



New Fellow Education Transfer Plan Cover Sheet

Title of ETP	Microbial Mat Investigation
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Fellow's year-round email	robin@bucaria.com
Sponsor Company	NASA AMES RESEARCH CENTER
Name of Mentor	Dr. Brad Bebout
National Board Certificate Area	Early Adolescence/English Language Arts
<p>I, the IISME Fellow named above, affirm that the ETP I am submitting is my own work, that I acknowledged sources where appropriate, and that I avoided including any proprietary information of the Sponsor Company. NASA holds the copyright for this Educational Transfer Plan(ETP). I understand that IISME and myself are granted use of the ETP for pedagogical purposes.</p>	
<hr style="width: 50%; margin: 0 auto;"/> Signature	<hr style="width: 50%; margin: 0 auto;"/> Date

Category	<p>Curriculum Subject: Integrated (list areas) _English, Math, Science, Technology Level: Elem Middle High Other</p> <p><i>Staff Development</i> Describe _____</p> <p><i>Other</i> Describe _____</p>
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Objectives

California English Standards:

- Identify topics, ask and evaluate questions; and develop ideas leading to inquiry, investigation and research (Grade 7, Research and Technology 1.4).
- Write summaries of reading materials:
 - Include the main ideas and most significant details,
 - Use the student's own words, except for quotations,
 - Reflect underlying meaning, not just the superficial details (Grade 7, Writing Applications, 2.5, a-c).
- Deliver research presentations (Grade 7, Speaking Applications, 2.3).

California Science Standards:

- Organisms in ecosystems exchange energy and nutrients among themselves and with the environment (Grade 6, Standard 5).
- All living organisms are composed of cells, from just one to many trillions, whose details usually are visible only through a microscope (Grade 7, Standard 1).
- Students know Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time (Grade 7, Standard 4a).
- Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands (Earth Science, Life Science and Physical Science), students should develop their own questions and perform investigations. Students will:
 - a. Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data,
 - b. Use a variety of print and electronic resources (including the World Wide Web) to collect information and evidence as part of a research project,
 - c. Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence (Grade 7, Standard 7a-c).

Objectives

California Science Standards continued:

- Principles of chemistry underlie the functioning of biological systems (Grade 8, Standard 6).

California Mathematics Standards:

- Students collect, organize, and represent data sets that have one or more variables and identify the relationships among a data set by hand and through the use of an electronic spreadsheet software program (Grade 7, Standard 1).

Early Adolescence/English Language Arts National Board Standards:

- Accomplished Early adolescence/ English Language Arts teachers provide instruction in the skills, processes, and knowledge needed for writing to ensure that their students write effectively across many genres and for a variety of purposes and audiences (Standard IX: Writing).
- Accomplished Early Adolescence/English Language Arts teachers develop students' skills in listening, speaking, and viewing in many ways and for many purposes (Standard X: Listening, speaking, and viewing).
- Accomplished Early adolescence/English Language Arts teachers integrate learning and learning activities within the English language arts classroom and across the disciplines (XII: Integrated Instruction).

Early Adolescence/Science National Board Standards:

- Accomplished science teachers involve students in inquiries that challenge them and help them construct their understanding of nature and technology (Standard VII: Science Inquiry).
- Accomplished science teachers use a variety of instructional strategies to expand student's understanding of the major ideas of science (Standard VII: Fundamental Understandings).
- Accomplished Science teachers create opportunities for students to examine a variety of contexts of science, including its history, reciprocal relationship with technology, ties to mathematics, and impact on society, so students make connections across the disciplines of science and into other subject areas(Standard XI: Contexts of Science).

Objectives	<p>Early Adolescence/Mathematics National Board Standards:</p> <ul style="list-style-type: none"> • Mathematics teachers draw on their broad knowledge of mathematics to shape their teaching and set curricular goals. They understand significant connections among mathematical ideas and the application of those ideas not only within mathematics, but also to other disciplines and the world outside of school (Standard III: Knowledge of Mathematics). • Accomplished mathematics teachers are knowledgeable about and, where available, use current technologies and other resources to promote student learning in mathematics. They select, adapt, and create engaging instructional materials and draw on human resources from the school and the community to enhance and extend student understanding and use of mathematics (Standard VIII: Technology and Instructional Resources).
Abstract (50 words or less)	<p>Microbial Mat Investigation is an interdisciplinary unit designed to increase student knowledge in the areas of photosynthesis, data analysis, scientific inquiry, microbiology, and ecosystems, by having students study the research of Dr. Brad Bebout at NASA on microbial mats, and integrating classroom laboratory experiences. Science, Math, English, and Technology skills integrated throughout the unit build student’s science knowledge. Lessons developed for Science, Math, and English classes focus students on knowledge gained from studying microbial mats, such as why were they important in the formation of earth’s atmosphere, what can we learn about their biogeochemical processes, and why is this research important to NASA now.</p>
<p>Describe how your ETP aligns with the National Board Standard stated in your proposal.</p>	<p>Integrating study of the biogeochemical processes in microbial mats within Science, Math and English content areas addresses National Board standards such as writing, listening, speaking, scientific inquiry, contexts of science, fundamental understanding and the knowledge of Math. The integrated curriculum focus allows students to apply knowledge and skills from Science, Math and English in a real-world context.</p>

Describe the connection between your ETP and the Summer Fellowship.	The ETP directly connects to my summer fellowship that was designing curriculum to teach the importance of and the processes conducted in Microbial Mats. Throughout my fellowship, I researched the microbial mats, conducted experiments and designed lesson plans for these experiments, as well as designed other learning activities for the classroom. During the school year, I plan to use this curriculum with my colleagues as part of a unit in our interdisciplinary team.
Resources Needed	The resources that are needed for this ETP are access to The Microbial Mat Education Page through Dr. Brad Bebout's Lab website at: http://exobiology.arc.nasa.gov/ssx/microecobiogeo/ , as well as classroom internet access. Lesson plans developed during the fellowship will be available through the Microbial Mat Education page. Lab equipment and supplies are listed in the lesson plans.
Evaluation/Assessment Measures Used	Evaluation and Assessment will be conducted through discussion, presentations, and check off rubrics.
Formatting specifications	PC <u> X </u> or Mac <u> </u> (Must be in Word or Text Format) Software used <u> Microsoft Word </u> <u> X </u>
Submitted Copy	Soft and hard copy due to peer coach by the end of the summer fellowship. Also, a copy of the cover sheet signed by a school site administrator submitted to IISME Oct.3, 2004 to receive \$300 grant.
<p>I, the Mentor named above [please select one of the following],</p> <ul style="list-style-type: none"> <input type="checkbox"/> have read the attached ETP, and my comments, if any, appear below. <input type="checkbox"/> have read the attached ETP, and, as outlined in the IISME-Company Fellowship Agreement, have reviewed it on behalf of the Sponsor Company, and have determined that the ETP does not contain any Sponsor-proprietary information. My additional comments, if any, appear below. <p>Comments:</p> <hr/> <p>Signature _____ Date _____</p>	
<p>Administrator's comments:</p> <hr/> <p>Signature _____ Date _____</p>	

Microbial Mat Investigations:
an Integrated Unit on Microbial Mat Ecosystems

Created by
Robin Bucaria,
NASA Ames Research Center Fellow

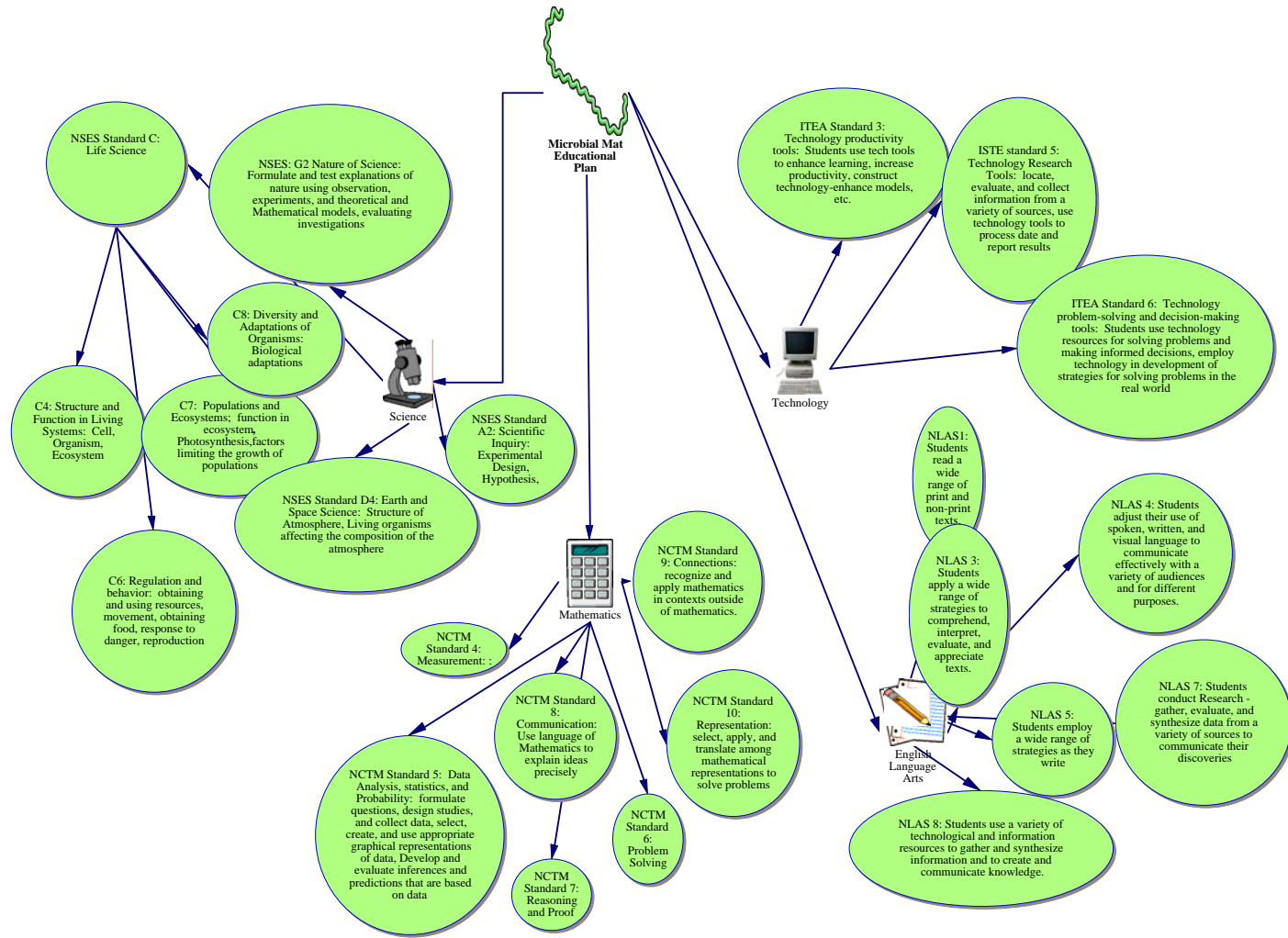
In cooperation with
Dr. Brad Bebout
NASA Ames Research Center
Summer 2004

Table of Contents

Introduction	3
Diagram of National Standards Addressed.....	4
Interdisciplinary Unit Calendar to be used by Math, Science and English Teachers.....	5
Unit Calendar to be used by one content area teacher.....	6
Science:	
Microscope Activity.....	7
Illustration: Life in a Microbial Mat.....	10
Interactive Biogeochemical Cycle.....	11
Cyanobacteria Races.....	18
Checklist Rubric for the Cyanobacteria Motility Experiment.....	34
Web Lab: Oxygen Concentration Profile.....	35
Diffusion Pictures.....	39
Lab Report.....	45
Lab Report Checklist.....	46
LabVIEW Directions.....	47
WebVIEW Livescope Directions.....	50
Oxygen Concentration Profile Model.....	51
Oxygen Concentration Profile Model Explained.....	52
Math: Data Analysis and Statistics.....	53
Line Graphs and Scatter Plots.....	55
Scatter Plots.....	58
Bar Graphs.....	61
Rubric: Nitrogen Fixation Experiment, Line Graph.....	63
Rubric: Nitrogen Fixation Experiment, Scatter Plot.....	64
Rubric: Oxygen Concentration Profile, Scatter Plot.....	65
Rubric: Cyanobacteria Motility Experiment, Bar Graph.....	66
English: Language Arts Lesson Plan Format.....	67
Reading Activity.....	67
Web Quest Abstract.....	68
Prefixes, Suffixes, and Roots for English Unit.....	69
Web Quest.....	72
KWL Chart.....	75
Research Note Taking Handout.....	76

Microbial Mat Investigation is a middle school interdisciplinary unit designed to increase student knowledge in the areas of photosynthesis, data analysis, scientific inquiry, microbiology, and ecosystems, by having students study the research of Dr. Brad Bebout at NASA on microbial mats, and integrating classroom laboratory experiences. Science, Math, English, and Technology skills integrated throughout the unit build student's science knowledge. Lessons developed for Science, Math, and English classes to focus students on knowledge gained from studying microbial mats, such as why were they important in the formation of earth's atmosphere, what can we learn about their biogeochemical processes, and why is this research important to NASA now.

Teachers should review the unit in advance of class use. If microscope activities and the lab on Cyanobacteria Races are used, cultures of cyanobacteria need to be ordered from a Biological Supply company so they arrive seven days before class use. An interdisciplinary option taught by a team composed of a Science, Math, and English Teacher, as well as a unit for a single teacher to teach are included.



Interdisciplinary Unit Schedule

Week 1

Science Microscope	Stromatolite Explorer Video, Interactive Biogeochemical Cycle
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Week 2

Classroom Lab: Cyanobacteria Races	Classroom Lab	Classroom Lab	Classroom Lab	Classroom Lab
Reading Activity	WebQuest introduction and begin research	Research	Research	Organize WebQuest presentations
Line graphs and scatterplots: Nitrogen Fixation	Line graphs and scatterplots continued	Scatterplots and write-up	Bar graphs	Write-up

Week3

Collect Motility Lab, Oxygen Diel Cycle Profile	Oxygen Diel Cycle Lab	Oxygen Diel Cycle Lab Due, Extension: Design Own Lab	Design Own Lab	Design Own Lab
Presentation Organization	Group Check for Presentation	Rehearsal	Presentations Due	Presentations at Elementary School

Bring in Science Motility Write-ups and review in Math		Design the way to display data from own lab		
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Unit for a Single Teacher, No Microscope Activities

	Monday	Tuesday	Wednesday	Thursday	Friday
Week 1	Stromatolite Explorer Video, Interactive Biogeochemical Cycle	Reading activity	WebQuest introduction and begin research	Research	Research
Week 2	Organize Presentation	Line graph and scatterplots: Nitrogen Fixation	Line graphs and scatterplots: Nitrogen Fixation continued and write-up	WebQuest Presentation: group check	Rehearsal
Week 3	Presentations due	Scatterplots and write-up, Oxygen Diel Cycle Profile	Oxygen Diel Cycle Lab	Oxygen Diel Cycle Lab Due, Extension: Design own lab	Presentations at Elementary School

Science Lesson Plan: Day One Microscope Activity

Main Concept: Living systems at all levels of organization demonstrate the complementary nature of structure and function. Bacteria cell structures differ from other organisms.

Scientific Question: How do Bacteria Cell structures differ from other organisms?

Objectives

1. The student will use a microscope to observe cyanobacteria.
2. The student will identify cyanobacteria that can be found in a Microbial Mat.

Abstract of Lesson

Using Cyanobacteria ordered from a biological supply store, students will observe cyanobacteria under the microscope and draw the organisms. Pictures of organisms that are not available from the supply store mat are included. If microscopes are not available for student use, pictures of Cyanobacteria, Diatoms, Purple Sulfur Bacteria, and Sulfur Bacteria are included for observation.

Prerequisite Concepts

Microscope Usage

Major Concepts

1. Bacteria structure varies by organism.
2. Bacteria cell structure different from other organisms since they do not have nuclei.

Misconceptions

Reading on Topic related to study

A book that can be purchased is:

Margulis, Lynn and Dorion Sagan, *The Microcosmos Coloring Book*, New York: Harcourt Brace Jovanovich, Publishers, 1988.

Materials List

Microscopes at 20X to 40X magnification (enough for student lab groups)

Pictures of bacteria and organisms titled Life in a Microbial Mat from the Microbial Mat Lesson Plans

Cyanobacteria cultures ordered in advance from a biological supply company:

- Gloeocapsa (freshwater)
- Lyngbya (freshwater)
- Oscillatoria (freshwater)
- Phormidium (freshwater)
- Spirulina. (marine)

Diatoms ordered from a biological supply company

Media to keep cultures alive ordered from a biological supply company

Microscope Slides

Cover Slips

Pipettes

White Paper for Drawing

Colored pencils

Access to Micro*scope from the Participate! Section of the Microbial Mat Education Page

Preparation

Order Cyanobacteria and Diatoms in advance so that they arrive several days before classroom observation.

Arrange Microscopes, slides, cover slips, pipettes for lab use.

Review Microscope use procedures with the class.

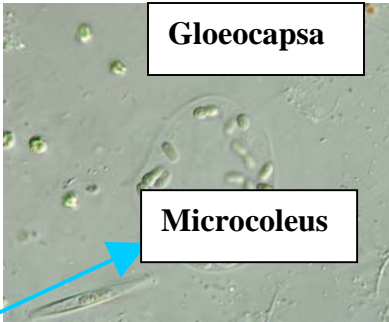
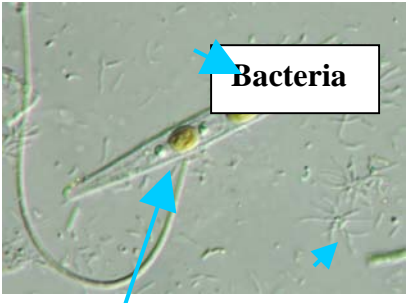
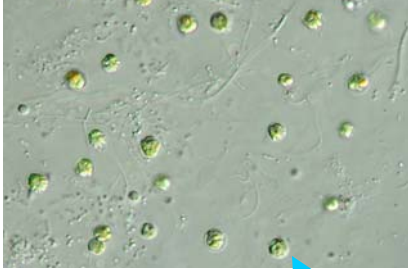
Note: The cyanobacteria ordered for this activity are freshwater, except for Spirulina. The microbial mats studied in the unit are marine, however; the freshwater bacteria ordered also have marine varieties that are present in the mats. Not all of the cyanobacteria in the mats are available for purchase. Therefore, pictures of Microcoleus, purple sulfur bacteria, sulfur bacteria and colorless sulfur bacteria are available to display. Micro*scope at the Marine Biological Laboratory in Woods Hole, Massachusetts is preparing pictures of organisms found in microbial mats. Check the link to this page at <http://www.mbl.edu.microscope>, to see if the file is available.

