**Abstract**

“It’s Greek to Me” focuses on reading strategies to help students comprehend difficult text. Given a scientific article on microbial mats, students will explore ways to make meaning of a text, explain how they reached the conclusions they did and apply these strategies to other reading experiences. Reading strategies include applying grammar and context clues to further comprehension, using knowledge of Greek and Latin prefixes, suffixes, and roots to break down unfamiliar words and determine their meaning, retelling and other methods to help determine meaning.

**Overview of 5 E Lesson Design**

**Engage**

(Pick the engage activity or activities that best meets the needs of the class, but make certain to use the pretest of words used in the Bebout et al. article before beginning the explore activities.)

- Brainstorm: What do you do when you have a difficult text to read?
- Gibberish passage
- Translate a “teen speak” Passage: What do you need to do to understand it if you are not a teen?
- Movie clip from “My Big Fat Greek Wedding” illustrating knowledge of Greek roots
- Pretest of words used in Bebout, Brad M. et al. (2002), Long-Term Manipulations of Intact Microbial Mat Communities in a Greenhouse Collaboratory: Simulating Earth’s Present and Past Field Environments, Astrobiology 2, 383-402.
- Prefix, suffix, root “dissection”
- Invent a new word with prefixes, suffixes or roots: Sniglet concept

**Explore**

- Model Think-Aloud Strategies
- Apply Think-Aloud Strategies: Pair/Share Activities
  - What strategies can you use to make sense of the passage?
  - What other strategies can you think of that would help make the passage comprehensible? (Document the Process)
  - Make a chart or table that evaluates the strong and weak points of each reading strategy used—comparison with other student team

**Explain**

- Students explain Pair/Share
  - Process
  - Strategies
  - Present best method and show how it works
Extend

- Retelling as a tool for textual comprehension
- Rewrite Introduction of Bebout, Brad M. et al. (2002), Long-Term Manipulations of Intact Microbial Mat Communities in a Greenhouse Collaboratory: Simulating Earth’s Present and Past Field Environments, Astrobiology 2, 383-402. In a different Genre

Evaluate

- Scoring Rubrics
- Post-Test

Engage

**Brainstorm**

1. Present the following scenario for students brainstorming and discussion: You have just been given a text to read. You look at the words on the page. You can say them—but the text that you are reading might as well be written in Greek. The words have no meaning for you. The text is important for you to read and understand. What are you going to do about it?

2. Break the class into groups of no more than five students for the Brainstorming activity. Give each group chart paper to write down their responses and present the following question for Brainstorming: What do you do (or what can you do) when you have a difficult text to read?

3. Large cards labeled: “Producers”, “Consumers” and “Decomposers”.

4. Have the group pick their two best ideas and give an example for each idea.

5. Have the group nominate a reporter for the group to share the ideas with the class.

6. In a full class discussion, have groups share the strategies and examples that they created for dealing with a difficult text. Make a class list of strategies to use on chart paper. Post these strategies in the classroom.

**Gibberish Passage**

**Handout:** The Monotillation of Traxoline by Judy Lanier

1. Present the gibberish passage, The Monotillation of Traxoline by Judy Lanier, to the class. Have them answer the questions at the bottom of the passage.

2. Discuss student answers to the questions.
   a. How were they able to answer the questions?
      **Answer:** Answers will vary. Possible answers include using the words in the passage that are located around the word(s) mentioned in the question to offer a response.

   b. Even though they can answer the questions, what is the problem with their answers?
      **Answer:** Even though they can tell you the answers to the questions, the answers have no meaning because they do not know the words.

   c. If this was a passage with real words, what strategies could you use to help determine the meaning?
      **Answer:** The words around the unknown word could help build meaning (context clues). A dictionary could be used to discover the meaning of unknown words.
3. Make certain that students arrive at the conclusion that even though one can use context clues to answer questions, if there is no understanding of the words or concepts that answer the question, the passage makes no sense. If a reader does not comprehend the passage, reading is not occurring. Reading is not decoding, or pronouncing the words on the page; it is a meaning-making process.

**Translate a “teen speak” Passage**

1. Have pairs of students in each class write a passage using teenage slang. Collect the passages and review them for class the next day.

2. Exchange teen speak passages between classes or students.

3. Have each student group read the passage and decide what a reader would need to understand if he or she did not know this slang.

