.

2. Review the student-designed experiments. Use the Science Inquiry Evaluation Rubric to evaluate the question, hypothesis, materials, and procedures. If the students run the experiment, then their data collection, results, and conclusions can also be evaluated.

Compare/Contrast Using Venn Diagrams

1. Review the Compare/Contrast Chart with the students.

2. Have the students do one of the following activities to compare and contrast methods used in this lesson with methods used by an astrobiologist:
   - Ask the students individually or in small groups to make a Venn diagram. Have the students write "Methods used by students" in the first circle, "Methods used by astrobiologists" in the second circle, and then "Methods used by both" where the circles join. Have the students record information in each part of the Venn diagram. Then on the board or on a large piece of paper make a class Venn diagram. Have the students add one or more of their answers to the class diagram. Discuss why there are similarities and why there are differences between the methods used by the students and those used by the astrobiologists. Use the Generic Rubric to evaluate the individual/group work.

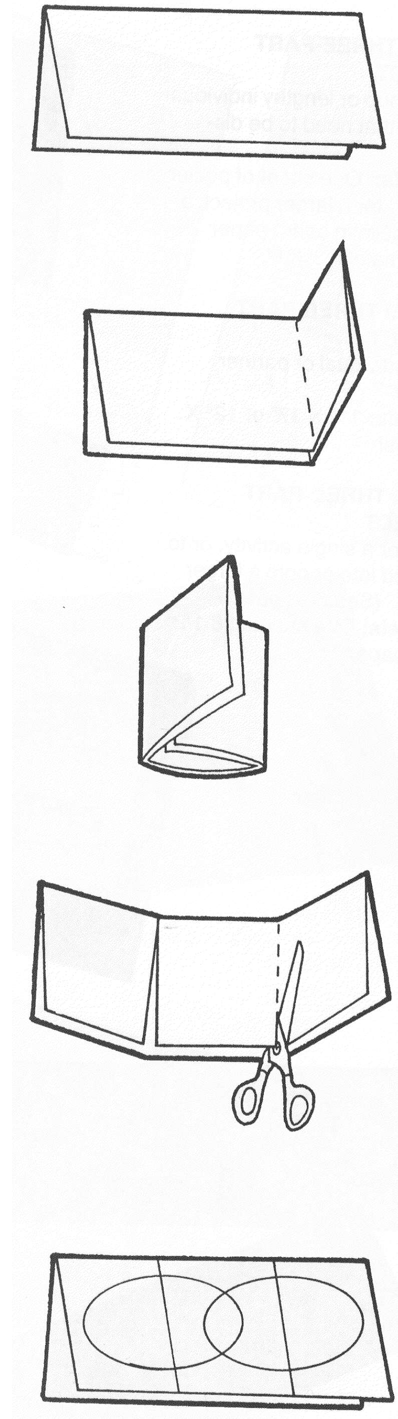
OR

   - Have the students construct a three-part book using the instructions below adapted from Dinah Zike's book The Big Book of How to Make Projects. *(Please see next page for directions and diagrams.)*

a. Fold paper or poster board like a hot dog.
b. Holding the paper horizontally with the fold of the hot dog up, fold the right side toward the center, trying to cover one third of the paper.
   Note: *Always fold the right edge over first so the final project will open and close like a book.*
c. Fold the left side over the right side to make a book with three folds.
d. Write the title of the project on the front of the closed book, and the student's name, the date, and any other important or required information on the back of the folded book.
e. Open the folded book. On the inside, or the side without writing, there are two folds. Place your hands between the two thicknesses of paper and cut up the "valleys" on the side that does not have writing.
   Note: Do not cut through the cover of the project, or the side with writing. If the cuts were made correctly, three inside tabs will be formed.
f. Draw a Venn diagram that covers the three-part book.
g. On the first flap, write "Methods used by students." On the middle flap, write "Methods used by both." On the last flap, write "Methods used by astrobiologists."
h. Have the students list information under each flap.
i. Encourage the students to be neat and creative when making their three-part books.
j. Use the Generic Rubric to evaluate their work.