Procedure:

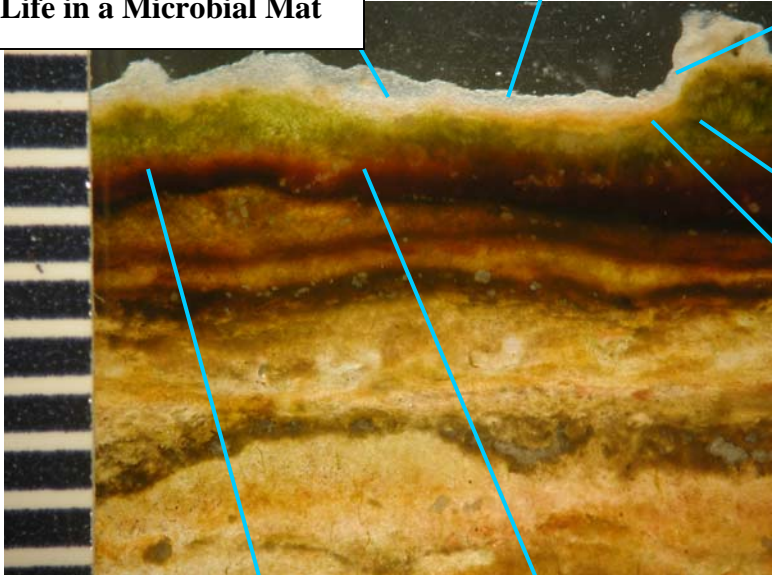
1. Introduce cyanobacteria bacteria to the students. Highlight that bacteria cells differ from other cell structures, because they do not have a nucleus. Because of this, genetic material is loose in the cell in the gel-like cytoplasm. Except for the protein-producing ribosomes, bacteria do not have organelles (specialized cell structures that have specific functions). However, bacteria do have cell walls and cell membranes. Cyanobacteria harvest the energy contained in sunlight and turn it into food (sugars) using the same process of photosynthesis found in higher plants. Cyanobacteria take the hydrogen atoms of water to reduce carbon dioxide and oxygen is produced.
2. Assign each student lab group one drawing to prepare in large scale (8 X 10 inches) for class tomorrow. The drawing should be labeled with the name or category of bacteria it represents. Student Lab groups should prepare pictures of Gloeocapsa, Oscillatoria, Spirulina, Unicellular Cyanobacteria, Diatoms, Phormidium, Sulfer Bacteria, Purple Sulfer Bacteria, Colorless Sulfer Bacteria, Fermenters, and Microcoleus for the interactive biogeochemical activity the next day. Note that some of these drawings will have to be made from pictures that the teacher obtains from the microbial mat education page.
3. Have students observe cyanobacteria and diatoms under the microscopes. Items to note:
 - Gloeocapsa have groups of cells held together by a sticky, gelatin-like polymer called a glycocalyx.
 - Spirulina look like a slinky and move in a corkscrew type fashion.

- Diatoms have several cell structures. Using a science book, have students label the nucleus and other visible cell structures. Compare these structures to bacteria cell structures.
4. During observation, the teacher should circulate around the room, checking for accuracy of drawings, assisting with microscope usage, etc.
 5. Conclude by collecting drawings for each class period. They will be used in the interactive activity tomorrow.

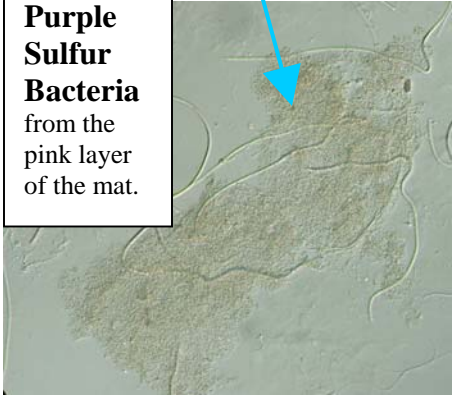
Unicellular Cyanobacteria



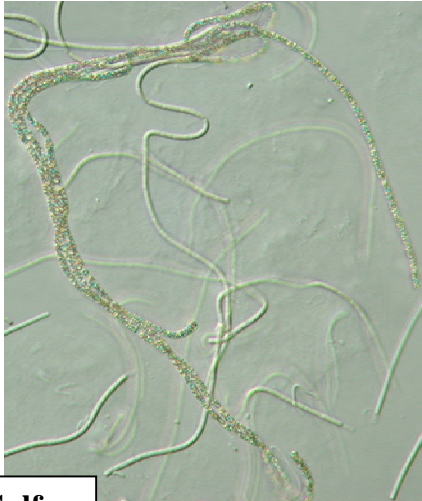
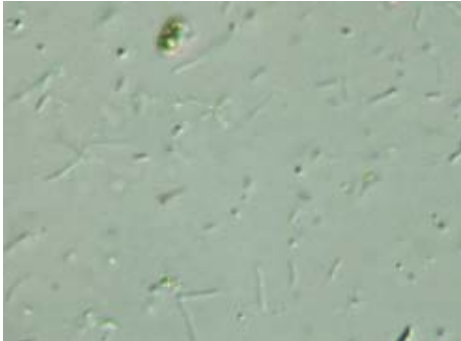
Life in a Microbial Mat



Purple Sulfur Bacteria from the pink layer of the mat.



Sulfur Bacteria



Spirulina

Fermenters are found below the Oxygen Zone. Cyanobacteria ferment at night to obtain energy.

Colorless Sulfur Bacteria can be found in anoxic zones during the day, but at night they move to the top.

Science Lesson Plans: Interactive Biogeochemical Cycle

Main Concept: The position that an organism occupies in a mat is predictive of its role in the ecosystem. Whether it uses or provides oxygen will be a clue to its position and biogeochemical functions.

Scientific Question: What are the functions of different bacteria in a microbial mat?

Objectives:

1. The student will gain a basic understanding of several of the biogeochemical processes in microbial mats.
2. The student will understand the different roles of organisms in a microbial mat ecosystem.
3. The student will gain an understanding of how microbial mat ecosystems contributed to the Earth's biosphere.

Abstract of Lesson: Students will act out the biogeochemical cycles in a microbial mat using the script below. Basic metabolic and chemical processes are explained in the activity.

Prerequisite Concepts:

Major Concepts:

Reading on Topic related to study:

The Microbial Mat Education Page can be accessed through <http://exobiology.arc.nasa.gov/ssx/microecobiogeo/>

Materials List

Different cards (8 1/2 by 11 or larger) labeled to represent different elements and compounds in the mat.

Oxygen
Carbon Dioxide
Water
Sugar
Sulfur
Sulfate
Methane
Sulfide
Hydrogen
Alcohol
Organic Acids

Labeled Pictures of Organisms found in the Mat (Gloecapsa(Cyanobacteria), Oscillatoria(Cyanobacteria), Spirulina(Cyanobacteria), Unicellular Cyanobacteria, Diatoms, Phormidium, Sulfur Bacteria, Purple Sulfur Bacteria, Colorless Sulfur Bacteria, Fermenters, and Microcoleus(Cyanobacteria)) drawn by students day one. A teacher can print pictures of Gloecapsa, Spirulina, Unicellular Cyanobacteria, Diatoms, Phormidium, Sulfur Bacteria, Purple Sulfur Bacteria, Colorless Sulfur Bacteria, Fermenters, and Microcoleus from the Life in a Microbial Mat handout if student drawings are not available.

Script for activity

Stromatolite Explorer video from Microbial Mat Education Page

Preparation

1. Label cards as outlined above.
2. Collect student drawings or prepare pictures as described above.
3. Make enough copies of the script for the students.
4. Download Stromatolite Explorer Clip from the Microbial Mat Education Page

Engage:

1. Explain that students are continuing the unit on Microbial Mats. The bacteria that they observed yesterday are members of microbial mat ecosystems. The bacteria and other microbes form a thick layer of biomass and conduct many of the processes necessary to control our planet. Bacteria living in the microbial mat produce different materials that are needed by other members of the mat community and other organisms to survive.
2. Show the Stromatolite Explorer Clip to introduce students to a Microbial Mat.
3. Conduct the Interactive Biogeochemical Cycle activity using the script below. Assign students the roles with drawings of the organism that they will represent and give them the cards representing the elements that they need to transfer to other members of the mat community. Line up students in the order that they will appear in the script.

Interactive Biogeochemical Cycle Script

Roles: Narrator 1

Narrator 2

Diatom

Cyanobacteria:

Gloecapsa,

Oscillatoria,

Spirulina,

Unicellular Cyanobacteria,

Microcoleus

Aerobic Heterotrophs

Fermenter 1

Fermenter 2

Sulfate Reducer 1

Sulfate Reducer 2

Colorless Sulfur Bacteria 1

Colorless Sulfur Bacteria 2

Purple Sulfur Bacteria

Methanogens

How do Microbial Mats work?

Narrator 1: All life forms require energy to grow and reproduce, and that energy must somehow be extracted from the environment. Humans, for example, breathe air and eat food. When the organic matter in the food combines chemically with the oxygen in the air, energy is released. Where did the oxygen and the organic matter come from? Both were made by other organisms, so that our survival is dependent upon the activity of other life forms.

Narrator 2: Microbial mats function in the same way as a complex food web in which each organism both depends and is depended on by other members of the community. Mats are remarkable in this regard because the organisms that live there constitute an amazing array of energy harvesting strategies. Nearly every type of metabolism known can be found in within the few millimeters of a microbial mat.

Narrator 1: Let us look at the top of the Mat.

Diatom: I am a Diatom and I am found on top of a mat since I do not survive well in hydrogen sulfide.

Cyanobacteria (*Gloecapsa sp.*, *Oscillatoria sp.*, *Spirulina sp.*, *Unicellular Cyanobacteria sp.*, *Microcoleus sp.*) come to the front of the room:

Unicellular Cyanobacteria: We are the primary producers of the microbial mats and the base of the food web in this ecosystem.

Microcoleus: We harvest the energy contained in sunlight and turn it into food (sugars) using the same process of photosynthesis found in higher plants.

Oscillatoria: We take carbon dioxide and water [Displays carbon dioxide and water cards]

Gleocapsa: to make food [Displays sugar cards]

Spirulina: and release oxygen. [Displays oxygen card]

[All cyanobacteria take water and carbon dioxide cards and exchange them for oxygen and sugar cards.]

[Cyanobacteria pass the sugar and oxygen to the Aerobic Heterotrophs]

Narrator 2: The next layer of the mat is composed of aerobic heterotrophs that use the sugar and oxygen produced by the Cyanobacteria.

Aerobic Heterotrophs: We use a process called aerobic respiration to break down the sugar produced by the cyanobacteria with the oxygen produced by the cyanobacteria. We make carbon dioxide and water during this process. We work only during the day, since this is when oxygen is produced through photosynthesis. The carbon dioxide and water that we produce is used by the Cyanobacteria during photosynthesis. [Passes carbon dioxide and water cards back to the Cyanobacteria.]

Narrator 1: Not all of the carbon dioxide produced by the aerobic heterotrophs is used by the cyanobacteria, some of this gas leaves the mat and may be used by other organisms or enters our atmosphere.

Cyanobacteria (all in unison): This is only part of one of the cycles in the mat. Other organisms also use the sugar that we produce. [Passes the sugar card to the fermenters.]

Fermenter 1: We are the Fermenters. We work just like brewer's yeast by fermenting sugars into smaller carbon compounds.

Narrator 2: Actually, the most general use of the word fermentation refers to a process in which carbon dioxide is not formed, but rather another form of carbon. Alcohol is only one of many, many types of fermentations.

Fermenter 2: While we do not completely break down the sugar, we do transform it to alcohol, organic acids, hydrogen and carbon dioxide that are used by other organisms in the community. [Passes the organic acids and hydrogen cards to the Sulfate reducers and the methanogens.]

Narrator 1: Did you know that some cyanobacteria act as fermenters at night?

Narrator 2: Yes, when cyanobacteria lack light and oxygen, they can still be busy working as a fermenter.

Narrator 1: Now we are entering a deeper level of the mat that does not contain oxygen. This is where sulfate reducing bacteria are found.

Sulfate Reducer 1: [Takes the organic acids card and the hydrogen card.] We do not need oxygen to survive and can use other chemicals other than oxygen to survive.

Narrator 2: The position of these sulfate reducers can change in a mat depending on the level of oxygen. At night, oxygen does not penetrate as deep in the mat, so there are more areas where sulfate reducers are comfortable.

Sulfate Reducer 2: We use iron, manganese, nitrate, sulfate and carbon dioxide in one of the anaerobic respiration processes. We use sulfate the way humans use oxygen, the way nitrate is used by a nitrate respirer, and in the way that iron and manganese are used by iron and manganese reducing microbes..

Sulfate Reducer 1: Because there is so much sulfate in seawater, we are the dominant anaerobic respirers in the mat. We consume organic matter in mats and we often leave the mat smelling like rotten eggs from the hydrogen sulfide that we make. We use sulfate to “burn” organic matter by anaerobic respiration and can consume one-third of all organic carbon. [Displays the carbon dioxide card, hydrogen sulfide card, and the water card.] [Passes the carbon dioxide and water cards to the cyanobacteria.]

Cyanobacteria: [All cyanobacteria hold up the carbon dioxide and water cards.] We can then re-use the carbon dioxide released by the sulfate reducers to continue producing sugar and oxygen for the rest of the community.

Colorless Sulfur Bacteria 1: We are Colorless Sulfur Bacteria and are a type of Chemolithotrophic Sulfur bacteria. We use the energy contained in the gradient between reduced sulfur compounds (produced by sulfate reduction), and oxygen (produced by the cyanobacteria) like a battery. [Holds up hydrogen sulfide card and oxygen card.] Using this redox gradient, we are able to synthesize organic matter.

Colorless Sulfur Bacteria 2: Using this redox gradient as an energy source in the same way that the cyanobacteria use sunlight for energy we are able to synthesize organic matter from carbon dioxide just like the cyanobacteria. We tend not to be so important where there is a lot of sunlight, but we are the main energy capturing organisms in deep-sea microbial mats , where there is no sunlight.

Colorless Sulfur Bacteria 1: We are among the most motile of the microbes in the mat because we need to locate precisely at this redox gradient. This gradient is deep in the mat during the day due to oxygen production by cyanobacterial photosynthesis, but can

move to the surface at night after all available oxygen has been consumed in aerobic respiration. We produce sulfuric acid and energy.

Narrator 1: Many of the organisms in the lower areas of the mat do not get enough light to produce photosynthesis. However, they have other ways of surviving based on compounds produced by other members of the mat community.

Purple Sulfur Bacteria 1: We are purple sulfur bacteria and are a type of phototropic sulfur bacteria. We do not live at the top of the mat and get all of the light needed for photosynthesis. Light at the top of the mat is used by cyanobacteria. Light is also scattered by sand and sediment. The light needed for cyanobacterial photosynthesis only penetrates a few millimeters into microbial mats. However, infrared radiation penetrates deeper.

Purple Sulfur Bacteria 2: We use infrared radiation and reduced sulfur to perform a type of photosynthesis called anoxygenic photosynthesis. This type of photosynthesis does not generate oxygen. Through this process, we are able to fix carbon dioxide into simple sugars in a process similar to that used by the cyanobacteria. Fermenters use the sugars that we produce. [Holds up sugar card.] We also produce acid. [Holds up sulfuric acid card.]

Methanogens: [Holds up the organic acid card and the acetate cards.] We are the methanogens and produce methane from acetate and hydrogen that is generated by fermentation. This process yields little energy and is the “last resort” for microbes in the mat. [Holds up the methane card. The methane card should be left at the top of the mat.]

Narrator 2: Even though many of the gases and elements are used in the mat, some are produced in greater quantities than are needed in the mat.

Narrator 1: Gases that are not used leave the surface of the mat.

[At this time, organisms bring up the gases they produce. Cyanobacteria bring Oxygen, Colorless Sulfur Bacteria bring Carbon Dioxide and Sulfur gases, Sulfate Reducers bring Carbon Dioxide, and Methanogens bring Methane.]

[Narrator 1 collects the gases.]

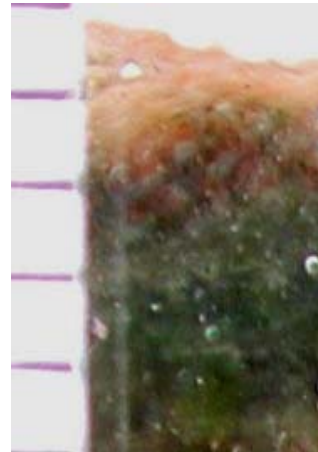
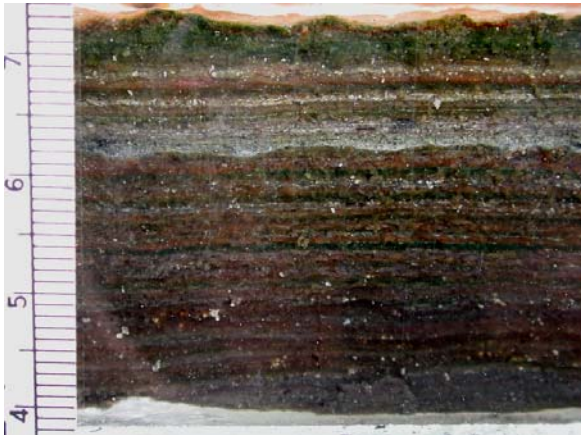
Narrator 2: A microbial mat is a productive community with organisms that depend on each other for survival.

Follow-up: The Microbial Mat Biogeochemical Cycling Diagram from the Microbial Mat Education Page may be used to reinforce concepts. The Microbial Mat Education Page can be accessed through <http://exobiology.arc.nasa.gov/ssx/microecobiogeo/>

Science strand of unit: Cyanobacteria Races: Cyanobacteria Motility Experiment for a Classroom

Background:

Cyanobacteria living in microbial mats can move, both up and down, and sideways. They may orient themselves, and find the optimal depth at which to live, using chemical, light or gravity clues¹. In this experiment, students will expose cultures of freshwater cyanobacteria to a directional light source, measuring their movement toward this light source with a ruler and recording measurements. Through analyzing cyanobacteria motility data, students will determine how cyanobacteria respond to light clues.



Notice the different colored layers of organisms living in the mats. Organisms orient themselves in the mats in response to light, nutrient, and chemical clues.

Microcoleus Mat from Baja California

The structures produced by the movement of cyanobacteria can be preserved in fossil records. Studying cyanobacteria movement and cultures can help scientists interpret those fossil records. By studying fossil records of cyanobacteria motility on earth, scientists are better able to identify fossil records in their search for life in the universe and beyond.