4. Have each group record their teen speak comprehension hints.

5. Have each group present one strategy to the class.

6. Have a student record these strategies on the board.

**Movie Clip**

**Materials**: Clip from “My Big Fat Greek Wedding”

1. Show a selection from “My Big Fat Greek Wedding” that illustrates how prefixes and suffixes and roots can be used to break down words.

3. Discuss how prefixes, suffixes and roots can be used to determine word meaning.

**Pretest of reading words used in Science Article**

**Handouts**: Pretest of Words used in Bebout et al. Article Key for Pretest of Words used in Bebout et al. Article

**Materials**: Clip from “My Big Fat Greek Wedding”

1. Give students a pre-test of unfamiliar words or words used in a different way in an article.

3. Collect the pre-test, score it as a class and demonstrate the need for using strategies to determine the meaning of the text, which contains material that is difficult to understand.

**Prefix, suffix and root “dissection”**

**Handouts**: Prefix, Suffixes and Roots for English Unit Prefixes, Suffixes and Roots for English Unit Teacher Reference Words for Dissection

**Methods**:

1. Break students into groups of two.

2. Pass out the Greek and Latin Prefixes, Suffixes and Roots handout to use to determine the meaning of unknown words.

3. Give each group a word to dissect using Greek and Latin Prefixes, Suffixes and Roots to determine word meaning.

4. Have students determine the meaning of the word by combining the meaning of the prefixes, suffixes and roots.

5. Students need to pick their best word to display on a poster a present to the class.
**Model Think-Aloud Strategies**


**Introduction**

One of the best ways to teach reading comprehension is to model the strategies that a good reader uses to make sense of an unfamiliar text. The purpose of a think aloud is for the teacher to take an unfamiliar passage of a difficult text and talk aloud, giving the students a dialogue of what happens inside the brain when reading. Another purpose is to demonstrate the strategies the teacher uses to make sense of a text. In this exercise, semantic and syntactic context clues will be used to determine the meaning of the text. Semantic context clues are those that help to determine meaning, such as using definition, synonyms, antonym, examples, explanation, experience or knowledge of a subject to understand the words in a text. Syntactic context clues give grammatical information, such as part of speech, or origin information, such as prefix, suffixes, and roots.

**Main Concept**

Students will apply reading strategies such as using context clues, grammatical structures, punctuation and Greek and Latin prefixes, suffixes, and roots to determine the meaning of a difficult text.

**Question:** What strategies can be used to understand a difficult text?

**Objectives:**

1. The student will apply knowledge of Greek and Latin affixes to determine the meaning of words in the article.
2. The student will apply knowledge of grammatical structures and punctuation rules to determine the meaning of words in an article.
3. The student will use context clues (definition, synonyms, antonym, example, explanation, experience or knowledge of a subject) to determine the meaning of the text.
4. The student will look for multiple meanings of words and apply the correct meaning to understand text.
5. The student will discover through reading how living organisms affect the composition of the atmosphere.
6. The student will learn how organisms in microbial mats function as ecosystems exchanging nutrients among themselves and with the environment.
## National Standards

**IRA/NCTE Standards for the English Language Arts (NLAS)**

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<td><strong>NLAS #1:</strong> Read range of print and non-print texts</td>
<td><strong>NLAS #8:</strong> Use technological and information resources to gather and synthesize information and create and communicate knowledge</td>
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<td><strong>NLAS #4:</strong> Adjust use of language to communicate effectively</td>
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<td><strong>NLAS #6:</strong> Apply knowledge of language to create, critique, and discuss print and non-print texts.</td>
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<td><strong>NSES C8(5-8):</strong> Diversity and Adaptations of Organisms b</td>
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## California Education Standards

**National Science Education Standards (NSES)**

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<tr>
<td><strong>LA Grade 6:</strong> Reading 1.0</td>
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<td><strong>Science Grade 8:</strong> Chemistry of Living Systems #6 a</td>
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<td><strong>LA Grade 8:</strong> Vocabulary &amp; Concept Development 1.3</td>
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<tr>
<td>Science Grade 6: Ecology #5 a, b</td>
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Abstract of Lesson

This lesson models comprehension strategies to use with a scientific text and then has students apply these strategies to their own reading.