OR

- Have the students write a paragraph that compares and contrasts the methods used by the astrobiologists with the methods used by the students. Use the Generic Rubric to evaluate the students' work.



Calendar for Building a Winogradsky Column

Teacher can move/change the date they do this activtiy.

Definite dates.

	Monday	Tuesday	Wednesday	Thursday	Friday
	10 SEPTEMBER What is a Microbe?	11 Nature Walk	12 Before 1st Webcast	13 **1st** Webcast	14 Forming a Hypothesis **First Day of Online** Forum
Participate in Online Forum	17 Before 2nd Webcast	18 **2nd** Webcast**: In the Field**	19 After 2nd Webcast	20 For teacher prior to building column	21 Building the column
	24	25 Collect Data	26	27	28
	1 OCTOBER	2 Collect Data	3	4	5
	8	9 Collect Data	10	11	12
	15	16 Collect Data	17	18	19
	22	23 Collect Data	24	25	26
	29	30 Collect Data	31	1 NOVEMBER	2
	5	6 Collect Data	7	8	9
	12 Results /	13 Conclusions	14 Before 3rd Webcast	15 **3rd** Webcast**: After the Field** **Last Day of Online Forum**	16 After 3rd Webcast
	19 Extend	20 Evaluate	21	22	23

Chat Question Generator

Name: ____________________

Directions:

- Read the resources of the people who will be hosting the chat found under Schedule of Events (These resources may include career fact sheets, biographies, journals, archived chats).
- List the expert's name, job title and description of what they do. (This information can be found in the resources listed for the expert on the Schedule of Events.)
- Based on the information given in the expert's resources, list at least five informed questions you would like to have answered during the chat. Your questions must comply with the following criteria:
  - the answer to the question cannot be found in the readings
  - the question cannot be answered by a simple "yes" or "no"
  - the question can be answered with a brief explanation
  - the question relates to the expert's work

Name	Job Title/Description	Questions

Winogradsky Column Lab Journal

1. Scientific Question:

2. Hypothesis: What is your educated guess to the question? Explain your reasoning.

3. Modified Hypothesis: After setting up your column, has your educated guess changed? If so, write your modified hypothesis and explain your reasoning.

4. Materials: What materials will you use to investigate?

Name:

5. Procedure: *Check each step off as you complete it.*

1. In a small bucket, add 5 cups of mud or sand. Remove any sticks, leaves, or rocks.
2. Stirring the mud or sand with a large spoon or paint stirrer, slowly add water until the mixture is like thick cream. Be careful not to add too much water.
3. Shred a full sheet of newspaper into very small pieces. Add the newspaper shreddings to the mixture.
4. Then add 1 tablespoon of powdered chalk to the mixture.
5. Add 1 teaspoon of mashed hard-boiled egg yolk or calcium sulfate to the mixture.
6. Stir the mixture gently using a large spoon or paint stirrer. Make sure the mixture is fluid so it will flow through the funnel.
7. Remove any labels from your bottle. Make a new label with the names of the students in your group as well as the source of the mud or sand.
8. Set the funnel into the mouth of the bottle. Secure the funnel with tape or have a group member hold the funnel in place.
9. Pour or scoop a small amount of the mixture into the base of the bottle.
10. Place your hand over the top of the bottle and tap the bottom of the bottle firmly on the table. This helps the mixture settle and removes oxygen that is trapped in the mixture.
11. Repeat the two previous steps of adding a small amount of mixture and settling the mixture until the bottle is about 90 percent full.
12. Stir the mixture in the bottle to remove any air bubbles.
13. Let the bottle sit for 30 minutes. The water that settles on top of the mixture should be about 2 cm deep. Add/remove the water in your bottle as needed.
14. Cover the bottle with foil or plastic wrap and a rubber band.

Winogradsky Column Lab Journal

1. Scientific Question:

2. Hypothesis: *What is your educated guess to the question? Explain your reasoning.*

3. Modified Hypothesis: *After setting up your column, has your educated guess changed? If so, write your modified hypothesis and explain your reasoning.*

4. Materials: *What materials will you use to investigate?*

Name:

5. Procedure: *Check each step off as you complete it.*

Winogradsky Column Lab Journal

6. Data Collection: Record and display your data in a chart, table, picture or graph.

Name:

7. Results: Summarize the most important observations and changes that occurred during the investigation.

8. Conclusions: Summerize the main points of the investigation. Was your hypothesis correct or not? Why do you think your hypothesis was or was not correct? How could the investigation be improved if it were run again?