Main Concept: Formulate and test explanations of nature using observation, experiments, and mathematical models to evaluate investigations.

Scientific Question: How important are light cues in affecting Cyanobacteria motility?

Objectives:

1. The student will formulate and test a hypothesis that is an explanation for Cyanobacteria movement using observation, experimentation and mathematical models.
2. The student will develop a better understanding of factors affecting movement in Cyanobacteria.

¹ Bebout, Brad. "Cyanobacterial Motility Experiment." Microbial Mat Education Page. NASA. 1 April 2004. http://nai.arc.nasa.gov/microbe/cyanobacterial_motility.cfm

Abstract of Lesson: Students will conduct an experiment and test their hypothesis on light affecting Cyanobacteria movement. Data collected from the experiment will be graphed for analysis so students can draw conclusions as to the results of the experiment.

Prerequisite Concepts:

Photosynthesis

Structure of Cyanobacteria cell

Major Concepts

- Experimental design, formulating a hypothesis, testing explanations of nature using observation, experiments, and theoretical and mathematical models, evaluating investigations
- Biological adaptations of cyanobacteria
- Function of Cyanobacteria in an ecosystem

Reading on Topic related to study

Cyanobacterial Motility experiment on the Microbial Mat Education Page

<http://exobiology.arc.nasa.gov/ssx/microecobiogeo/>

Materials List

Cyanobacterial Motility experiment data set on the Microbial Mat Education Page

<http://exobiology.arc.nasa.gov/ssx/microecobiogeo/>

For classroom Lab for 30 students:

Agar²

Media³: 3 quarts: Alga-Gro Freshwater Medium (ER-15-3752 Carolina Biological Supply)

Cyanobacteria Cultures: Lyngbya (ER-15-1830 Carolina Biological Supply), Oscillatoria (ER-15-1830 Carolina Biological Supply)

If dissecting microscopes are available, additional cyanobacteria cultures may be ordered:

Anabaena (ER-15-1710 from Carolina Biological uses Alga-Gro Freshwater Medium-order an additional quart), Spirulina major (ER-15-1900 from Carolina Biological uses Alga-Gro Seawater Medium ER-15-3754 from Carolina Biological-order one quart of Seawater Medium)

5 cm x 2.5 cm clear plastic boxes to use for plates

² If you do not want to mix agar and alga-Gro medium to make your plates, Carolina Biological can provide custom agar formulations. The order needs 1 to 2 weeks for delivery after receipt of order. (800)227-1150.

³ If you choose to mix media from Alga-Gro concentrate, separate instructions are available.

Black Electrical tape
Pipette
Tweezers
Metric ruler
Black poster board to cover the top and bottom of the plates.
Plastic boxes with lids
Light source: an Aquarium light has close to a full spectrum light bulb (for each set of class experiments)
Two sheets of stiff black poster board (foam-filled) for each class period.
Scissors
Fine-tip permanent markers (one for each lab group in a class period)
Duct Tape
Balance
Autoclave or pressure cooker
Spatula for measuring agar
Stirring rod
Oven for maintaining the temperature of the Agar
Erlenmeyer flasks (2000 ml)
Stoppers for flasks
Graduated cylinder
Thermometer
Incubator or warm location near a window or full spectrum light source
Dissecting Microscopes or hand-lenses

Handouts:

Lab notebook
Rubric for Lab evaluation

Video:

Time-lapse video of cyanobacteria motility experiment in our lab, access through the Microbial Mat Education Page on the Internet

Preparation:

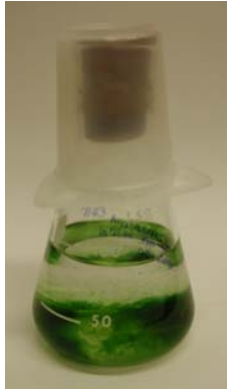
MATERIALS NEED TO ARRIVE AT LEAST SEVEN DAYS BEFORE YOUR IN-CLASS LAB

Order two quarts of Alga-Gro Freshwater Medium (ER-15-3752 Carolina Biological Supply) and Cyanobacteria Cultures: Lyngbya (ER-15-1830 Carolina Biological Supply), Oscillatoria (ER-15-1830 Carolina Biological Supply) so they arrive at least seven days in advance of your in-class laboratory experience.

SEVEN DAYS BEFORE YOUR IN-CLASS LAB

1. When cultures arrive, transfer each culture from its container into 100 ml of Alga-Gro medium to grow cultures. Reserve remaining Alga-Gro medium to use in

making agar plates. Keep each culture in a separate flask and close with a stopper.



Label all flasks with the date, media type, and bacteria species.

You will be growing the Cyanobacteria for seven days before your classroom experiment. Growing the bacteria in media produces filaments that are more visible to the naked eye. See the following example:



On 7/6/04, Cyanobacteria were inoculated on an Alga-Gro and Agar plate in Box 3. The Cyanobacteria had been grown in the Alga-Gro medium since 6/25/04 before they were inoculated on the plates. The box was placed 19 cm from the light source. The left end is where the bacteria were inoculated. Notice the Oscillatoria filament loops that were photographed on 7/13/04.

2. Once the Cyanobacteria culture is suspended in the medium, place the flask containing the mixture in an incubator containing a light source that is set at 27°C. If an incubator is not available, place the flasks containing cyanobacteria cultures by a full spectrum light source or window. Cool white fluorescent tubes of 200 to 400 foot candles work best for growing cultures. If bacteria are cultured by a window, tissue paper should be placed on the glass to diffuse the sunlight and

keep the temperature from being too hot.⁴ The temperature should be at least 22°C but not greater than 27°C.

3. Check the flasks filled with Cyanobacteria cultures daily to make certain the temperature is between 22°C-27°C, the cultures are growing, and the medium is not evaporating. If media is evaporating, add media so that there is 100 ml of liquid in the flask. If the culture is growing rapidly, transfer 50 ml of culture and media into another flask and add 50 ml of Alga-Gro media. Label all flasks with the date, media type, and bacteria species. Remember that freshwater cyanobacteria such as *Lyngbya*, *Oscillatoria* and *Anabaena* should be cultured in Alga-Gro Freshwater Medium. If you have ordered the marine cyanobacteria, *Spirulina*, it should be cultured in Alga-Gro Seawater Medium.

ONE DAY BEFORE IN-CLASS LAB

4. One day before the in-class laboratory experience, prepare agar plates for students to inoculate in class.
5. Prepare Alga-Gro Media to mix with agar.
For Alga-Gro and Agar plates:
Measure 3.2 grams of Agar and add to 400 ml of Alga-Gro medium. (This yields an agar and alga-Gro solution with 8 grams of Agar to 1 liter of Alga-Gro.) Place a magnetic stirrer in the flask and place on stir plate. This will yield enough media to fill 40 plates with 10 ml of agar.
6. Autoclave or pressure-cook the solution for 15 minutes at 15 lbs pressure. Keep mixtures at a temperature of 45°C (113°F) until ready to pour the agar-medium into the plastic boxes to form plates.
7. Set out 40 clear plastic boxes and a sterile pipette of 10 ml. You are pouring additional plates to allow for classroom calamities. You will need one box for each lab group, as well as a control box for each cyanobacteria species for each row in the experimental set-up. There will be four rows for each experimental set-up, so four additional plates of Alga-Gro are needed for each cyanobacteria species in each experimental set-up. Do not autoclave the plastic boxes or they will melt. Keep agar mixture heated and stirring on stir plate so the agar does not set. Fill each plastic box with 10 ml of agar and media solution. Cover and set aside in a cool, dark place for use in lab tomorrow.

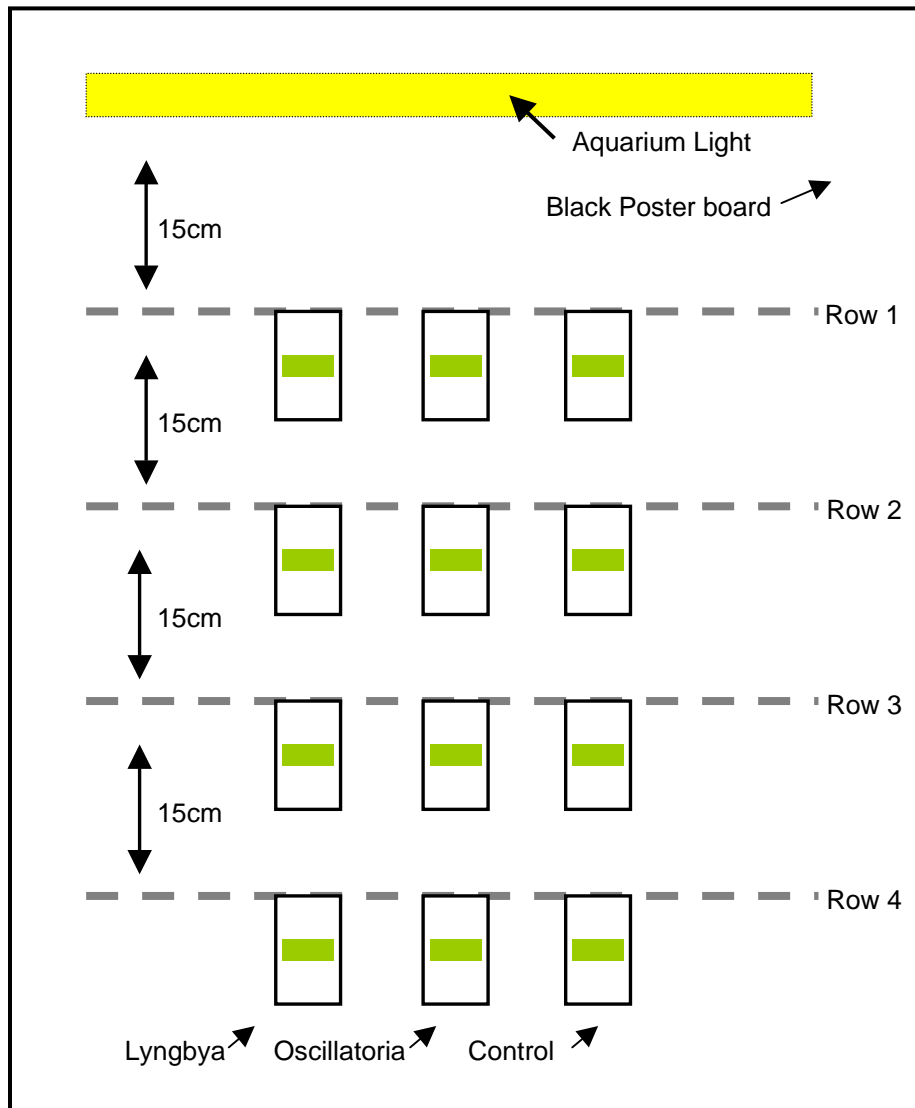
⁴ For more information, read: N/A. Culturing Algae. Burlington, N.C.: Carolina Biological Supply Company, 1978.

CAN BE DONE IN ADVANCE OF DAY NINE:

8. Prepare one light set-up for each class period.

Take an aquarium light with a close to full-spectrum light tube and duct tape it at the end of the table. Take one sheet of stiff black poster board approximately 71 cm X 60 cm (the stiff kind with the foam in-between works best) and divide it into four sections. Starting with the first section 15 cm from the light source, draw a line horizontally across the poster board and label it Row 1. Measure 15 cm from the Row 1 line and draw another line horizontally across the paper. Label this line Row 2. Measure 15 cm from the Row 2 line and draw a line horizontally across the paper. Label this line Row 3. Finally, measure 15 cm from the Row 3 line, draw a line horizontally across the paper and label it Row 4.

See Diagram below:⁵



⁵ Diagram courtesy of Heather Huntspeger

Place the poster board on a flat surface, with the labeled rows showing. The end closest to the Row One label (This is the top of the board.) should be placed as close to the light source as possible. Secure the board to the table with duct tape. Take two small clear boxes and set them at the top far corners of the poster board. These boxes will hold up the poster board enough to let the light through. Place the poster board on top of the boxes. At the opposite end of the top sheet of poster board, use duct tape to secure it to the table. Students will place their inoculated agar plates at different intervals on the rows on the first sheet of poster board, and then use the top sheet to cover the plates so extra light does not change the results of the experiment.

9. Obtain the following materials for each laboratory group:

- Agar plate (Lab groups will be given one plate)
- A species of Cyanobacteria to inoculate on the plate
- Pipette
- Inoculating loop
- Metric ruler with millimeter measurements
- Black electrical tape (enough to go around three sides of the width of the box)
- Black paper to cover the top and bottom of the box
- Masking tape to label experiment
- Scissors
- One fine-tip permanent marker

CLASSROOM LAB PROCEDURE

1. Student lab groups should include 2-4 students.
2. Give the background information on the experiment.

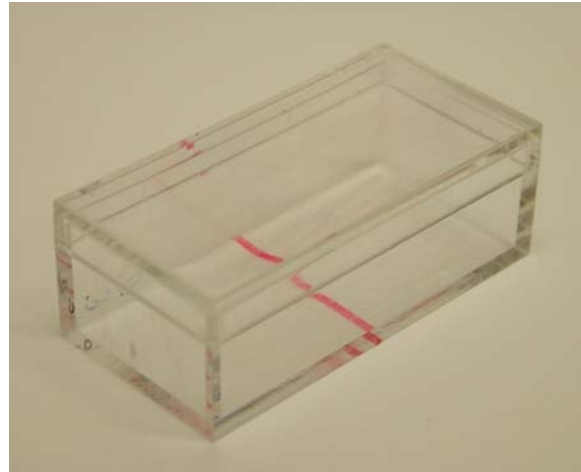
Background: Cyanobacteria living in microbial mats can move, both up and down, and sideways. They may orient themselves, and find the optimal depth at which to live, using chemical, light or gravity clues⁶. In this experiment, you will expose cultures of freshwater cyanobacteria to a directional light source, measuring their movement toward this light source with a ruler and recording measurements. Even though Cyanobacteria are oriented vertically in a microbial mat, horizontal placement reduces variables in the experiment. When cyanobacteria are flat, they have equal access to carbon dioxide, oxygen and nutrient agar making light the only variable. Through analyzing cyanobacteria motility data, you will determine how cyanobacteria respond to light clues.

The structures produced by the movement of cyanobacteria can be preserved in fossil records. Studying cyanobacteria movement and cultures can help scientists interpret those fossil records. By studying fossil records of cyanobacteria motility on earth,

⁶ Bebout, Brad. "Cyanobacterial Motility Experiment." Microbial Mat Education Page. NASA. 1 April 2004. http://nai.arc.nasa.gov/microbe/cyanobacterial_motility.cfm

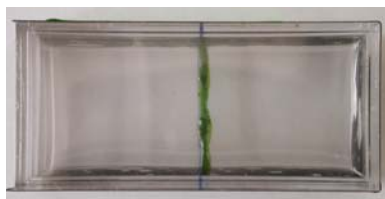
scientists are better able to identify fossil records in their search for life in the universe and beyond.

3. Discuss possible outcomes of the experiment with the class.
 - What do you think that the Cyanobacteria will do in general?
 - How do you think the distance from the light source corresponds to cyanobacteria motility?
 - What do you think causes your proposed outcome?
4. Have students formulate a hypothesis and write it in their lab notebooks. The hypothesis should be a prediction of the results of the experiment and should be testable. Sometimes an if...then statement is a good format for creating a hypothesis.
5. Have students take a fine-tip permanent marker and ruler and draw a line across the bottom width of the box, dividing it into two equal sections. See diagram below:



This line will be used as a guide to inoculate the cyanobacteria. Warn students not to open the plates or mutilate the agar when turning the box upside down.

6. If dissecting microscopes are available, have students observations look for any signs of bacterial or other microbial life on the agar plate. Have students record their initial observations.
7. Model how to inoculate the plate. Remove lids from the plates. Students will be placing a line of cyanobacteria in the middle of the plate on top of the line that they have drawn. The line of bacteria that the student is inoculating needs to be as close to the middle of the box as possible and not be more than 2 mm thick. See example:



Note that the culture was inoculated on a line drawn in the middle of the bottom of the box. The other areas of the box are kept free of culture at the start, so that motility can be observed.

8. Plates need to be inoculated and placed on the Rows in the following manner:

For the group conducting Part 1: Place Oscillatoria plate on Row 1

For the group conducting Part 2: Place Oscillatoria plate on Row 2

For the group conducting Part 3: Place Oscillatoria plate on Row 3

For the group conducting Part 4: Place Oscillatoria plate on Row 4

For the group conducting Part 5: Place Lyngbya plate on Row 1

For the group conducting Part 6: Place Lyngbya plate on Row 2

For the group conducting Part 7: Place Lyngbya plate on Row 3

For the group conducting Part 8: Place Lyngbya plate on Row 4

For the group conducting Part 9: Place Oscillatoria Control plate on Row 1

For the group conducting Part 10: Place Oscillatoria Control plate on Row 2

For the group conducting Part 11: Place Oscillatoria Control plate on Row 3

For the group conducting Part 12: Place Oscillatoria Control plate on Row 4

For the group conducting Part 13: Place Lyngbya Control plate on Row 1

For the group conducting Part 14: Place Lyngbya Control plate on Row 2

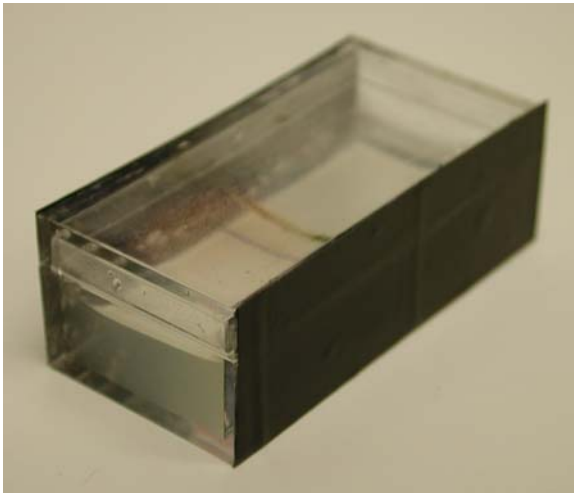
For the group conducting Part 15: Place Lyngbya Control plate on Row 3

For the group conducting Part 16: Place Lyngbya Control plate on Row 4

If there are additional lab groups, additional plates cultured with Lyngbya and Oscillatoria can be placed on each row. If Anabaena and Spirulina cultures are used, one plate of each culture must be placed on each row.