Prerequisite Concepts

1. Words are formed using prefixes and suffixes and roots that have meaning from Greek and Latin.

Major Concepts

1. Knowledge of Greek and Latin affixes can be used to figure out the meaning of a difficult word.
2. Sentence syntax, punctuation and grammar can be used to figure out the meaning of word in a sentence.
3. Context clues such as definition, synonym, antonym, examples, explanation, experience, and knowledge of subject can be used to determine meaning.
4. Definition substitution and context clues can help establish the meaning of words that have multiple meanings.
5. Living organisms in microbial mats affected the composition of the atmosphere.
6. Organisms in microbial mats are self-sustaining ecosystems exchanging nutrients among themselves and with the environment.

Misconceptions

1. Nothing can be done to aid comprehension when a text is difficult to understand.
2. If words are unfamiliar or difficult to understand, they can be ignored when reading.

Materials

1. Overhead transparencies of a clean copies of the passages from Long-Term Manipulations of Intact Microbial Mat Communities in a Greenhouse Collaboratory: Simulating Earth’s Present and Past Field Environments.
2. Copies of the passages from Long-Term Manipulations of Intact Microbial Mat Communities in a Greenhouse Collaboratory: Simulating Earth’s Present and Past Field Environments for the class.
3. A marked sample of a teacher think aloud to use as a model for the classroom teacher’s preparation of this strategy. There are different copies that are marked for the different strategies that the students are using. Examples are taken from the pretest. Note that it is better if you document your thinking process on the clean copy of the text for your students. This is included as a guide for preparation if the strategy is unfamiliar.
4. Copies of other passages from Long-Term Manipulations of Intact Microbial Mat Communities in a Greenhouse Collaboratory: Simulating Earth’s Present and Past Field Environments to use with the class for paired practice after teacher modeling of strategies.
Methods

1. Have students complete the reading pretest to determine which strategy to model in your Think-Aloud.

2. Score the Reading Pretests. The strategies that are covered by each section are:

   • **Syntactic Context Clues using Grammar** (A grammar or punctuation rule helps determine word meaning): Questions 1 and 8

   • **Multiple Meanings and Context Clues** (Context clues, the words, phrases or sentences around an unfamiliar word, help to determine the meaning of a word that has multiple meanings): Question 4

   • **Prefixes, Suffixes, and Roots** (A knowledge of Greek or Latin prefixes, suffixes, and roots helps to break down the word into parts to determine meaning): Questions: 2 and 5

   • **Syntactic Context Clues using Grammar and Prefixes, Suffixes, and Roots** (A grammar or punctuation rule helps determine word meaning when combined with a knowledge of Greek or Latin prefixes, suffixes, and roots helps to break down the word into parts to determine meaning): Questions 3, 6 and 10

   • **Semantic Context Clues** (The words, phrases or sentences around an unfamiliar word that help determine its meaning): Question 7 and 9

3. Divide students into strategy study groups based on the section where the student missed the most questions. In the strategy workshops, it is easier to apply one strategy at a time. If a student misses an equal number of questions in several sections, it would be best to start the student in one of the following sections where he or she has missed questions:

   • Semantic Context Clues
   • Prefix, Suffixes, and Roots
   • Syntactic Context Clues using Grammar.

   The strategy workshops where strategies will be combined are more difficult:

   • Multiple Meanings and Context Clues
   • Syntactic Context Clues using Grammar and Prefixes, Suffixes, and Roots.

   After reviewing the pretests, divide your class into groups to model the strategy that each student needs the most practice using. If strategies are modeled at one time, students will become confused. Therefore, divide the class into groups, model one strategy and allow for practice and application time. If students have trouble applying several strategies the other strategies can be modeled latter in the year after students have a chance to master the application of one strategy.

4. Depending on the number of groups, prepare alternative activities for the group members who are not involved in the Think-Aloud strategy instruction group. This is a good time for independent reading.

5. For each group, place a copy of the selected passage from Long-Term Manipulations of Intact Microbial Mat Communities in a Greenhouse Collaboratory: Simulating Earth’s Present and Past Field Environments on the overhead and pass out copies to students. Make certain that you select the model for the strategy instruction that you are modeling.