Scientific Inquiry Evaluation Rubric

	4 Senior Scientist	3 Junior Scientist	2 Assistant Scientist	1 Science Student
Hypothesis	• Clearly stated • Complete sentence • Explanation is detailed, logical and strongly supports prediction.	• Clearly stated • Reasonable prediction • Satisfactory explanation supports prediction.	• Reasonable prediction • Explanation doesn't show strong logic or reasoning to support the prediction.	• Lacks clarity • Hypothesis doesn't relate to the scientific question. • No explanation is given to support the prediction.
Materials	• All necessary materials are listed. • All materials are accurately described.	• All materials needed are listed. • Some are not accurately described.	• The list of materials is missing some items.	• The list of materials is not given.
Procedure	• A plan is detailed and clear. • All steps are included and in order. • Steps are detailed, complete sentences.	• A plan is needs some clarification. • Some steps are missing. • Some steps need more detail.	• A plan is satisfactory but needs clarification. • Some steps are missing or are out of order. • Some steps need more detail. • Not all steps are in complete sentences.	• A plan needs a lot of clarification. • Important steps are missing and are out of order. • Most steps need more detail. • Steps are not written in sentences.
Data Collection	• Two or more data charts, tables, diagrams or graphs are included. • Charts, tables, graphs and diagrams are accurate, complete, detailed, titled and labeled. • Recorded observations are accurate and detailed, using four to five senses.	• One data chart, table, diagram or graph is included. • Charts, tables, graphs and diagrams are accurate but lack some details. • Recorded observations are accurate but could have more detail and use only three senses.	• At least one data chart, table, diagram or graph is included. • Charts, tables, graphs and diagrams are incomplete, poorly labeled, messy, inaccurate or incorrectly labeled. • Some recorded observations are inaccurate, lack detail and use only two senses.	• No data chart, table, diagram or graph is included. • Recorded observations are inaccurate, lack detail and use only one sense.
Results	• Results are expressed clearly, accurately and in detail. • Some patterns are described well in a written summary statement.	• Data results are expressed accurately, but some further explanation is needed. • Some patterns are described well in a general summary statement. • Sentence structure needs to be clearer.	• Data results are expressed accurately, but data is too specific for a summary. • No patterns are indicated. • Results are given in incomplete sentences.	• Data results are expressed inaccurately, don't match the data and/or data is too specific for a summary. • No patterns are indicated. • Results are given in incomplete sentences.
Conclusions	• Clearly explained • Complete sentences • Explanation is detailed, logical and strongly supports differences from prediction.	• Clearly explained • Reasonable explanation supports conclusions and differences from prediction.	• Explanation lacks detail or good logic. • Some sentences are incomplete.	• Conclusion lacks clarity. • Conclusion doesn't fit with the results and data. • No explanation is given to support the conclusions. • Sentences are incomplete.

Generic Rubric

	4 You're looking to be promoted!	3 You're qualified to do your job	2 Some training might help	1 Still learning your job?
Completeness	• Complete • Extra information is given.	• Complete	• Missing one or two key parts	• Incomplete • Inadequate • Needs to be redone
Grammar/ Spelling	• Well-written, clear • Grammar and spelling are accurate.	• Grammar and spelling are acceptable.	• May have some grammar or mistakes.	• Grammar and spelling errors prevent the audience from understanding the content.
Neatness / Creativity	• Very neat and well-organized • Many creative and original ideas are included.	• Neat and organized • Some creative ideas are in-cluded.	• Neatness or organization needs improvement.	• Neatness or organization prevents the audience from understanding the content.
Content	• Accurate • In-depth	• Accurate	• Inaccurate	• Inaccurate and incomplete

Contributed by Nancy Stubbs from Rancho Del Rey Middle School in Chula Vista, California