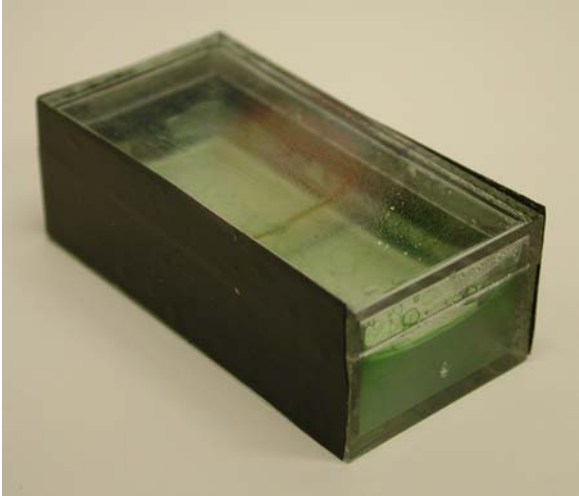
The control plates will have black electrical tape on all four sides. One Lyngbya Control plate and one Oscillatoria Control plate will be placed on each row in the experimental set-up.

1. Once students have inoculated their cultures, have them cover the boxes with the lids. Tape around the two length sides of the box with black electrical tape.



The two ends need to be open so light can enter the plate and flow to the plate behind it when placed in the experimental light box.

If the box is to be placed on row four, three sides of the box need to be taped to block ambient light flow. The open side will face the light. See example:



Mark the date, group name, time, and type of media and culture on masking tape and place on the side of the box. An arrow needs to be made showing the direction the cyanobacteria should be migrating toward the light. The arrow should point away from the inoculation line and toward the end of the box that is facing the light source. The masking tape should only be placed over black electrical tape.

2. Student groups that are inoculating control boxes need to cover the edges of the box on all sides with black electrical tape. See example:



Control box with all four sides covered in black electrical tape.

Students should mark the date, group name, time, and type of media and culture on masking tape and place on the side of the box. An arrow needs to be made showing the direction the cyanobacteria should be migrating toward the light. The arrow should point away from the inoculation line and toward the end of the box that is facing the light source. The masking tape should only be placed over black electrical tape.

3. Control boxes for each medium placed on each row will allow students to compare the difference in motility between the cyanobacteria in the boxes exposed to the light and the cyanobacteria that were not exposed to any light.

Student boxes need to be placed in the experimental set-up in the following locations:

For the group conducting Part 1: Place Oscillatoria plate on Row 1

For the group conducting Part 2: Place Oscillatoria plate on Row 2

For the group conducting Part 3: Place Oscillatoria plate on Row 3

For the group conducting Part 4: Place Oscillatoria plate on Row 4

For the group conducting Part 5: Place Lyngbya plate on Row 1

For the group conducting Part 6: Place Lyngbya plate on Row 2

For the group conducting Part 7: Place Lyngbya plate on Row 3

For the group conducting Part 8: Place Lyngbya plate on Row 4

For the group conducting Part 9: Place Oscillatoria Control plate on Row 1

For the group conducting Part 10: Place Oscillatoria Control plate on Row 2

For the group conducting Part 11: Place Oscillatoria Control plate on Row 3

For the group conducting Part 12: Place Oscillatoria Control plate on Row 4

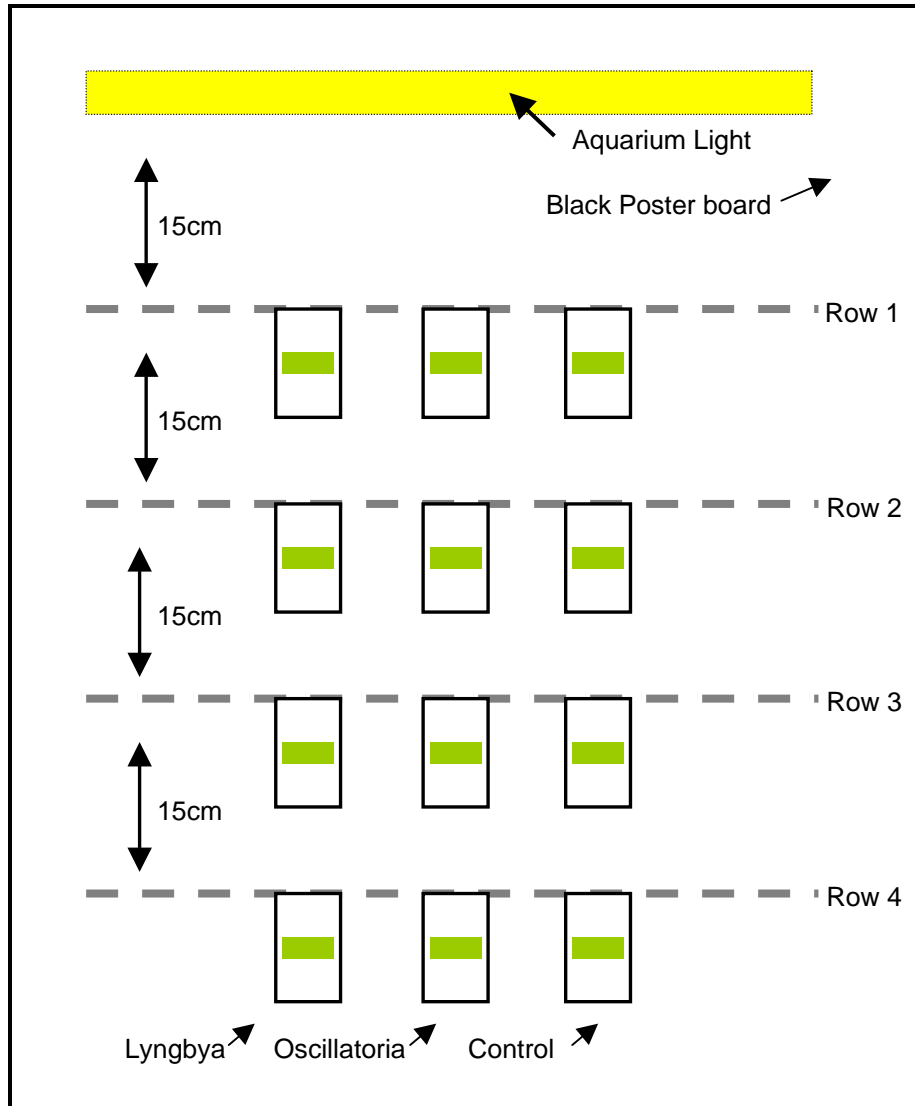
For the group conducting Part 13: Place Lyngbya Control plate on Row 1

For the group conducting Part 14: Place Lyngbya Control plate on Row 2

For the group conducting Part 15: Place Lyngbya Control plate on Row 3

For the group conducting Part 16: Place Lyngbya Control plate on Row 4

The boxes should be orientated so that one end of the box is facing the light and is touching the line. Make certain that the end of the box that faces the light source corresponds to the direction that the arrow indicates on the masking tape in the box. See diagram:



4. Turn on Aquarium light and cover with the second sheet of black poster paper.

Daily (The number of days needed to take motility measurements varies according to the conditions that the cyanobacteria are under. Motility measurements may be taken from three to five days after inoculation and placement in the experimental set-up depending on the speed at which the cyanobacteria move.)

Procedures:

1. If dissecting microscopes are available, have students view and measure cyanobacteria motility under a dissecting microscope. If microscopes are not available, use a hand-lens. Large *Oscillatoria sp.* and *Lyngbya sp.* filaments should be visible with the naked eye.
2. Have students record measurements toward the light and away from the light each day in their lab notebook for their plate. Use the inoculation line as zero when measuring movement in millimeters.
3. Students should record observations about the appearance of the filaments. Any changes in the direction of movement should also be recorded in the lab journal. Drawings and diagrams can be made to illustrate observations.
4. When students complete recording measurements in their lab notebook, have them record measurement on a class data sheet.
5. Daily discussion can include:
 - Did the cyanobacteria respond to light?
 - Did the different species respond in the same way?
 - How far did the cyanobacteria move toward the light?
 - How far did the cyanobacteria move away from the light?
 - Is your species of cyanobacteria moving at the same speed as it did on previous days?
 - Compare your cyanobacteria species with another species on your row, which were faster or slower?

Conclusion: Bar Graphing Activity to be completed when final data measurements have been recorded.

1. Students graph the data they collected for their plate from their science experiments on cyanobacteria motility in the following ways:
 - a. Create a line graph plotting the daily movements of cyanobacteria over time. One line should be made connecting the measurements of movement toward the light. Another line should be made connecting the measurements of movement away from the light. Be certain that the y-axis (distance) does not start at zero so that movement away from the light can be marked in negative numbers. See the graphs for the Cyanobacteria Motility Experiment performed at Ames Research Center on the Microbial Mat Education Page in the Participate section. This page can be accessed through the Microbial Ecology/Biogeochemistry Research Laboratory at <http://exobiology.arc.nasa.gov/ssx/microecobiogeo/>

Students need to graph their data on the same scale to compare data. If the graphs are made on overhead transparencies, graphs can be overlaid to compare results and analyze relationships between experimental groups.

- b. Create a summary bar graph for the total movement cyanobacteria made toward and away from the light. Handout the Rubric: Cyanobacteria Motility Experiment for guidelines. For each plate:
 1. average the total distance the cyanobacteria made toward the light
 2. Average the total distance the cyanobacteria made away from the light.
- c. On a class bar graph, plot the distance each culture of bacteria moved. Again, the y-axis does not start with zero, but allows negative numbers to be plotted that signify movement away from the light. Label each bar with the plate number and Row number. Use separate colors to distinguish movement away from the light and toward the light. See the graphs for the Cyanobacteria Motility Experiment performed at Ames Research Center on the Microbial Mat Education Page in the Participate section. This page can be accessed through the Microbial Ecology/Biogeochemistry Research Laboratory at <http://exobiology.arc.nasa.gov/ssx/microecobiogeo/>

2. Using the data displayed in the graphs, ask the following questions at the conclusion of the lab:

- Did the cyanobacteria respond to light?
- Did the different species respond in the same way?
- Did they move at the same speed over the course of the experiment?
- Which were faster or slower?
- After looking at your graph, what questions do you have for further research?
- Why do you think the cyanobacteria responded in the way that they did?

Possible explanations may include:

- Research by Niels B. Ramsing and Lee Prufert-Bebout, *Motility of Microcoleus chthonoplastes subjected to different light intensities quantified by digital image analysis*, suggests several potential strategies to find optimal light conditions:
 - 1) Total movement: minimize movement if conditions are favorable
 - a. Frequency of movement: Move less frequently if light conditions are favorable
 - b. Speed of Movement: Move slower if conditions are favorable
 - 2) Reversing direction of movement
 - a. Reverse direction of movement more frequently if conditions are favorable.
 - 3) Change direction(curling up)
 - a. Change direction more frequently (create bends) if conditions are favorable.
- Cyanobacteria may be responding to conditions other than light. For example, the nutrients in the agar might be a variable.

[0]

2. Have students complete a written summary interpreting their Bar Graph. Use the Rubric: Cyanobacteria Motility Experiment for guidelines in completing the summary.
3. Compare student experiment data to data from Baja Stromatolite Cyanobacteria on the web site for the Cyanobacterial Motility Experiment.

Questions:

Did the Baja cyanobacteria have a different response to light than our classroom cultures?

Which were faster or slower?

What other differences or similarities do you notice between the Baja Cyanobacteria Motility Experiment and our classroom experiment?

Follow-up lab questions:

What do you know about Cyanobacteria motility?

What other questions do you have about factors affecting Cyanobacteria motility?

What do you want to learn?

How would you find it out? (Experimental Design)

Evaluation: Use the Rubric for the Cyanobacteria Motility Experiment to assess student graphs and graph interpretation summaries.

Checklist Rubric: Cyanobacteria Motility Experiment

Bar Graph (Summary Graph)

- ___ The graph has a title.
- ___ The graph has an appropriate scale on the vertical axis.
- ___ The graph has different treatments listed on the horizontal axis.
- ___ The graph has labels on both axes.
- ___ Units or increments on the graph are equally spaced and identified.
- ___ The graph has a key or legend.
- ___ Bars are drawn correctly on the graph reflecting an accurate use of data.
- ___ The graph is neatly drawn with a ruler and labels are neatly written and easy to read.
- ___ Separate Colors are used to distinguish movement away from the light and toward the light.

Graph Interpretation Summary

- ___ The Introduction to the paper contains:
 - ___ A summary of the experiment.
 - ___ A thesis statement that indicates why the graph looks the way it does.
- ___ The Body includes an explanation of how one can draw conclusions from the graph. For example, how does the graph picture show:
 - ___ Did the cyanobacteria respond to the light?
 - ___ Did the different species respond in the same way?
 - ___ Did they move at the same speed over the course of the experiment?
 - ___ Which were faster or slower?
- ___ The Conclusion contains:
 - ___ A summary of the inferences drawn from the experiment.
 - ___ Which cultures would be most likely to be found at the top of the stromatolite?
 - ___ Which would be more likely to be at the bottom?
 - ___ An idea for further research or other questions relating to the Cyanobacteria Motility Experiment.
 - ___ An analysis of errors and any variation in data.
- ___ The paper contains an accurate analysis of data.
- ___ The paper uses correct spelling, punctuation, and grammar.

Web Lab: Oxygen Concentration Profile

Web Lab Information: The Web Lab is located in the Microbiology Ecology/Biogeochemistry Research Lab at NASA Ames Research center in Mountain View, California and is classroom accessible through an internet connection to the Microbial Mat Education Page though:

<http://exobiology.arc.nasa.gov/ssx/microecobiogeo/>

A microsensors within the lab can be remotely controlled by users to collect data on oxygen concentrations within a microbial mat. In order to participate in Web Lab experiments, remote sites will need to download LabVIEW run time engine version 6.1 <http://ni.com>. Users will need to register with National Instruments in order to download the LabVIEW run time engine. In order to ensure that users can access the Web Lab for classroom experiments at specific times, please email Dr. Brad Bebout at (add new web address for Educational Outreach activities) to reserve a run time.

Background: Because they are so directly tied to the energy coming from our sun, the metabolic activities of microorganisms living in microbial mats dramatically change over a 24-hour (diel) cycle. Oxygen is produced by photosynthesis (which only occurs in the light) and is consumed by respiration. The diel changes in activity dramatically alter the concentrations of oxygen present in the mat over the same diel period. By measuring the concentrations of oxygen in a mat, microbial ecologists can determine the net balance of photosynthesis and respiration in the community. A set of measurements of oxygen with depth is called a “profile of oxygen concentration”.

In this experiment, students will expose a microbial mat to light in the Web Lab. A microsensors will record the amount of oxygen present in varying depths of the mat during the exposure to light. Through analyzing profiles of oxygen concentration data, students will determine the relationship between light and the net export or import of oxygen from the mat, and the ability of cyanobacteria to produce and consume oxygen.

Main Concepts: Formulate and test explanations of a natural system using observation, experiments, and mathematical models to evaluate investigations.

1. Aerobic metabolism both requires and produces oxygen:
 - a. Cyanobacteria produce oxygen in the light
 - b. Cyanobacteria consume oxygen in the dark
2. Diffusion: Oxygen moves from places of higher concentration to places with lower concentration. Oxygen not consumed by the microbes in the mat leaves the mat and is added to the atmosphere.
3. Anoxic: zero oxygen
4. Oxic: oxygen present
5. There are places in the mat that are both anoxic and highly oxic at different times in the day, as well as places in a mat that stay anoxic or oxic.
6. Light decreases with depth in a mat.

7. Respiration: Cyanobacteria consume oxygen at the same time that they produce it. In the light, however, more oxygen is produced than consumed and oxygen escapes. Chemical processes also consume oxygen.
8. Photosynthesis: the fixation of carbon dioxide into biomass. Usually, but not always results in the production of oxygen.

Scientific Question: How does light change the distribution of oxygen in a microbial mat?

Objectives:

1. The student will formulate and test a hypothesis that is an explanation for oxygen concentration at different levels of the mat using observation, experimentation and mathematical models.
2. The student will develop a better understanding of photosynthesis, respiration, and diffusion in a microbial mat.

Abstract of Lesson:

Students will test their hypothesis on oxygen concentration in a microbial mat using a demonstration module in which microbial mats maintained in a Web Lab are accessible with a web cam. Microsensor measurements within the community can be automated, or can be remotely controlled by users to collect data on oxygen concentrations within the mat. Students will interpret data recorded in scatter plots (oxygen concentration profiles) in LabVIEW to draw conclusions about the mat community that they are studying.

Prerequisite Concepts:

1. Photosynthesis
2. Production and consumption of oxygen

Misconceptions:

- 1) Respiration is not breathing. It is the chemical process of converting sugars to usable energy. Respiration releases energy and produces carbon dioxide.

Readings on Topic Related to study

Microbial Mat Education page:

<http://exobiology.arc.nasa.gov/ssx/microecobiogeo/>

Materials List

Internet Connection to Microbial Mat Education Page

Links to Web Lab on the Microbial Mat Education Page

Copies of scatter plot from the oxygen concentration profiles from LabVIEW in the Web Lab

LCD Projector

Handouts:

1. Copies of scatter plot from the oxygen concentration profile after the profile is finished using LabVIEW
2. Microbial Mat Education Page and web Lab Data may be printed and handed out if there are few computers for students to use.

Preparation:

1. Make certain that you have a live Internet connection to the Web Lab. Make certain that you will be able to show data sampling at the time of your class. Contact Dr. Brad Bebout at ([insert new Education Outreach Address](#)) one week before you want to use the Web Lab in your classroom to request a specific run time.
2. Download LabVIEW run time engine version 6.1 from <http://ni.com> Users will need to register with National Instruments in order to download the free LabVIEW run time engine. Only one computer will be able to control the microsensors. Other computers may view the screen.
3. Arrange for a LCD projector to display the web cam and oxygen concentration profiles live from the web site.
4. Have copies of scatter plot data from an oxygen concentration profile in case you are not able to run the experiment live or you have technical difficulties. (Possible CD ROM with material on it.)

Engage: Activities to introduce concepts in the mat:

Diffusion: Dye Diffusion Activity

Objective: Students will understand that gasses move from high levels of concentration to lower levels of concentration through simulating the characteristics of a microbial mat.

Materials:

Clear rectangular container. (4.1 centimeters wide X 5.7 centimeters high)
Agar
Water
Red food coloring
Blue food coloring

Methods: Please note that this activity took seven hours to complete. A teacher might want to have several containers of agar that had dye added to them at different times which are labeled and displayed at the front of the class in addition to the demonstration completed in class. Pictures of the diffusion activity are included below.