6. When reading, mark the passage with questions, comments, and the thinking process used to make sense of an unfamiliar text. Have students mark your thinking strategies on their handouts. (If comments are made on clear overhead arrows that you tape to the overhead, the comments can be removed and rearranged to use when writing a summary. A master of large overhead arrows can be made by using a word processing program to create the master and then by copying the master on overhead transparency film using the copy machine.)
7. As unfamiliar terms come up use the strategy you are modeling (context clues, a knowledge of prefixes, suffixes and roots, and reference materials such as dictionaries and/or the internet) to make sense of the material. Have students look up unfamiliar terms and share them with the class. Add them to your mark-up of the passage.

8. Discuss the methods used and any other questions about strategies that the students might have.

9. Select other passages from the text to have students read in pairs. In this paired reading, students practice the strategy, marking the article with comments post-it-notes that can be later removed to organize the material for summary writing.

10. Apply think-pair-share strategies.

**Explain**

Have students take the introduction to the Bebout et al. article and rewrite it in a different genre. Models are included in the handouts that can be made into overhead transparencies.

**Extend**

Use retelling to aid in comprehension of a text.

**Methods:**

1. Have students take the introduction to the Bebout et al. article and rewrite it in a different genre. Models are included in the handouts that can be made into overhead transparencies.

   - Model the Rephrasing Activity for Narrative Retelling with the passage from Bucaria, R. and Bebout B. A Teacher’s Guide to Stromatolite Explorer. Microbes @ NASA. http://microbes.arc.nasa.gov p.9

     a. Read the passage as a class.
     b. Highlight the main ideas of the passage.
     c. Rephrase main ideas in your own words.
     d. Number the ideas in the order you want to write about them.
     e. Select the type of narrative retelling for writing.

        i. Narrative: write a fictional story written from the bacteria’s perspective on life in a microbial mat.

           **Narrative structure includes:**

           - Hook
           - Description
           - Dramatic detail
           - Voice
           - First person (bacteria) narration
           - Plot: introduction (character, setting, etc.), inciting incident, rising action, climax, denouement, and resolution

        i. Picture Book: write a children's story using the same structure as the original picture book text. For example, use Cynthia Rylant’s When I was Young in the Mountains, Bill Martin Jr.’s Brown Bear, Brown Bear, What do you see?, Dr. Seuss’ books, etc. and follow the patterns, sentence structure, rhythm and style using content from the article you are retelling.
Picture Book structure includes:
- Same structure and rhythm as the original picture book text.
- Repetition of words, phrases, or images
- Words help reader picture ideas

ii. Poem: write a poem using images, word choice, line breaks, flow or rhythm to convey the information in the article.

Poetry structure includes:
- Vivid words and images used to convey ideas
- Succinct language
- Link breaks used to emphasize meaning.
- Flow or rhythm draws readers into the poem

b. Review the Narrative Retelling Rubric when planning the rewrite to make certain that all criteria are addressed in the retelling.

c. Write the narrative.

Evaluate

Scoring Rubrics
- Narrative Retelling Rubric with Content from Bebout Article
- Narrative Retelling Rubric (master)

Pretest
- Pretest of words used in Bebout Article

Posttest
- Posttest of words used in Bebout Article

List of Models and Handouts (That follow this page.)

Gibberish Passage: The Monotillation of Traxoline
KEY: The Monotillation of Traxoline
Pretest of words used in Bebout Article
KEY: Pretest of words used in Bebout Article
Prefixes, Suffixes and Roots
Words to use for Prefix, Suffix, and Root Dissection
Prefixes, Suffixes and Roots with Related Science Words
Unmarked Think-Aloud: Syntactic Context Clues using Grammar(Questions 1 and 8 from Pretest)
Marked Think-Aloud: Syntactic Context Clues using Grammar(Questions 1 and 8 from Pretest)
Unmarked Think-Aloud: Multiple Meanings and Context Clues (Question 4 from Pretest)
Marked Think-Aloud: Multiple Meanings and Context Clues (Question 4 from Pretest)

Unmarked Think-Aloud: Prefixes, Suffixes, and Roots (Questions 2 and 5 from Pretest)

Marked Think-Aloud: Prefixes, Suffixes, and Roots (Questions 2 and 5 from Pretest)

Unmarked Think-Aloud: Syntactic Context Clues using Grammar and Prefixes, Suffixes and Roots (Questions 3, 6, and 10 from Pretest)

Marked Think-Aloud: Syntactic Context Clues using Grammar and Prefixes, Suffixes and Roots (Questions 3, 6, and 10 from Pretest)

Unmarked Think-Aloud: Semantic Context Clues (Questions 7 and 9)

Marked Think-Aloud: Semantic Context Clues (Questions 7 and 9)

Unmarked Paragraph from Bebout Article: Introduction

Marked Paragraph from Bebout Article: Introduction: Prefixes, Suffixes and Roots (marked using comment feature)

Marked Paragraph from Bebout Article: Introduction: Syntactic Context Clues using Grammar and Prefixes, Suffixes and Roots (marked using comment feature)

Marked Paragraph from Bebout Article: Introduction: Semantic Context Clues (need to marked using comment feature)

Unmarked Think-Pair-Share: Syntactic Context Clues using Grammar

Marked Think-Pair-Share: Syntactic Context Clues using Grammar

Unmarked Think-Pair-Share: Multiple Meanings and Context Clues

Marked Think-Pair-Share: Multiple Meanings and Context Clues

Unmarked Think-Pair-Share: Prefixes, Suffixes, and Roots

Marked Think-Pair-Share: Prefixes, Suffixes, and Roots

Unmarked Think-Pair-Share: Syntactic Context Clues using Grammar and Prefixes, Suffixes, and Roots

Marked Think-Pair-Share: Syntactic Context Clues using Grammar and Prefixes, Suffixes, and Roots

Unmarked Think-Pair-Share: Semantic Context Clues

Marked Think-Pair-Share: Semantic Context Clues

Posttest of words used in Bebout, Brad M. et al. Article

Key for Posttest of words used in Bebout, Brad M. et al. Article

Unmarked Narrative Retelling Model from A Teacher’s Guide to Stromatolite Explorer

Unmarked Narrative Retelling Model from A Teacher’s Guide to Stromatolite Explorer: Find the main ideas in the paragraph

Marked Narrative Retelling Model from A Teacher’s Guide to Stromatolite Explorer: Find the main ideas in the paragraph

Rephrasing Activity for Narrative Retelling with text

Rephrasing Activity for Narrative Retelling with text and rephrasing

Introductory Paragraph to use with Narrative Retelling (for independent practice)

Rephrasing Activity for Narrative Retelling (blank)

Narrative Retelling Rubric with Content from Bebout Article

Narrative Retelling Rubric (master)
The Monotillation of Traxoline
By Judy Lanier

It is very important that you learn about traxoline. Traxoline is a new form of zionter. It is monotilled in Ceristanna. The Ceristannians gristeriate large amounts of fevon and then bracter it to quasel traxoline. Traxoline may well be one of our most lukized snezlaus in the future because of our zionter lescelidge.

What is traxoline?

Where is traxoline monotilled?

How is traxoline quaselled?

Why is it important to know about traxoline?
It is very important that you learn about traxoline. Traxoline is a new form of zionter. It is monotilled in Ceristanna. The Ceristannians gristerlate large amounts of fevon and then bracter it to quasel traxoline. Traxoline may well be one of our most lukized snezlaus in the future because of our zionter lescelidge.

What is traxoline?

Traxoline is a new form of zionter.

Where is traxoline monotilled?

Traxoline is monotilled in Ceristanna.

How is traxoline quaselled?

First, large amounts of fevon is gristerlated. Next, the gristerlated fevon is bractered to quasel traxoline.

Why is it important to know about traxoline?

It is important to know about traxoline because it may well be one of our most lukized snezlaus in the future because of our zionter lescelidge.
A. to make smaller

B. rock-like layers of sand or minerals produced by microorganisms trapping, binding or precipitating sediment

C. in a new position

D. the addition of oxygen to a physical system

E. unstable salt concentration

F. to remove oxygen from a substance

G. able to change position

H. existing without oxygen

I. the pigment change caused by certain microorganisms moving to the top of a mat

J. in the original position

K. the gases that surround the earth

L. able to obtain energy from light

M. high salt concentration

N. the solid part of the earth known as the crust and the mantle

Match the highlighted words in each passage on the left, with the letter of the correct definition located at the top of the page. Underline the words or parts that give a clue to the meaning of the bold word in the sentence.

1. Geochemical evidence of the existence of photosynthetic microbial mats, and their mineralized counterparts, stromatolites, has been identified in rocks as old as 3.0 Ga (Beukes and Lowe, 1989) (page 384). (Ga= billion years ago)

2. Because these microbial mats are considered to be useful analogs of ancient marine communities, they offer insights about evolutionary events during the >3 billion year time interval wherein mats co-evolved with Earth’s lithosphere and atmosphere (page 383).