1. Before class, pour 50 ml of Agar solution into a clear rectangular container and allow to set.
2. Measure 5 ml of Red food coloring and set aside. Measure 5 ml of Blue food coloring and set aside. Measure 5 ml of water and set aside. Do not mix food coloring and water.
3. During class, explain to the class that gasses in a microbial mat move from areas of higher concentration to areas of lower concentration. The agar in the container is simulating a microbial mat. The food coloring and water represents oxygen concentration in a mat.
4. Add red food coloring, water and blue food coloring separately to the agar block in the clear container. Explain to the class that the colored liquid at the top of the agar represents the oxygen in the mat. Now, oxygen as shown by the dye is concentrated at the top of the mat.
5. Ask students: What do they think will happen to the food coloring in the mat?
Answers: The food coloring will change the agar from clear to purple.

Ask students: If the food coloring represents oxygen in a microbial mat, what is happening to the oxygen in the mat and why?

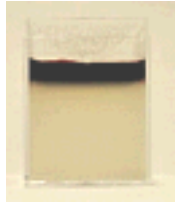
Answer: The oxygen is moving to different areas of the mat where oxygen was not as concentrated, because gasses move from areas of higher concentration to lower concentration.

6. Explain that just as the food coloring moves to color the agar, so does oxygen move to fill areas of lower concentration. This is diffusion. The line where there is a difference between the higher area of concentration and the lower area of concentration is the diffusion gradient. This gradient shows the change in oxygen concentration over distance.
7. Leave the box filled with agar at the front of the room for students to observe the progress of the diffusion of the food coloring in the agar. Note that as the red and blue dye diffuse, they mix, creating purple. This shows how gasses diffuse in an area.
8. During breaks in the Web Lab activity, return to the agar box and have students take measurements of how far the food coloring has diffused in the agar. Students should record the measurements to graph.

Diffusion Pictures



1:16 p.m.



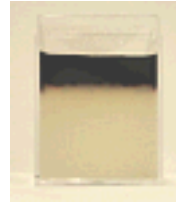
1:17 p.m. red
and water



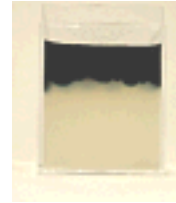
1:18 p.m. blue



1:30 p.m.



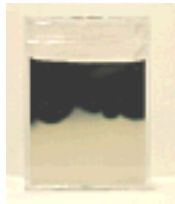
1:38 p.m.



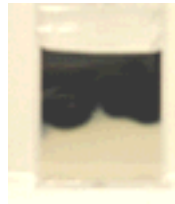
1:50 p.m.



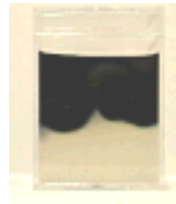
2:03 p.m.



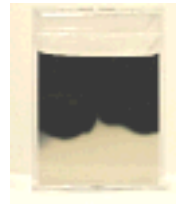
2:34 p.m.



2:54 p.m.



3:16 p.m.



3:45 p.m.



4:17 p.m.



5:05 p.m.



5:36 p.m.



6:40 p.m.



8:47 p.m.



9:43 p.m.

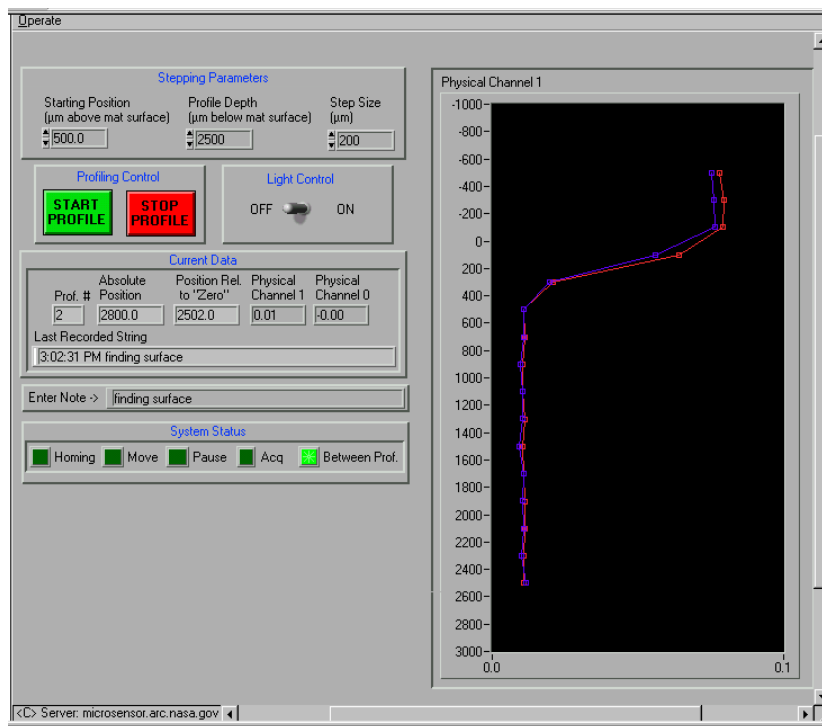


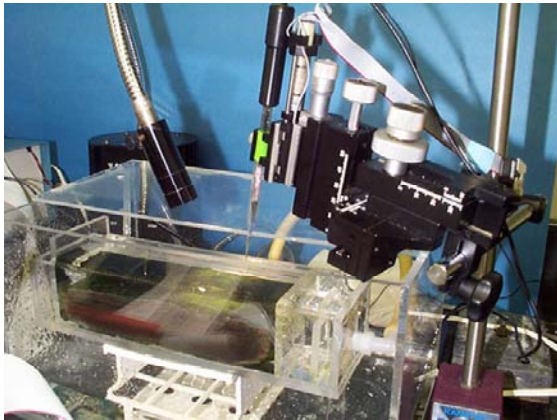
12:53 a.m.

Classroom Lab Procedure

1. Project live connection to the Web Lab and LabVIEW remote panel. Directions for LabVIEW operation are included at the end of this lesson. While students can observe LabVIEW from individual computers, only one computer can control the experiment in the Web Lab. The teacher computer which is attached to the LCD projector, should be the computer used to control the Web Lab experiment.

This is a screen shot of the LabView remote panel available on the internet to run the oxygen diel cycle profile.





This is a picture of the experimental set-up in our lab that you can control remotely using LabView.



This is a picture of a microsensor profiling a microbial mat. Notice the oxygen bubbles just above the surface of the mat.

2. Ten Minutes before the start of class turn the light off in the Web Lab by selecting and clicking the light on/off button on the LabVIEW remote panel. Wait 10 minutes to make certain that the microbes are at a steady state. In a steady state, things are not changing with time.
3. Make certain students write down the hypothesis that they will be testing. Make certain that the hypothesis is testable. Sometimes an if...then statement is a good

format for creating a hypothesis. Example—If the light is on the microbial mat, then _____ will happen.

4. Start profile by selecting and clicking the start profile button.
5. When the first profile is finished, confirm that the profile is indeed a steady state profile by running it again. When profiles are plotted similarly, one knows that the profile is at a steady state because readings have not changed with time.
6. Once a steady state is reached, turn on the light in the Web Lab on the LabVIEW remote panel by selecting and clicking the light on/off button.
7. When a minute has passed, the mat is ready to profile at a non-steady state with the light on. Select and click on start profile in LabVIEW in order to begin the profiling of oxygen.
8. After this profile is completed, wait 5 minutes to attain a steady state in the mat before making the next profile.
9. The computer will display scatter plot of oxygen profiles in LabVIEW. Make copies of the LabVIEW Oxygen profile scatter plots for students.(If profiles are run one day, scatter plots can be copied for data analysis the next day.) Scatter plots can be copied from LabVIEW with a right click on the physical channel panel.

Analysis Questions: Have students study the graph and answer the following questions:

- Are the mats producing oxygen?
- How do we know that they are producing oxygen?
- Are the mats consuming oxygen?
- How do we know that they are consuming oxygen?
- What happens to the oxygen in the mat when the light is on?
- What happens to the oxygen in the mat when the light is off?
- At what depths are production and consumption highest?
- At what depths are production and consumption the lowest?
- Are these mats a source or sink of oxygen?

Teacher note: These questions explained with a sample scatter plot of oxygen concentration profiles that is attached to this unit (See the handout titled, *Oxygen Concentration Profile Model Explained* for an explanation.)

Questions about the picture shown by the graph

- Is there more oxygen in the mat or in the water in the light?
Answer: 1) There is a higher concentration of oxygen than the water.
Photosynthetic processes produce oxygen.
2) Deeper penetration of oxygen occurs in the mat when the light is on.

- In the dark, is the highest oxygen concentration in the mat or in the water?
Then, in the dark, which way would oxygen move, from the water to the mat, or from the mat to the water?
Answer: a) The organisms consume oxygen in the dark through the process of respiration. Respiration occurs. Less oxygen is available in the mat than in the water column. Therefore, oxygen is moving, by diffusion from the water to the mat.
b) Oxygen does not penetrate as deeply in a mat when it is dark.
- What is the difference in the depth where zero oxygen is in the mat during dark and light periods?
o What factors account for this difference in depth?
- When and where does oxygen leave the mat? (Diffusion Gradient)
- Which places in the mat are oxic? (Contain oxygen)
- Which places in the mat are anoxic? (Oxygen is absent)
- Are there places in the mat that are oxic and anoxic?
- What might microorganisms that live in the zones of the mat that are oxic and anoxic do during oxic periods?
Answer: Anoxic organisms might move to a place in the mat where oxygen is not present. Organisms that use oxygen will be more active in their chemical processes. Organisms that produce oxygen will be conducting photosynthesis.
- What might microorganisms that deal with both oxic and anoxic conditions do during anoxic periods?
Answer: Organisms that are living in oxic conditions use *aerobic* metabolism, whereas organisms in anoxic conditions use *anaerobic* metabolism. Organisms that are primarily oxic, but can deal with anaerobic conditions are called “facultative anaerobes”. Some organisms with aerobic metabolism may move to a place in the mat where oxygen is still available (this may only be at the surface of the mat). Some organisms may also conduct anaerobic processes.

Scientific Inquiry Questions:

Does the data confirm your initial hypothesis? Why or Why not?

Why would you repeated the profiling process with the same conditions?

Answer:

Until the experiment is replicated several times under the same conditions, one cannot be certain of the outcome of the results.

Discussion: Discuss the results of the experiment and analysis questions as a class. What other experiments can you design for oxygen profiling? What conditions can you change and still profile oxygen?

Evaluation:

Lab Notebook: Using the Lab Notebook form, have students complete a written lab report. Use the rubric to evaluate student work.

Lab Report

Complete the following lab report in your Lab Notebook giving specific details and writing in complete sentences.

- I. **Purpose:** What are you trying to learn in this experiment?
- II. **Hypothesis:** What are you testing in this experiment?
- III. **Materials:** What materials and equipment did you use to conduct this experiment? (Give specific details.)
- IV. **Procedures:** What methods did you use to conduct the experiment? List in step-by-step detail what you did during the experiment.
- V. **Observations:** What did you observe during the experiment? What data did you collect? Make certain graphs, data collection tables, etc. are included.
- VI. **Conclusions:** Does your data support or reject your hypothesis? Explain why. Relate your conclusions to the information that you are learning in science.
- VII. **Further Study:** What ideas for further research do you have? Explain your idea(s) in a complete paragraph.

Lab Report Checklist

Your lab being evaluated on the following criteria:

_____ The purpose for the experiment is clearly explained.

_____ A testable hypothesis is written.

_____ The materials and equipment used to conduct this experiment are given using specific details.

_____ The procedures taken to conduct the experiment are listed in detail in sequential order. Transition words such as First, Next, Last, etc. are used to indicate the order of the methods used in the experiment.

_____ Observations describe changes in the dependent variable and include data in the form of graphs, data collection tables, etc.

_____ Conclusions explain whether the data supports or rejects the hypothesis and why. This section relates conclusions to the information learned in science.

_____ Ideas for further research are explained in a complete paragraph.

_____ The notebook is neat, complete, detailed, and written in complete sentences.

How to Use LabVIEW

1. Go to the Oxygen Microsensor Remote Control Web Page located at: http://microsensor.arc.nasa.gov/move_and_profile_demo.htm
2. Install the LabVIEW panel on each computer that accesses LabVIEW.
3. The first time one has access to the Oxygen Microsensor Remote Control Web Page, a Security Warning window will ask, "Do you want to install and run LabVIEW Runtime Engine?" Select yes. This will allow downloading of the LabVIEW Runtime Engine from <http://ni.com>
4. If the error message, "remote panel connection exceeds maximum number of licenses" appears, select the refresh button on the panel located at the top of your browser. If further problems exist, contact Dr. Bebout at (new education outreach email address). The LabVIEW panel on your screen should look like the one pictured below.
5. In order to control the experiment in the Web Lab, one must request control by right clicking anywhere in the instrument panel. A window will appear. Select and click Request Control of VI. Control granted will appear on the panel when authorized.
6. The instrument panel contains several sections labeled in the Remote LabVIEW panel diagram in this document.
 1. The Stepping Parameters section is located in the upper left of the control panel. This section allows the user to set the starting position of the microelectrode above the mat surface, determine the profile depth or how far the microelectrode penetrates the mat and define the step size or distance between the readings in the mat. Side arrows allow the user to change parameters.
 2. The Profiling Control section is located on the left side of the control panel below the Stepping Parameters section. By selecting and clicking the green button, one starts a profile of oxygen concentration in the mat. Selecting and clicking the red button, stops the profile of oxygen concentration in the mat. Usually, there is no need to stop an oxygen profile, the system status section will show when the profile is complete.
 3. The Light Control switch is located next to the Profiling Control section. By touching the switch with the hand cursor and clicking, one can turn the light on and off. The direction of the switch indicates the light status.
 4. The Current Data section is located below the Profiling Control and Light Control sections. This section gives information about the current data sample and the time the last probe occurred. Displayed at the left of this section is the Profile number. Absolute position indicates the position of the probe overall. Another probe position shown is the position of the probe related to the surface of the mat. This is the Position Related to Zero window. The last window displays the Oxygen Electrode Signal in volts.
 5. The Enter Note panel is located below the Current Data section. This section gives information on the status of the probe.

6. The System Status section is located in the lower left corner and gives specific information on the probe. When the box next to probe status is light green, the probe conducts the operation listed next to the box.
 - Homing lets the user know that the probe position is being located.
 - Move informs the user that the probe is moving.
 - Pause means that the probe stops for a short period.
 - Acquire means that the probe is sampling oxygen concentration data.
 - Between profiles shows completion of the current profile. The remote user may start a new profile when the box located next to Between Profiles is light green.
7. The Physical Channel on the right side of the instrument panel shows the graph of the data collected. Notice that the axis have switched: the independent axis (depth) is now along the y-axis and the dependent axis (oxygen concentration) is now along the x-axis. This is to simplify visualization of the mat. The mat surface is at zero. Negative numbers indicate the distance of the water or air above the mat. Positive numbers indicate the depth of the mat. Measurements of depth are in microns (μm). Each oxygen profile reading display is in a different color, allowing users to compare oxygen profiles in light and dark conditions. This also allows users to determine when the concentration of oxygen is at a steady state.

By right clicking on the Physical Channel panel, a window appears that allows one to select several options.

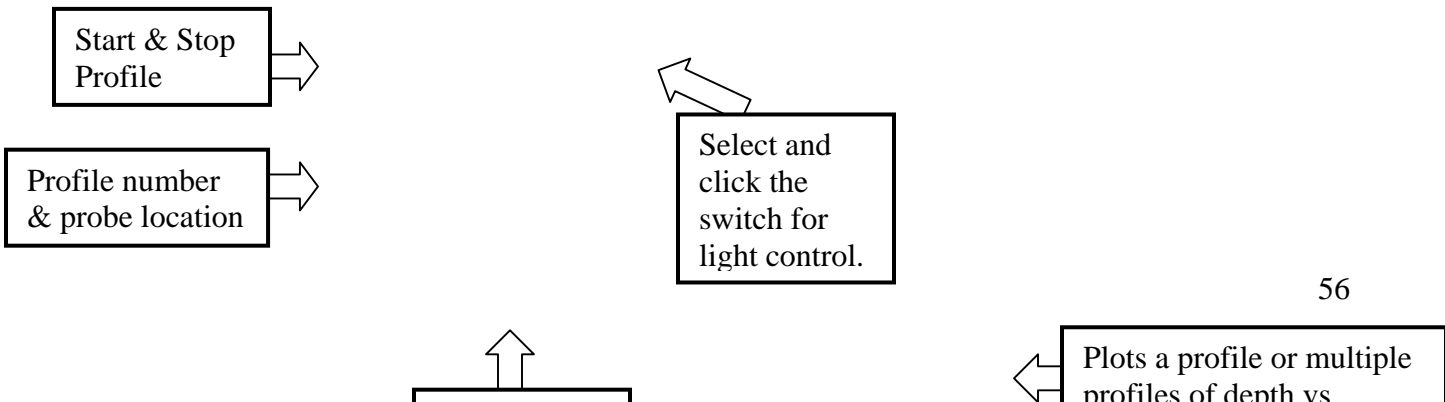
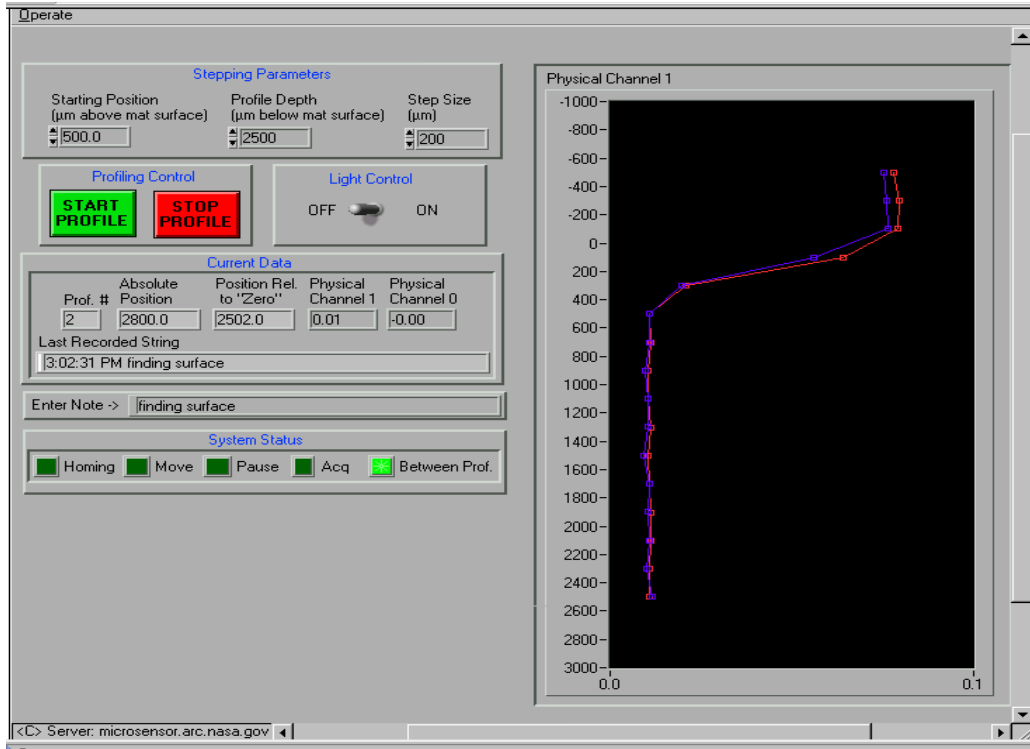
- Copy Data: Allows users to copy the graph of the oxygen concentration profile. By importing this graph into a word processing document, users can print graphs of data for interpretation by students.
- Visible Items: Allows users to see a Plot Legend. One can also choose to display x and y scales.
- Clear Graph: Clears the graph. However, previous readings will show during the plotting of a new profile.
- Smooth Updates: Allows all data to fit into the display window.
- Remote Panel Client: This information shows as a separate window any time the user clicks on the instrument panel.