3. To understand the overall structure and function of mat communities, it is thus critical to determine the nature and extent of the interactions between phototrophic and non-photosynthetic microorganisms, including anaerobic microorganisms (page 384).

4. When oxygenic photosynthesis ceases at night, the upper layers of the mat become highly reduced and sulfidic (Jørgensen et al., 1979) (page 384).

5. Photosynthetic microbial mat communities were obtained from marine hypersaline saltern ponds, maintained in a greenhouse facility, and examined for the effects of salinity variations (page 383).

6. As dominant components of our biosphere for at least 2 billion years of its >3.5 billion year history, microbial mats played a pivotal role in shaping the composition of Earth’s early atmosphere, including its eventual oxygenation (page 385).

7. Normal in situ daily water column temperature variations were simulated in the greenhouse by (1) controlling the temperature increase (attributable to solar heating) during the daytime to stay below the maximum temperature observed in situ and (2) turning off temperature control at night to allow the water temperature in the flow boxes to decrease slowly with the decrease in greenhouse air temperature (page 387).

8. 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 (page 390).

9. Furthermore, many mat microorganisms are motile, utilizing light and/or UV radiation as a cue to adjust their position in the mats vertically (Castenholz, 1994; Bebout and Garcia-Pichel, 1995) (page 398).

10. In this way, exposure of the deeper anaerobic layers of the mats to air and light was minimized (page 385).
Geochemical evidence of the existence of photosynthetic microbial mats, and their mineralized counterparts, stromatolites, has been identified in rocks as old as 3.0 Ga (Beukes and Lowe, 1989) (page 384). The word stromatolites is defined by grammar and context clues. The definition photosynthetic microbial mats, and their mineralized counterparts is given before the commas setting off the appositive containing the word, stromatolites, which has just been defined. Words are often set off by commas for emphasis or definition.

Because these microbial mats are considered to be useful analogs of ancient marine communities, they offer insights about evolutionary events during the >3 billion year time interval wherein mats co-evolved with Earth’s lithosphere and atmosphere (page 383). Breaking the word, lithosphere, into parts helps determine its meaning. Litho is a Greek prefix meaning stone, sphere means round. Literally, the lithosphere is the stone sphere around the earth or the earth’s crust and mantle.

To understand the overall structure and function of mat communities, it is thus critical to determine the nature and extent of the interactions between phototrophic and non-photosynthetic microorganisms, including anaerobic microorganisms (page 384). The meaning of the word phototrophic can be determined through a combination of grammatical context clues and a study of prefixes, suffixes and roots. The grammatical structure, interactions between phototrophic and non-photosynthetic microorganisms, implies a contrast between microorganisms that are phototrophic and those that are non-photosynthetic. It can be inferred that phototrophic organisms are photosynthetic, since there is an interaction between those organisms that are phototrophic and those that are non-photosynthetic. A study of the word parts confirms this guess from context clues. Photo is a Greek prefix that means light. Troph is a Greek root means nourishment. The affix, ic, is Middle English suffix which means relating to. If a phototrophic is a microorganism that relates to getting nourishment from light, then a phototrophic organism is photosynthetic and able to obtain energy through light.

When oxygenic photosynthesis ceases at night, the upper layers of the mat become highly reduced and sulfidic (Jørgensen et al., 1979) (page 384). This is an example of a word, reduced, that has multiple meanings and may be used in an unfamiliar way. The context clues in the sentence show that the common definition, to make smaller, is not the best one, because reduced is linked with the word sulfidic through the use of “and”. Earlier in the sentence, the statement is made, “When oxygenic photosynthesis ceases…” providing the clue that removing oxygen from a substance would be the correct definition.

Photosynthetic microbial mat communities were obtained from marine hypersaline saltern ponds, maintained in a greenhouse facility, and examined for the effects of salinity variations (page 383). Break down each of the word parts to find the meaning of this word: hyper is a Greek prefix used before nouns and adjectives meaning excessive, overly, too much, or unusual. The word part, sal, is Latin for salt and ine is a Latin suffix meaning of or relating to. Hypersaline would mean excessively salty.