This window allows the user to:

- Request Control of VI: A user must have control in order to operate the microsensor from remote location. The computer will acknowledge control.
- Release Control of VI: When a user is finished with all desired oxygen concentration profiles, the user must click on Release Control of VI to make the site available for another user to control.
- Show last message: Displays the last message window.

- Show Control Time Remaining: If limits were set on control time, the window displays remaining time.

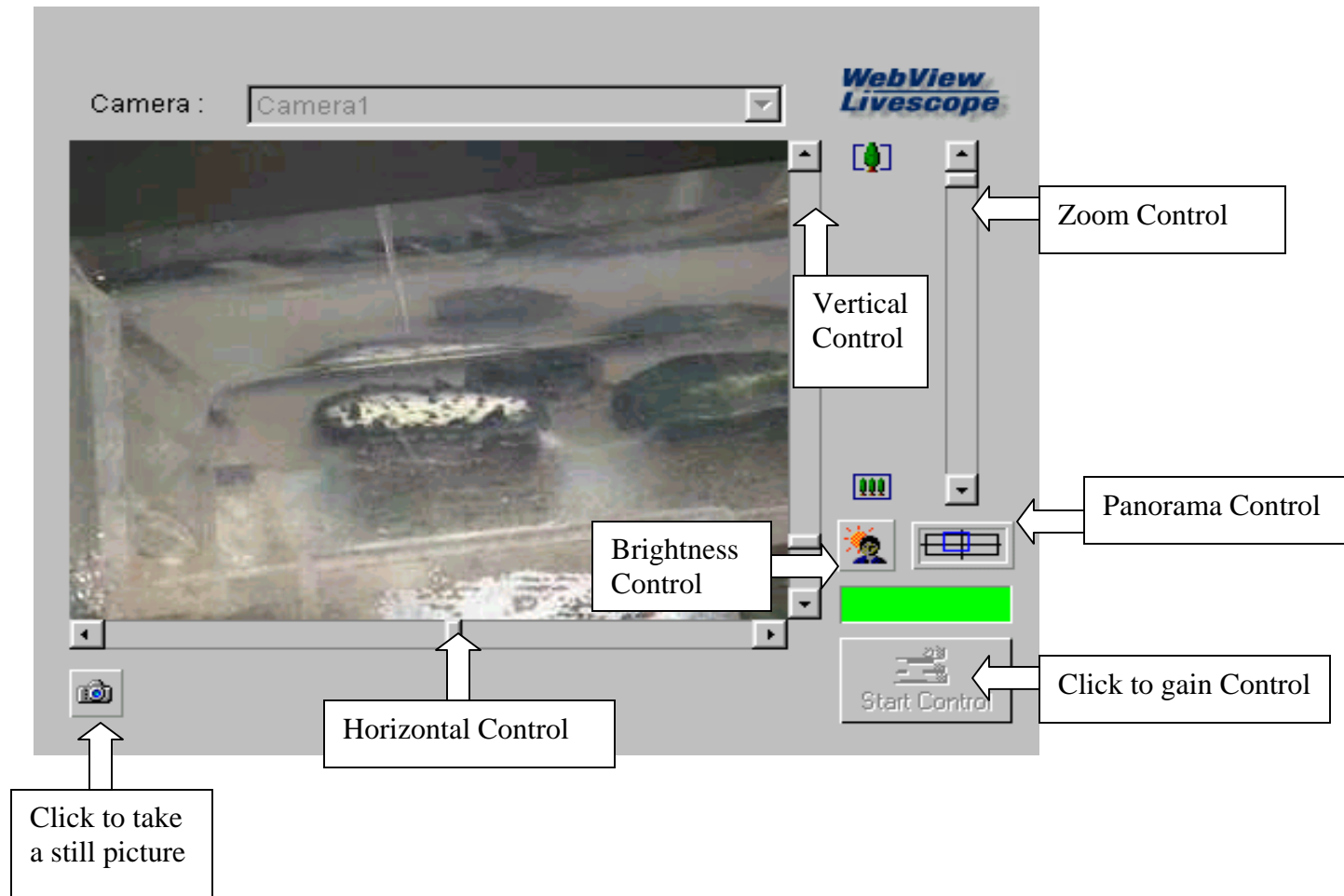
Set starting position, profile depth, and step size. Units are in microns (μm).



8. Be certain to release control of VI when the experiment is finished in your classroom.

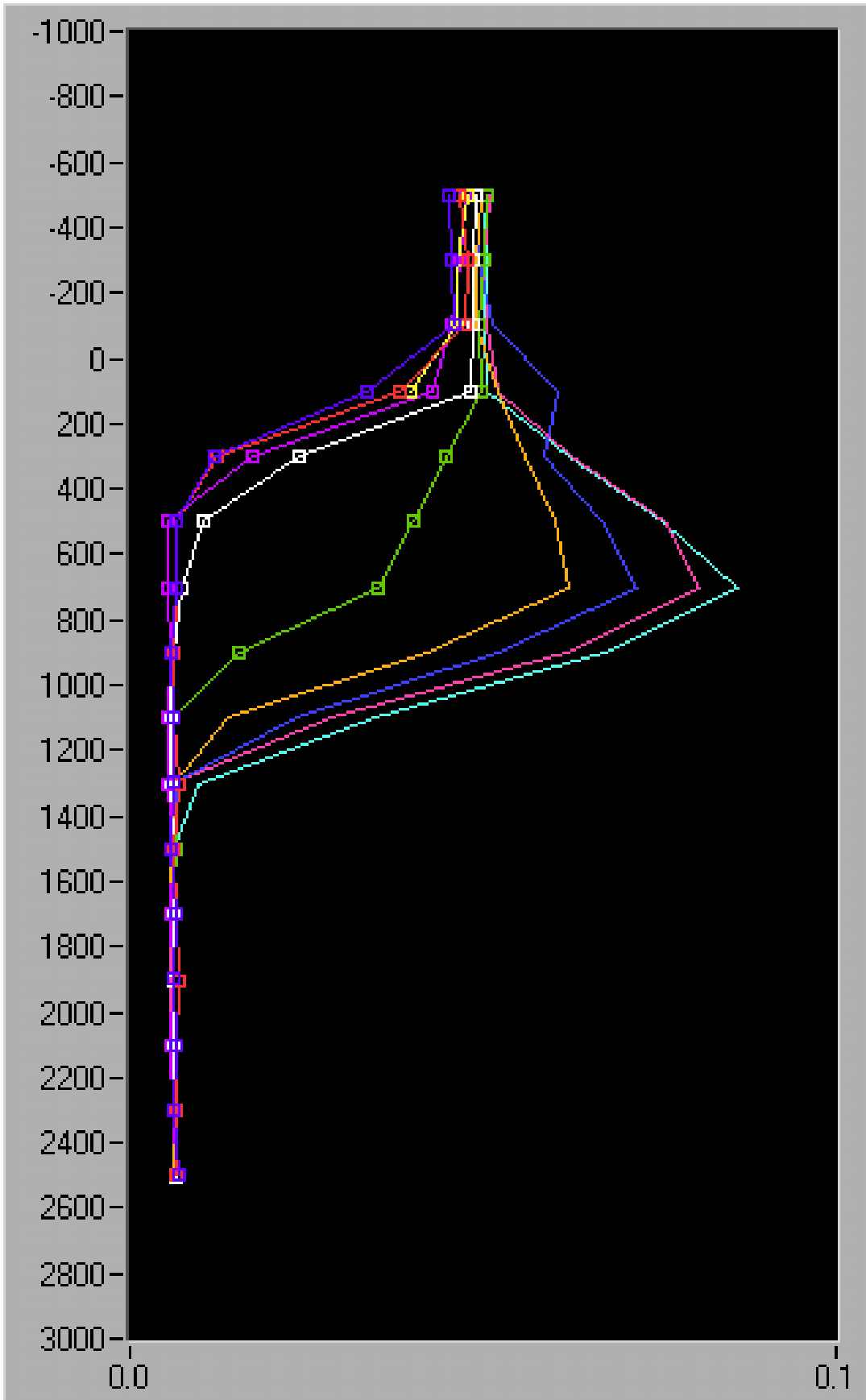
How to use the WebView Livescope

1. Connect to the WebView Livescope at <http://labcam.arc.nasa.gov/sample/LvAppl/lvappl.htm>
2. Select and click on the Start Control button located in the lower right corner of the image on your screen. The computer will show 20 seconds of wait time and then the window above the start control button will be green.
3. The far right scroll bar is the zoom. The bottom arrow located by the three small trees is for distance viewing. The upper arrow located by the picture of the single tree is for close-up viewing.
4. The scroll bars on either side of the picture allow the user to orient the camera either up and down or left and right.
5. The picture of the person with a sun in the background allows the user to control brightness.
6. The button with the picture of the black and blue squares is the panorama controller. By changing the position of the yellow cursor and square, one can also select the view show in the camera window.
7. The button with a picture of a camera on it, allows the user to take a still image from the web cam.
8. To relinquish control, exit the website.



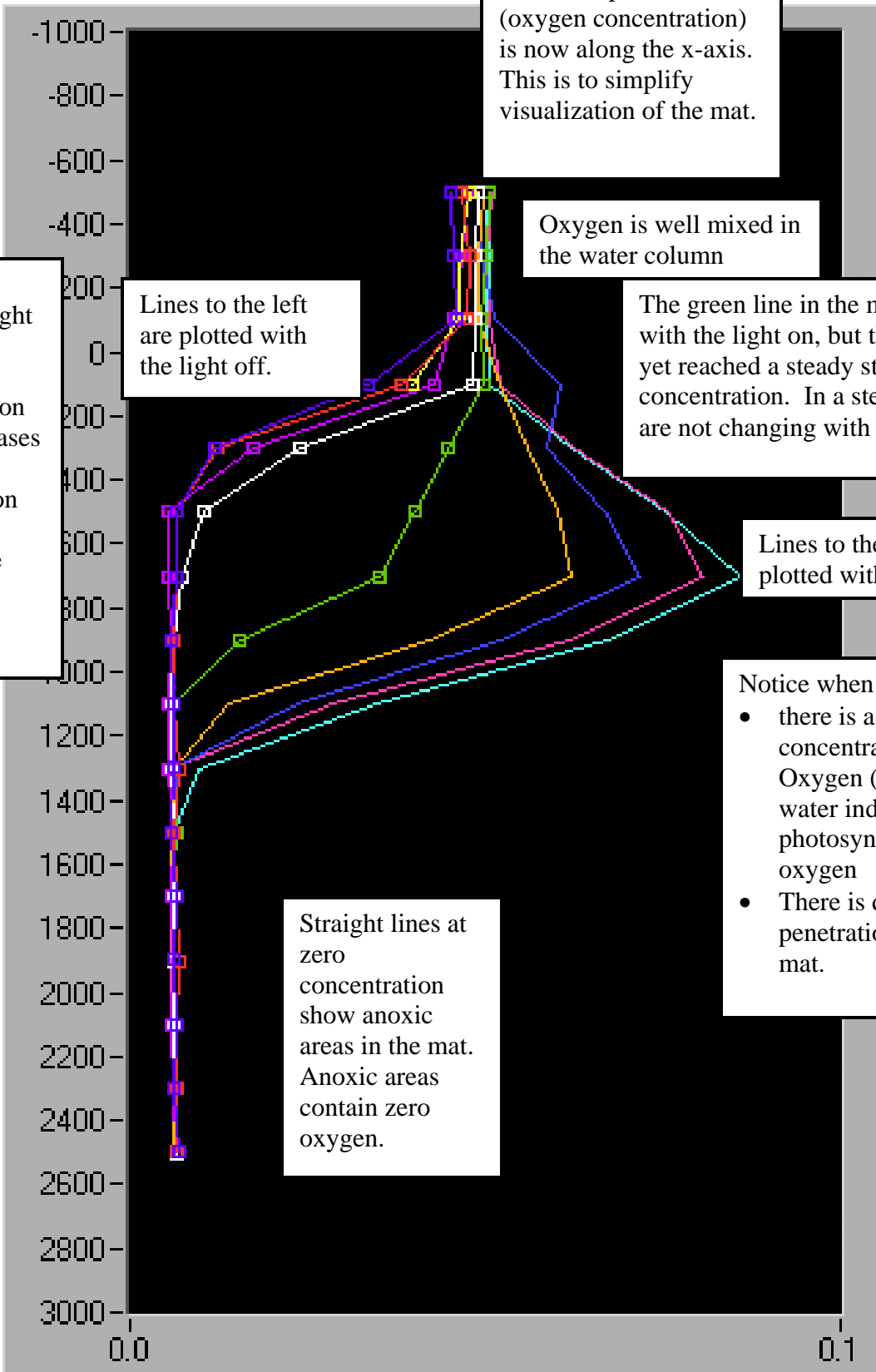
Oxygen Profile Graph taken 7/29/04

Physical Channel 1



Oxygen Profile graph taken 7/29/04

Physical Channel 1



Notice that the axis have switched: the independent axis (depth) is now along the y-axis and the dependent axis (oxygen concentration) is now along the x-axis. This is to simplify visualization of the mat.

Oxygen is well mixed in the water column

The green line in the middle is plotted with the light on, but the mat has not yet reached a steady state of oxygen concentration. In a steady state, things are not changing with respect to time.

Lines to the right are plotted with the light on.

Notice when the light is on:

- there is a higher concentration of Oxygen (O_2) than in the water indicating that photosynthesis produces oxygen
- There is deeper penetration of O_2 in the mat.

Lines to the left are plotted with the light off.

Notice that when the light is off, the oxygen concentration level decreases indicating consumption of oxygen through the process of respiration.

Straight lines at zero concentration show anoxic areas in the mat. Anoxic areas contain zero oxygen.

Data Analysis and Statistics

Main Concept: Appropriate graphical representations of data are used to develop and evaluate inferences and predictions that are based on that data.

Scientific Question: How can one use a mathematical model (graph) to evaluate the results of scientific investigations?

Objectives:

1. The student will know the differences between dependent and independent variables.
2. The student will pick an appropriate graph to represent data.
3. The student will determine an appropriate scale for the graph.
4. The student will use graphical representations to make predictions and inferences about the results of a scientific experiment.
5. Given a variety of graphical representations of the same data, student will draw conclusions about the differences in how one perceives the data.
6. The student will express analysis of data in written format.

Abstract of Unit: Through guided practice, independent practice, and cooperative learning activities, students will understand how independent and dependent variables, scale changes, and scale inconsistencies affect the way one perceives the results of an experiment. The unit includes three sequential lessons on graphing using data from experiments conducted on microbial mats. During lesson one, students will use line graphs to represent data from a Nitrogen Fixation Experiment conducted by Dr. Bebout at NASA's Ames Research Center. Lesson two utilizes scatter plots to represent data from an Oxygen Concentration Profile Experiment conducted by Dr. Bebout. Finally, lesson three requires students to graph data they collect in a Cyanobacteria Motility experiment in their Science Classroom using bar graphs.

Prerequisite Concepts:

Line graphs are used to show relationships of something over time (or space or quantity)
Graphing in coordinate plane (x, y)
enzyme, chemical reaction basics
mean

Major Concepts:

Dependent variable—the variable that changes according to the results of the experiment.
Independent variable—this is the variable that the experimenter changes when the experiment is set up; the dependent variable is dependent on the independent variable; the established independent value will influence what value the dependent variable reaches.
Scale—needs to be consistent when plotting a graph
Visual representation of data can be misleading—one has to consider how the data is represented on a graph (scale, etc.)
Gathering Data
Plotting Results
Analyzing Results using graphical representations of Data

Inverse and direct relationships in graphs.

Misconceptions:

The conclusions of an experiment can change just because the graph is plotted in a different way. The data from the experiment does not change and the results do not change when the graph is plotted in a different way. However, the interpretation of the data can change because of the picture shown by the graph. It is important that students learn to look at the graph and the scale of the graph to interpret the graph correctly.

Reading on Topic related to study:

Details of the experiments conducted at NASA that are listed on the Microbial Mat Education Page

1. Profiles of Oxygen Concentration experiment

http://nai.arc.nasa.gov/microbe/oxygen_profiles.cfm

2. Nitrogen Fixation Experiment

http://nai.arc.nasa.gov/microbe/nitrogen_fixation.cfm

3. Cyanobacterial Motility Experiment

http://nai.arc.nasa.gov/microbe/cyanobacterial_motility.cfm

Materials List

1. Data sets from Profiles of Oxygen Concentration Experiment, Nitrogen Fixation Experiment, and Cyanobacterial Motility Experiment from the Microbial Mat Education Page
2. Graph paper for each student
3. Rulers for each student
4. Overhead graph transparency film for each student group.
5. Overhead markers for each student group
6. Samples of graphs of the same data drawn with variances to be prepared by the teacher:
 - a. Independent variables and dependent variables reversed on x-y axis
 - b. Scale change (graphs of the same data plotted at different scales)
 - c. Scale inconsistent (for example, the scale changes from increments of 5 to 10 within the same axis)
 - d. Shape of graph – graph stretched horizontally or vertically to show more or less exaggerated slope.

Preparation:

1. Obtain access to the Microbial Mat Education Page <http://nai.arc.nasa.gov> in a computer lab for real time use of experiment descriptions and data sets or copy materials from the site for classroom use.

2. Make copies of graph grid lines on overhead transparency film.
3. Make copies of model graphs on overhead transparency film.

Differentiation:

Students with Learning Disabilities and English Language Learners: Cooperative Learning Groups can be used to accommodate students with learning disabilities. High, medium and low Math students can be paired within groups to balance instruction and help all students meet standards.

Visual cues, for example, pictorial representations of graphs can be used along with verbal instructions to model steps of the teaching process to provide a scaffold for student learning.

Advanced Learners: Extension activities can include providing more extensive data sets to plot, compare, and analyze results. Live Data from the web cam at NASA can be plotted and analyzed. Excel can be used to plot data.

Day One, Lesson One: Line Graphs and Scatter plot

Introduce Nitrogen fixation Experiment to students. All organisms need nitrogen to survive, but most organisms cannot use Nitrogen alone when it is in the form of a gas. Microorganisms can supply themselves with nitrogen by combining nitrogen with another element to form a compound. This is called Nitrogen fixation. Nitrogen from the atmosphere is reduced into ammonia (NH₃) using an enzyme called nitrogenase. In the NASA experiments, nitrogen fixation rates in microbial mats were measured over about nine months. In the six mats used, two had 200 μmol nitrogen added to them, two had 12 μmol phosphorus added to them, and two had nothing added to them. The ratio of nitrogen and phosphorus added was determined using the Redfield marine ratio of 106 Carbon to 16 Nitrogen to 1 Phosphorus.

How to make a graph using NASA Research:

1. Have students prepare data for graphing. For each experimental treatment, students should:
 - a. Determine the mean for phosphorus, nitrogen and no addition for each day by adding the measurements for each treatment and dividing by the number of measurements.
2. Introduce dependent and independent variable and x and y-axis.
3. Introduce how to determine scale.
4. Model plotting of data on a graph on the board or overhead. Have students make their graphs at their own desks as activity is modeled.
 - a. To plot a line graph:
 - i. plot points for the mean of a treatment
 - ii. appropriately place the line so that there are equal numbers of points above and below the line(a line of best fit)
 - iii. Repeat the process for the data for each treatment.
 - b. To plot a scatter plot:

- i. Plot points for the mean of a treatment
 - ii. Draw a line connecting each point of the treatment (connect the dots)
 - iii. Repeat the process for the data for each treatment.

- 5. Ask: what relationships are you showing when you have data sets that give different readings at different times of day?
 Answer: They are showing the relationships of nitrogen over time.

- 6. Ask: What type of graph would you use to plot this relationship and why?
 Answer: A line graph because it shows a relationship over time and a general trend (with slope) can be seen. Histogram might also be an acceptable answer, but it is harder to generalize a trend.

- 7. Determine the independent and dependent variable. Ask: Which axis does each variable go on?
 a. Answer: The independent variable is time and goes on the x-axis. The dependent variable is Nitrogen Fixation and goes on the y-axis.
- 8. Set up axes. X is the horizontal axis. Y is the vertical axis.
- 9. Determine the scale for the data that is being plotted.
 - a. First, look at the numerical range of the data.
 - b. Measure the paper to determine the size of the graph.
 - c. Next, determine which scale best fits on the graph paper.
 - i. Both scales should start at zero
 - 1. If there is a large gap between 0 and data then a break line can be used to show a break in the graph. It is best not to use a break line if possible.
 - 2. Example of a break line:
 - ii. The scale used at on the model graph was increments of 500 on the y-axis and 30 days on the x-axis. Scales started at zero. Two centimeters separated each increment mark.
 - d. Mark scale increments on both the x-axis and y-axis.
 - e. Neatly label the x-axis and y-axis.
- 10. Plot data sets for each of the mats. One color should be used for each treatment.
 - a. Red: mean of nitrogen additions #1 and #2
 - b. Blue: mean of phosphorus additions #1 and #2
 - c. Green: mean of mats with no additions #1 and #2
- 11. To make Line Graphs: Plot points and draw a line of best fit. The line of best fit should be appropriately placed so there are equal numbers of points above and below the line. Post graphs for the entire class to see.
- 12. To make Scatter Plots: Plot points and connect them on student graphs, then post them for the entire class.
- 13. Once the graphs are made, ask the following questions from the microbial mat website:

- a. What do the graphs show us?
- b. Are there any differences between the line graph and the scatter plot?
- c. Did the mats fix nitrogen? How do you know?
- d. Did the amount of nitrogen fixation change over time?
- e. If we were to continue plotting these lines, would you expect the trend to continue as you saw? Why, or why not?
- f. Were there differences in the treatments?
- g. How does the addition of different elements influence the nitrogen fixation over time?

14. Display the line graph: Ask: What is the trend shown by the graph?

Answer: The graph indicates a trend toward an increase in nitrogen fixation as time passes.

15. As an extension activity, have students plot the data for the repetition for each treatment separately. One color should be used for each treatment, for example:
- a. Purple: nitrogen addition #1
 - b. Pink: nitrogen addition #2
 - c. Yellow: phosphorus addition #1,
 - d. Orange: phosphorus addition #2
 - e. Teal: no addition #1
 - f. Light Blue: no addition #2

Model plotting points and connecting them for one addition for one mat, have students come up and plot the respective points, after they have made the graphs at their desks.

15. Ask the following question about the scatter plot that the students just completed:
- a. How did the two samples where elements added were the same compare?
 - b. What could explain differences in results?
 - c. Would you expect them to be the same?

16. After discussing all of the graphs above, ask:

- a. What conclusions can you draw about nitrogen fixation in Microbial Mats?
- b. How can we explain any differences in nitrogen fixation with respect to the treatments?

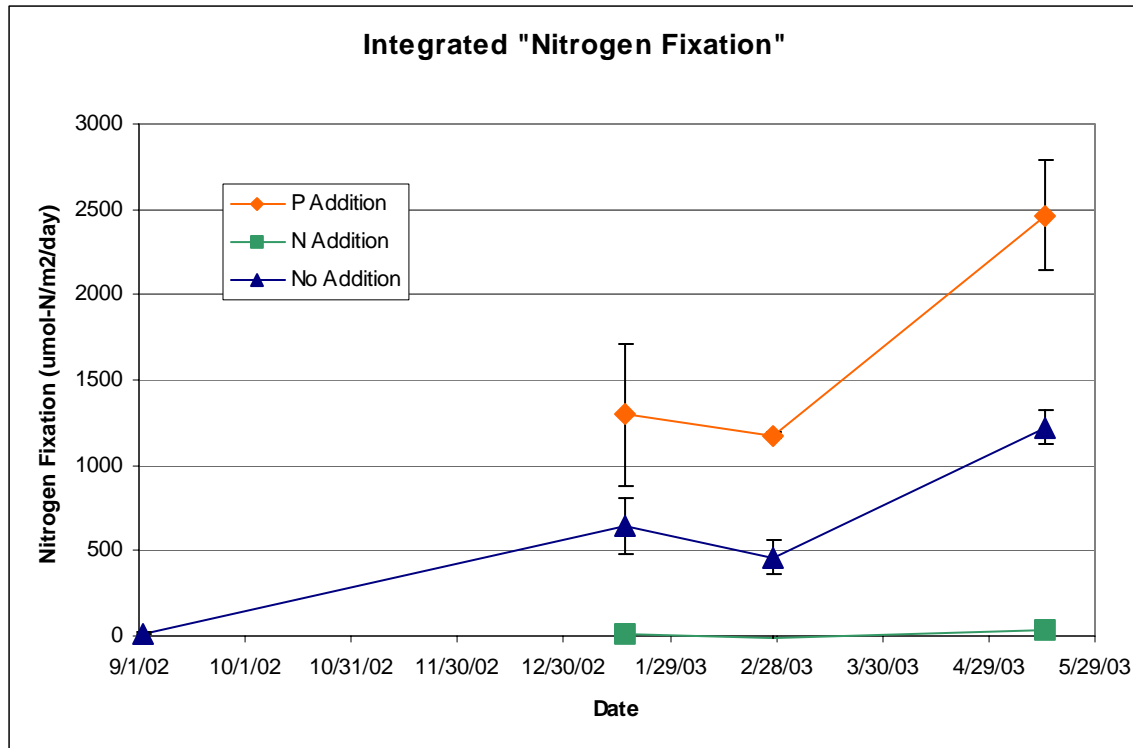
c. Why wouldn't all organisms fix nitrogen?

Answer: Not all organisms have the metabolic processes to fix Nitrogen. Nitrogen Fixation requires a large amount of energy. Not all organisms have that energy.

d. How do people get nitrogen (we need it to survive, too)?

Answer: People obtain nitrogen from food.

16. Extension Activity: Display the Integrated Nitrogen Fixation graph from the Participate section of the Web Site.



17. Show students the error bars on the graph. Explain that the bigger the error bar, the larger the fluctuations in data. Pick a section of the graph with a large bar and a section with a small error bar. Ask: Which data is more reliable and why?
 Answer: The section with the small error bar. There is a small difference between the two data samples.

Day Two, Lesson Two: Scatter Plots

This lesson uses data from experiments conducted by Dr. Brad Bebout at NASA Ames Research Center on Oxygen Concentration in Microbial Mats. Cyanobacteria living in microbial mats produce a variety of levels of oxygen during a 24-hour (diel) cycle. Oxygen is produced by photosynthesis and consumed by respiration. By measuring the concentrations of oxygen in a mat, it is possible to see what the net balance of photosynthesis and respiration is in the community. By measuring oxygen concentrations at various depths, it is possible to see what the net balance is at each of the depths. A set of measurements of oxygen with depth is called a “profile of oxygen concentration”.



Students will also have an opportunity in the science strand of this unit to conduct Oxygen Diel Cycle Profiles using an internet connection to the Web Lab at NASA Ames Research Center in Mountain View, California. In their science class, they will remotely operate a microsensors to record the amount of oxygen produced in varying depths of the mat under light and dark conditions on LabVIEW. Students will then analyze the graph produced by LabVIEW. If the science teacher is not utilizing the Web Lab: Oxygen Diel Cycle Profile, the math teacher can run the virtual experiment in the math room. (In the

interdisciplinary unit calendar, the Web Lab: Oxygen Dial Cycle Profile follows the Data and Statistics: Scatter Plot graphing lesson in the science classroom.)

Materials:

1. Profiles of Oxygen Concentration Experiment and data sets
2. Transparency Film printed with grid lines (Enough Sheets for each group)
3. Enough overhead markers for each group
4. Transparencies of graphs created by the teacher, which include:
 - a. A graph with reversed independent and dependent variables.

Note that the NASA graph reverses independent and dependent variables to simplify visualization of the mat.

- b. Graphs of scale change (students will be graphing data sets in different scales, but this graph is for those with small classes (they can also be used to check student work))
 - c. A graph showing scale inconsistencies (for example a graph started in increments of 5 that change to increments of 10)
5. Introduce Profiles of Oxygen Concentration Experiment (Students will conduct this experiment using the LabVIEW connection to the Web Lab at NASA) (English class should have completed KWL activity to define terms such as photosynthesis, respiration, concentrations, net balance, incubated, robotic table, etc from the description of the experiment on the Microbial Mat Education Page website.)

Background: Because they are so directly tied to the energy coming from our sun, the metabolic activities of microorganisms living in microbial mats dramatically change over a 24-hour (diel) cycle. Oxygen is produced by photosynthesis (which only occurs in the light) and is consumed by respiration. The diel changes in activity dramatically alter the concentrations of oxygen present in the mat over the same diel period. By measuring the concentrations of oxygen in a mat, microbial ecologists can determine the net balance of photosynthesis and respiration in the community. A set of measurements of oxygen with depth is called a “profile of oxygen concentration”.

A microsensor will record the amount of oxygen present in varying depths of the mat during the exposure to light. Microsensor measurements will also be taken in the dark. Through analyzing profiles of oxygen concentration data, students will determine the relationship between light and the net export or import of oxygen from the mat, and the ability of cyanobacteria to produce and consume oxygen.

Procedure:

1. Form groups of two students. Have students graph data sets on overhead transparencies that are printed with graph grid lines using the scale below.
 - Groups one-six will use the same scale increments when plotting experimental data on their graph:
 - Groups 7-12 will use the same scale increments when plotting their graphs.
 - Groups 13-18 will use the same scale increments when plotting their graphs.

2. Once students have graphed data, have them consider the questions on the handout, using their graphed results. The sample oxygen concentration profile that is attached to this unit explains the answers.

- Are the mats producing oxygen?
- Are the mats consuming oxygen?
- At what depths are production and consumption highest?
- At what depths are production and consumption the lowest?

Ask the additional questions listed below, once all mat data graph transparencies have been overlaid on the overhead projector.

- Are these mats a source or a sink of oxygen?
- What is the difference in oxygen concentration during light and dark periods?

3. Have groups one-six overlay transparencies of their graphs on the overhead projector.

4. Display graphs from the other student groups (Method B and C) that were drawn to different scales.

- Ask: Is there a difference in oxygen concentration levels in these graphs?
Answer: While the picture may exaggerate data, the oxygen concentration level is the same as shown in the earlier graphs. The data is the same, just the scale is different.

5. Display transparencies of the graphs the teacher prepared for this lesson:

- 1) independent and dependent variable reversed
- 2) scale inconsistencies

Next, have students compare the graphs from each of the methods used:

How do scale, orientation, and dimensions of a graph change the way we perceive things?

What conclusions do you draw about the experiment when you look at how data is displayed on different graphs?

What information do you need to know about a graph to make more accurate inferences about the relationship of the data? Students should talk about labeling axes, labeling scale.

Written Analysis: Students will submit a written analysis of why the graph looks the way it does and how the way the graph is drawn influences data analysis.

Day Three: Introduction to Bar Graphs

This graphing activity is an introduction to the line and bar graphs that students will complete with their own data from the Cyanobacteria Races in Science Class. Cyanobacteria Motility data sets and graph samples for this activity may be accessed through: <http://exobiology.arc.nasa.gov/ssx/microecobiogeo/> on the Microbial Mat Education Page in the Participate section.

Procedure:

1. Graph the data on Baja cyanobacteria motility in the following ways:
 - a. Create a line graph plotting the daily movements of cyanobacteria over time. One line should be made connecting the measurements of movement toward the light. Another line should be made connecting the measurements of movement away from the light. Be certain that the y-axis (distance) does not start at zero so that movement away from the light can be marked in negative numbers. See the graphs for the Cyanobacteria Motility Experiment performed at Ames Research Center on the Microbial Mat Education Page in the Participate section. This page can be accessed through the Microbial Ecology/Biogeochemistry Research Laboratory at <http://exobiology.arc.nasa.gov/ssx/microecobiogeo/>
 - b. Create a summary bar graph for the total movement cyanobacteria made toward and away from the light. Handout the Rubric: Cyanobacteria Motility Experiment for guidelines. For each culture:
 1. Average the total distance the cyanobacteria moved toward the light.
 2. Average the total distance the cyanobacteria moved away from the light.
 - c. On a bar graph, plot the distance each culture of bacteria moved. Again, the y-axis does not start with zero, but allows negative numbers to be plotted that signify movement away from the light. Label each bar with culture identification. Use separate colors to distinguish movement away from the light and toward the light. See the graphs for the Cyanobacteria Motility Experiment performed at Ames Research Center on the Microbial Mat Education Page in the Participate section. This page can be accessed through the Microbial Ecology/Biogeochemistry Research Laboratory at <http://exobiology.arc.nasa.gov/ssx/microecobiogeo/>
2. Using the data displayed in the graphs, ask the following questions at the conclusion of the lab:
 - Did the cyanobacteria respond to light?
 - Did the different species respond in the same way?
 - Did they move at the same speed over the course of the experiment?
 - Which were faster or slower?
 - After looking at the graphs, what questions do you have for further research?

- Why do you think the cyanobacteria responded in the way that they did?
Possible explanations may include:
 - Research by Niels B. Ramsing and Lee Prufert-Bebout, *Motility of Microcoleus chthonoplastes subjected to different light intensities quantified by digital image analysis*, suggests several potential strategies to find optimal light conditions:
 - 4) Total movement: minimize movement if conditions are favorable
 - a. Frequency of movement: Move less frequently if light conditions are favorable
 - b. Speed of Movement: Move slower if conditions are favorable
 - 5) Reversing direction of movement
 - a. Reverse direction of movement more frequently if conditions are favorable.
 - 6) Change direction(curling up)
 - a. Change direction more frequently (create bends) if conditions are favorable.
 - Cyanobacteria may be responding to conditions other than light. For example, the nutrients in the agar might be a variable.

[0]

4. Have students complete a written summary interpreting their Bar Graph. Use the Rubric: Cyanobacteria Motility Experiment for guidelines in completing the summary.
5. Students need to keep their graphs of Baja Stromatolite Cyanobacteria for science class to compare with their own data from the Cyanobacteria Races they conduct in science.

Evaluation: Use the Rubric for the Cyanobacteria Motility Experiment to assess student graphs and graph interpretation summaries.

Extension: Take the graphs of the data students collected from their science experiments on cyanobacteria motility and analysis them in math class. Use the Summary Rubric to set guidelines for written Summaries.

Rubric: Nitrogen Fixation Experiment

Line Graph

- ___ The graph has a title.
- ___ The horizontal axis (x-axis) is correctly labeled with the independent variable.
- ___ The vertical axis (y-axis) is correctly labeled with the dependent variable.
- ___ Units or increments on the graph are equally spaced and identified.
- ___ The graph has a key or legend.
- ___ Points are plotted correctly on the graph reflecting an accurate use of data.
- ___ The graph is neatly drawn with a ruler and labels are neatly written and easy to read.
- ___ Separate Colors are used for each different experimental treatment.
- ___ The line is appropriately placed so there are equal numbers of points above and below the line(a line of best fit).

Graph Interpretation Summary

- ___ The Introduction to the paper contains:
 - ___ A summary of the experiment.
 - ___ A thesis statement that indicates why the graph looks the way it does.
- ___ The Body includes an explanation of how one can draw conclusions from the graph. For example, how does the graph picture show:
 - ___ What is the trend shown by the graph?
 - ___ Did the mats fix nitrogen?
 - ___ Did the amount of nitrogen fixation change over time?
 - ___ Were there differences in the treatments?
- ___ The Conclusion contains:
 - ___ A summary of the inferences drawn from the experiment.
 - ___ An explanation of any variation in data or an error analysis.
 - ___ An idea for further research or other questions relating to the

Nitrogen Fixation Experiment

- ___ The paper contains an accurate analysis of data.
- ___ The paper uses correct spelling, punctuation, and grammar.

Rubric: Nitrogen Fixation Experiment

Scatter Plot

- ___ The graph has a title.
- ___ The horizontal axis (x-axis) is correctly labeled with the independent variable.
- ___ The vertical axis (y-axis) is correctly labeled with the dependent variable.
- ___ Units or increments on the graph are equally spaced and identified.
- ___ The graph has a key or legend.
- ___ Points are plotted correctly on the graph reflecting an accurate use of data.
- ___ Lines are drawn connecting the data points in the scatter plot.
- ___ The graph is neatly drawn with a ruler and labels are neatly written and easy to read.
- ___ Separate Colors are used for each different experimental treatment.