As dominant components of our biosphere for at least 2 billion years of its >3.5 billion year history, microbial mats played a pivotal role in shaping the composition of Earth’s early atmosphere, including its eventual oxygenation (page 385). Context clues and word part analysis help one to determine the meaning of this word. If one knows that the atmosphere is composed of oxygen and other gasses, then one can guess that oxygenation has something to do with oxygen. When one looks at the word parts, one finds that the oxy or ox-prefix means oxygen, gen is a Greek root meaning origin or source, and ion is a suffix which means condition or action. Put it together and one has the condition or action of the origination of oxygen.
7. *Normal* in situ daily water column temperature variations were simulated in the greenhouse by (1) controlling the temperature increase (attributable to solar heating) during the daytime to stay below the maximum temperature observed *in situ* and (2) turning off temperature control at night to allow the water temperature in the flow boxes to decrease slowly with the decrease in greenhouse air temperature (page 387). *The context clues, normal, daily, were simulated in the greenhouse, as well as, to stay below the maximum temperature observed in situ indicate that in situ would be the opposite of conditions in the greenhouse, or the conditions in the natural environment. Also the italics indicate that it is another language, Latin in this case, from the web “Latin for ‘in original place.’ Refers to measurements made at the actual location of the object or material measured.”*

8. 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 (page 390). *The context clues that define the unfamiliar term “greening” are set apart by the appositive, “in which motile cyanobacteria migrate to the surface of the mat.” We know that the microorganisms, cyanobacteria, move to the top of the microbial mat causing the mat to become greener since cyanobacteria have a blue-green pigment.*

9. Furthermore, many mat microorganisms are motile, utilizing light and/or UV radiation as a cue to adjust their position in the mats vertically (Castenholz, 1994; Bebout and Garcia-Pichel, 1995) (page 398). *The context clue, adjust their position in the mats vertically, indicates that motile refers to movement.*

10. In this way, exposure of the deeper anaerobic layers of the mats to air and light was minimized (page 385). *Word parts and context clues reveal the meaning of the word anaerobic. The context clues “exposure” and “deeper anaerobic layers of the mats to air and light was minimized” indicate that the anaerobic layer does not have contact with air and light. No air present, means an environment without oxygen. Also, the absence of light does not allow photosynthesis. A break down of the word parts confirms this guess: a and an are Greek prefixes meaning not, without, or lacking. The Greek prefix aero, aer means air, atmosphere, or gas. The Middle English suffix, ic, is used after nouns to form adjectives meaning of or relating to or it is used after nouns to form adjectives meaning having some characteristics of or in the style of. When you combine the definitions of the word parts, something anaerobic exists without oxygen.*
### Prefixes, Suffixes and Roots

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Suffix</th>
<th>Root</th>
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<tbody>
<tr>
<td>aero, aer-&lt;sup&gt;(Greek)&lt;/sup&gt; air, atmosphere, gas</td>
<td>ic-(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</td>
<td>astro-(Greek) star, heavenly body, outer space</td>
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<tr>
<td>atmo-steam; vapor</td>
<td>ion- condition or action</td>
<td>bene-(Latin) well</td>
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<tr>
<td>auto-(Greek) self</td>
<td>ine-(Latin) of or relating to</td>
<td>geo-(Greek) the earth, ground</td>
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<tr>
<td>a, an-(Greek) not, without, lacking</td>
<td>logy-(Middle English) study of, field of study, discipline, list of</td>
<td>gen-(Greek) origin or source</td>
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<td>bio-(Greek) life</td>
<td></td>
<td>meter-(Greek) measure</td>
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<tr>
<td>chem-chemicals, chemical</td>
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<td>troph-(Greek) food, nourishment</td>
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<td>di-(Greek) two, double</td>
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<tr>
<td>eco-home</td>
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<td>electro-(New Latin) electric, electricity</td>
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<tr>
<td>hyper-(Greek) used before nouns and adjectives excessive, overly, too much, unusual</td>
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<tr>
<td>hypo-(Greek) under, beneath</td>
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<td>in-(Old English) used before verbs and nouns meaning in, into, on</td>
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<tr>
<td>in- (Latin) used before adjectives meaning not</td>
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<td>iso-(Greek) equal</td>
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<td>litho-(Greek) stone</td>
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<tr>
<td>micro-(Latin) 1) small or very small in comparison with others of it’s kind 2) restricted in scope</td>
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<tr>
<td>milli-&lt;sup&gt;1/1000&lt;/sup&gt;-(Latin)</td>
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<tr>
<td>meta-(Greek) after, along with, beyond, among, behind</td>
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<tr>
<td>oxy or ox-oxygen</td>
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<tr>
<td>photo-(Greek) light</td>
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<tr>
<td>physio, physi, phys-&lt;sup&gt;(Greek)&lt;/sup&gt; nature</td>
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<tr>
<td>syn-(Greek) with, together</td>
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<tr>
<td>terra, terr-(Latin) land, earth</td>
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</tbody>
</table>
ad, at (Latin) 1) toward, to 2) near, at
chrono-(Greek) time
flu, fluct, flux-(Latin) to flow
hetero- (Greek) different
logic- (Greek) of reasoning, logic
sal- (Latin) salt
topos-(Greek) place