Graph Interpretation Summary

- ___ The Introduction to the paper contains:
 - ___ A summary of the experiment.
 - ___ A thesis statement that indicates why the graph looks the way it does.
- ___ The Body includes an explanation of how one can draw conclusions from the graph. For example, how does the graph picture show:
 - ___ What does the graph show?
 - ___ Did the mats fix nitrogen?
 - ___ Did the amount of nitrogen fixation change over time?
 - ___ Were there differences in the treatments?
- ___ The Conclusion contains:
 - ___ A summary of the inferences drawn from the experiment.
 - ___ An explanation of any variation in data or an error analysis.
 - ___ An idea for further research or other questions relating to the

Nitrogen Fixation Experiment

- ___ The paper contains an accurate analysis of data.
- ___ The paper uses correct spelling, punctuation, and grammar.

Rubric: Oxygen Concentration Profile

Scatter Plot

- ___ The graph has a title.
- ___ The independent and dependent variables are reversed on the graph to simplify visualization of the mat. The independent axis (depth) is now along the y-axis and the dependent axis (oxygen concentration) is now along the x-axis.
- ___ Units or increments on the graph are equally spaced and identified.
- ___ The graph has a key or legend.
- ___ Points are plotted correctly on the graph reflecting an accurate use of data.
- ___ Lines are drawn connecting the data points in the scatter plot.
- ___ The graph is neatly drawn with a ruler and labels are neatly written and easy to read.
- ___ Separate Colors are used for each Profile of Oxygen Concentration. Light, Dark, and non-steady states should be graphed.

Graph Interpretation Summary

- ___ The Introduction to the paper contains:
 - ___ A summary of the experiment.
 - ___ A thesis statement that indicates why the graph looks the way it does.
- ___ The Body includes an explanation of how one can draw conclusions from the graph. For example, how does the graph picture show:
 - ___ Are the mats producing oxygen?
 - ___ Are the mats consuming oxygen?
 - ___ At what depths are production and consumption highest?
 - ___ At what depths are production and consumption the lowest?
- ___ The Conclusion contains:
 - ___ A summary of the inferences drawn from the experiment.
 - ___ What would explain the differences in the profiles?
 - ___ Are these mats a source or sink of oxygen?
 - ___ An explanation of variation in data and error analysis.
 - ___ An idea for further research or other questions relating to the Oxygen Concentration experiment.
- ___ The paper contains an accurate analysis of data.
- ___ The paper uses correct spelling, punctuation, and grammar.

Checklist Rubric: Cyanobacteria Motility Experiment

Bar Graph (Summary Graph)

- ___ The graph has a title.
- ___ The graph has an appropriate scale on the vertical axis.
- ___ The graph has different treatments listed on the horizontal axis.
- ___ The graph has labels on both axes.
- ___ Units or increments on the graph are equally spaced and identified.
- ___ The graph has a key or legend.
- ___ Bars are drawn correctly on the graph reflecting an accurate use of data.
- ___ The graph is neatly drawn with a ruler and labels are neatly written and easy to read.
- ___ Separate Colors are used to distinguish movement away from the light and toward the light.

Graph Interpretation Summary

- ___ The Introduction to the paper contains:
 - ___ A summary of the experiment.
 - ___ A thesis statement that indicates why the graph looks the way it does.
- ___ The Body includes an explanation of how one can draw conclusions from the graph. For example, how does the graph picture show:
 - ___ Did the cyanobacteria respond to the light?
 - ___ Did the different species respond in the same way?
 - ___ Did they move at the same speed over the course of the experiment?
 - ___ Which were faster or slower?
- ___ The Conclusion contains:
 - ___ A summary of the inferences drawn from the experiment.
 - ___ Which cultures would be most likely to be found at the top of the stromatolite?
 - ___ Which would be more likely to be at the bottom?
 - ___ An idea for further research or other questions relating to the Cyanobacteria Motility Experiment.
 - ___ An analysis of errors and any variation in data.
- ___ The paper contains an accurate analysis of data.
- ___ The paper uses correct spelling, punctuation, and grammar.

Language Arts Lesson Plan Format

Main Concept: Microbial mats conduct processes that control our planet.

Question: What are microbial mats and why are they important?

Objectives:

1. The student will identify topics, ask and evaluate questions; and develop ideas leading to inquiry, investigation, and research.
2. The student will use technology research tools to locate, evaluate, and collect information from a variety of sources.
3. The student will write summaries of reading materials that include the main ideas, most significant details, and reflect the underlying meaning of the material.
4. The student will deliver research presentations.
5. The student will discover how living organisms affect the composition of the atmosphere.
6. The student will learn how organisms in microbial mats function as ecosystems exchanging energy and nutrients among themselves and with the environment
7. The student will learn how bacteria cell structure differs from other living organisms.

Abstract of Reading Lesson: Students will learn reading comprehension strategies to apply to their attack of difficult scientific reading material.

Question: It is Greek to me: How can I understand what I am reading?

Materials:

1. Post-it-Notes
2. Science Article: Bebout, Brad M. ET. Al, *Long-Term Manipulations of Intact Microbial Mat Communities in a Greenhouse Collaboratory: Simulating Earth's Present and Past Field Environments*, ASTROBIOLOGY. Volume 2, Number 4, Mary Ann Liebert, Inc, 2002.
3. prefix/suffix/root handout
4. dictionary or online dictionary

Methods:

Give students a pre-test of unfamiliar words or words used in a different way in an article. Collect the pre-test, score it and demonstrate the need for using strategies to determine the meaning of text, which contains material that is difficult to understand.

Teach strategies which include:

1. Use Greek and Latin prefixes, suffixes and roots to use to determine the meaning of unknown words. (Pick several affixes from words that are in the text. Define the prefixes, suffixes, and roots. Use the Prefix, Suffix and Root Handout that is provided. Give students words that they can break apart using this technique from your article to define.)
2. Keeping a running list of unfamiliar words, using the internet or a dictionary to determine meanings, and writing definitions by the list of unfamiliar words.
3. In pairs: Have students read specific paragraphs in the text with a partner where they highlight words that they do not know or words that do not make sense in

- context because they are used in an unfamiliar way. Next, have them look up the words in either a dictionary or online (good for difficult scientific terms) and write down the definition that best fits the context of the sentence that they are reading.
4. Use post-it notes to write word definitions, questions about the meaning, or writing down comprehension “guesses”. Stick post-it notes next to the appropriate place in the article. Give students post-it notes to use to write down definitions to unfamiliar words—make certain that you teach students that they need to understand the definition “rewrite it in kid speak”. Also, have them write down questions that they have when they are reading and answers as they find them in the article. Have them write comprehension guesses to check later.
 5. Use context clues to help determine the meaning of unfamiliar words. (Pull a sentence to model from the reading on the overhead that has an unfamiliar word, show how the words around it can give clues to meaning (sentence clues, paragraph clues). Give students different sentences imbedded in paragraphs, so they can practice using context clues to determine meaning. Share results including having students explain what clues in the sentence or paragraph helped them determine the meaning.

Post-test on reading material: What were students able to understand now that they did not before? Compare results with the pretest.

MATERIALS TO BE DEVELOPED:

1. Pretest based on words in the article
2. Posttest based on words in the article

Abstract of Web Quest Lesson: During this student web quest, students will utilize the internet as a source of information on microbial mats, practice summarizing, and give a report of research.

Materials:

1. Internet access
2. 3 X 5 and 4 x 6 inch Note cards
3. Handout on Research Note taking

Methods:

1. Students will be assigned to cooperative groups of 4-5 to research different aspects of Astrobiology and Microbial Mats using a web quest. A jigsaw format will be used with each student researching a different question, so the students can combine to answer a greater question: How does one use Earth’s microbial ecosystems to look for life on other planets? The greater question will be answered at the end of the unit, after students have completed all science, math, and other English activities.

Smaller questions include:

- What are microbes?
- What are microbial mats?

- Why are microbial mats important?
- What is Astrobiology?
- What does NASA want to learn from studying Microbial Mats?
- What is included in the study of Astrobiology?
- What kind of gases, liquids, and solids are in microbial mats?
- What biological processes can be seen in microbial mats?
- For life to exist, what do scientists think is required?

2. All students will be taught to summarize and research using the Research Note taking Handout.

3. Next, students will go to the web with their question. Some websites will be given for initial research, other websites students will have to search to find. (Review use of search engines and quality web sites.)

4. Students who have researched the same question will share ideas with others who have completed the same research to see if they need to add or change anything in their research before they share the information with the members of their group who have researched different topics.

5. Material is presented to the group in some format: speech, PowerPoint, etc. All students need to take notes on the information in each presentation since they will need it in other classes to understand the material in the unit and they will need it at the end to answer the big question.

Prefixes, Suffixes and Roots for English Unit

astro- root(Greek) star, heavenly body, outer space

auto- prefix (Greek) self

an- prefix (Greek) not, without, lacking **anaerobic**

bio-prefix (Greek) life

di- prefix(Greek) two, double

electro-prefix (New Latin) electric, electricity

hyper- prefix(Greek) used before nouns and adjectives excessive, overly, too much, unusual

in- prefix (Old English)used before verbs and nouns in, into, on

in-prefix (Latin) used before adjectives not

iso- prefix(Greek) equal

micro- prefix (Latin) 1) small or very small in comparison with others of it's kind
2) restricted in scope

milli- prefix (Latin) 1/1000

meta- prefix (Greek) after, along with, beyond, among, behind

photo-prefix (Greek) light

syn- prefix (Greek) with, together **photosynthesis**

logy- suffix (Middle English) study of, field of study, discipline, list of

troph-root (Greek) food, nourishment **phototrophic**

geo-root(Greek) the earth, ground

bene-root(Latin) well

ic-suffix(Middle English) used after nouns to form adjectives meaning: of or relating to;
used after nouns to form adjectives meaning: having some characteristics of; in the style of

gen-root(Greek) origin or source

meter-root(Greek) measure

litho-prefix(Greek) stone

atmo-prefix() steam; vapor

chem-prefix ()chemicals, chemical

oxy or ox-prefix()oxygen

eco-prefix() ecology

meta-prefix(Greek) beside, after

Web Quest : Extra, Extra, Read All About it: Earth Life May Trace to Scum Gas

Introduction

You have been selected as a member of a group to interest fourth and fifth grade students in current science issues. As you search for science topics to capture their attention, you came across this headline: *Earth Life May Trace to Scum Gas.*⁷ Although this seems like a tabloid heading, it is not. NASA researchers are studying bacteria, other microbes, and the gases they produce in microbial mat ecosystems to see how life formed on Earth. Early microbial ecosystems are also studied to help scientists discover life on other planets. This scum research is even being used in the quest for life on Mars. You wonder, how do you use earth's microbial ecosystems to look for life on other planets?

Task: Your group has been selected to give an interactive lesson on microbial mats to a fifth grade class. This lesson will capture the attention of the students, excite them about science, and answer the following questions:

- What are microbes?
- What are microbial mats?
- How do mats function as ecosystems?
- What do microbial mats tell us about life on early earth?
- What do microbial mats tell us about the search for life on other planets?

Your group may select the format for your presentation. For example, you may choose to present a skit, activity, PowerPoint presentation, movie, or other idea. Be creative and engage your audience.

As you design your interactive lesson, remember the following:

1. Your presentation must be appropriate for a 4th or 5th grade audience.
2. Your final presentation must involve the learners, but be contain accurate science facts.
3. Your presentation must be a minimum of 15 minutes, and a maximum of 25 minutes.
4. Your presentation must include a way to check that students understand the material that they learned.

Write the problem statement: As a team, what do you consider your task and problem to be? Write a question to address for your task.

⁷ *Earth Life May Trace to Scum Gas.*⁷ 3 August 2001. Silicon Valley Business Journal <http://www.bizjournals.com/sanjose/stories/2001/07/03/daily.57.html> (Cached from Google search

<http://www.google.com/search?q=cache:kOT89GqTE3gJ:sanjose.bizjournals.com/sanjose/stories/2001/07/30/+Earth+life+may+trace+to+scum+gas&hl=en>

Sample: How can we create an interactive lesson, which shows how Earth's Microbial Ecosystems can be used to look for life on other planets?

Determine Learning Issues : Know Want to know Learned format

Step One:

In your team, complete the KWL chart, answering the questions as follows:

In the Know section of the chart: What do you know about microbes, microbial mats, astrobiology, slime, space exploration using mats to find life on other planets?

In the Want to know section of the chart: What do you need to need to learn about microbes, astrobiology, microbial mats, the search for life on other planets, etc. in order to create your presentation to the elementary school students? Remember, if you do not know anything about the topic, you will need to learn a little bit about the topic, determine new learning issues, and then research other items.

The Learned section of the chart will be completed after you do research.

Step Two: Decide as a team how to group your learning issues from the “Want to Know” section of the chart into 4 categories to research. Make group research assignments.

(One class period will be given for the initial research. The group will meet after the initial class period to share what they have learned. (Design issue—maybe they should meet with students from other groups who are researching the same topic to assist each other with what they have learned about the topic before they meet with their original group. This allow for a double check of information before they communicate knowledge to their team.)

Information Sources:

Dyer, Betsey Dexter. A Field Guide to Bacteria. Cornell University: Ithaca, NY, 2003. (pp. 32-33 for guide on using microbes to seek life on other planets, pp. 232-275--cyanobacteria)

Microbe Zoo, Communication Technology Laboratory Center for Microbial Ecology, Michigan State University:, <http://commtechlab.msu.edu/sites/dlc-me/zoo/index.html>

“What is Microbial Ecology?” Communication Technology Laboratory Center for Microbial Ecology, Michigan State University: 2000, <http://commtechlab.msu.edu/sites/dlc-me/zoo/ziwime.html>

“Introduction to the Cyanobacteria: Architects of earth’s atmosphere,”
<http://www.ucmp.berkeley.edu/bacteria/cyanointro.html>

micro*scope <http://www.mbl.edu/microscope>

NASA Astrobiology Institute <http://nai.arc.nasa.gov>

The SETI Institute <http://seti.org/epo/>

Schneegurt, Dr. Mark A., Cyanosite, Department of Biological Sciences, Purdue University, <http://www-cyanocite.bio.purdue.edu/> (Source of images and heavy research articles, may not be that good for kids)

Bebout, Brad. Web Page.

http://nai.arc.nasa.gov/students/this_month/index.cfm

“Production and Consumption of Trace Gases in Microbial Mats,”

http://exobiology.arc.nasa.gov/ssx/microecobiogeo/html_documents/trace_gases.htm

Astrobiology: http://www-space.arc.nasa.gov/branches_EB.htm

Blake, Dr. David F. Exobiology, <http://exobiology.arc.nasa.gov/> (NASA’s interest in microbes, links to lab pages)

Microbe World, American Society for Microbiology: 24 February, 2003

<http://www.microbeworld.org/home.htm> (General Information on microbiology)

Activities for Microbiology Education

Ewald, Heather t. James H. Brashears III, Christine N. Huynh, Eric B. Freeman, Micahael V. Corvini, Meghan F. Davis, Elizabeth M. Femenia, Billie R. Hart and Carl W. Vermeulen, “Micro-Organisms for Education,” Department of Biology, The College of William & Mary:1997, <http://www.science-projects.com/safemicrobes.htm#xlist>

Process, Evaluation, and Teacher Pages under development.

KWL Chart

What do you know?

**What do you want to
know?**

What have you learned?

Research Note taking Handout

Note taking Guidelines

1. Write one note on each card.
2. Double-check the spelling of names and technical terms.
3. Use quotation marks whenever you include exact words from your source in a report.
4. Summarize or Paraphrase information. (Put it in your own words.)
5. Make a bibliography card for each source.
6. Label each note card with the source number and card number.

Summary Example:

A summary is a short piece of writing that restates the main idea of a reading selection and gives only the important details that are needed to explain the main idea. Use your own words and style when you write a summary.

Example:

Original Reading Selection:

Excerpt from: Bebout, Brad M., et al. "Long-Term Manipulations of Intact Microbial Mat Communities in a Greenhouse Collaboratory: Simulating Earth's Present and Past Field Environments," *ASTROBIOLOGY*, Volume 2, Number 4, 2002, Mary Ann Liebert, Inc.

Microbial mats kept in the greenhouse facility retained an overall appearance remarkably similar to that of freshly collected mats. In particular, no evidence of the mat "greening," in which motile cyanobacteria migrate to the surface of the mat (Bebout and Garcia-Pichel, 1995), was apparent. During the first few weeks of greenhouse incubation, there was a notable increase in the abundance of loosely attached microbial "floc" at the surface of the mats, as well as the development of small dark green spots containing large numbers of cyanobacterial filaments in some mats. However, after the first 2 months, the loose floc disappeared, and the mat surface was smooth and homogeneous in appearance once again. Extensive, but nonquantitative, microscopic observations revealed no major changes in community composition. More specifically, the major populations of cyanobacteria did not seem to change, and *M. chthonoplastes* remained in the dominant phototroph in all of the sections of mat characterized microscopically.

1. Who/What:

2. Important details:

3. In 15-20 words, write the main idea of the passage:

Write your summary in the box below to create a note card:

_____	1-1
	Page

2) A bibliography card gives your source information. Use the format below to help you write the entry. For more information on Internet entries go to: thewritesource.com

Items in an on-line Entry:

Author or editor. <e-mail address>. "Post title." Book Title. Editor(if not listed earlier). Printed version information(if any). Site title or description.
Administration. Version number, volume, issue, etc. Post date, or last update.
Listserv or forum name. Site sponsor. Date accessed. <Electronic Address>.

Article:

Author's last name, first name. "Title of Article." Title of Publication. Day Month year of publication. Day Month Year found on internet <internet address>.

Web site:

Title of Site. Administrator of site, title of administrator. Day Month Year put on net.
Site Sponsor. Day Month Year accessed on web. <Internet Address>.

Make up a Bibliography Card for the article you summarized above:

1

Take notes on the information that you are studying on 4X6 cards. Remember to put one idea on each note card. You need a minimum of 50 note cards. Depending the focus for your part of the research, the notes might include information on:

- 1) What is a microbe?
- 2) What is a microbial mat?
- 3) How do mats function as ecosystems?
- 4) What do microbial mats tell us about life on early earth?
- 5) What do microbial mats tell us about the search for life on other planets?

Make certain that you complete a bibliography card for each source that you have taken notes on. Bibliographic information should be written on 3 X 5 cards. You will need to have a minimum of 5 sources.