Words for Prefix, Suffix and Root Dissection

anaerobic
astrobiology
autotroph
biogeochemical
biology
ecology
geology
heterotroph
hypersaline
isotope
isotrophic
microbiology
oxygenic
phototrophic
saline
Prefixes, Suffixes and Roots with Related Science Words

**ad, at** (Latin) 1) toward, to 2) near, at

**aero, aer**-prefix (Greek) air, atmosphere, gas

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

**atmo**-prefix () steam; vapor **atmosphere**

**auto-** prefix (Greek) self **autotroph**

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

**bene**-root (Latin) well **beneficial**

**bio-**prefix (Greek) life **biosphere, biology, biomarker**

**chem-**prefix () chemicals, chemical **chemical, biogeochemical**

**chrono-** (Greek) time **chronology**

**di-**prefix (Greek) two, double **dioxide**

**eco-**prefix home **ecology, ecosystem**

**electro-**prefix (New Latin) electric, electricity

**flu, fluct, flux-**(Latin) to flow

**geo-**root (Greek) the earth, ground **geology, biogeochemical**

**gen-**root (Greek) origin or source **genetic**

**hetero-** (Greek) different

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

**hypo-**prefix (Greek) under, beneath

**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 **isotrophic**

**ion-**suffix condition or action

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

**in-**prefix (Latin) used before adjectives meaning not

**ine-**suffix (Latin) of or relating to
iso- prefix (Greek) equal

litho-prefix (Greek) stone

logic- (Greek) of reasoning, logic

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

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

milli- prefix (Latin) 1/1000

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

meter-root (Greek) measure

oxy or ox- prefix oxygen

photo- prefix (Greek) light

physio, physi, phys- prefix (Greek) nature

sal- (Latin) salt

syn- prefix (Greek) with, together

terra, terr- prefix (Latin) land, earth

topos- (Greek) place

troph- root (Greek) food, nourishment

isotope

lithosphere

microbial

photosynthesis

hypersaline, saline

photosynthesis

phototrophic, autotrophy, heterotroph, isotrophic
Question 1:

INTRODUCTION

MODERN MICROBIAL MATS are thought to be extant representatives of Earth’s most ancient ecosystems (Walter, 1976). Geochemical evidence of the existence of photosynthetic microbial mats, and their mineralized counterparts, stromatolites, has been identified in rocks as old as 3.0 Ga (Beukes and Lowe, 1989).

Question 8:

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 (page 390).
(A grammar or punctuation rule helps determine word meaning): Questions 1 and 8 from the pre-test

Selections from:

**Question 1:**

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*Because the word stromatolite is enclosed in commas it explains what has gone before. Here the appositive, stromatolite, gives the word for the definition (of photosynthetic microbial mats, mineralized counterparts) that preceded it. Therefore, a stromatolite would be the microbes layered in minerals that conduct photosynthesis.*

**Question 8:**

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 (page 390).

*The context clues that define the unfamiliar term “greening” are set apart by the appositive, “in which motile cyanobacteria migrate to the surface of the mat.” We know that the microorganisms, cyanobacteria, move to the top of the microbial mat causing the mat to become greener since cyanobacteria have a blue-green pigment.*
(Context clues, the words, phrases or sentences around an unfamiliar word, help to determine the meaning of a word that has multiple meanings.): Question 4 from the pre-test

Selection from:

**Question 4:**

When oxygenic photosynthesis ceases at night, the upper layers of the mat become highly reduced and sulfidic (Jørgensen et al., 1979) (page 384).
Unmarked ThinkAloud: Multiple Meanings and Context Clues

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Question 4:

When oxygenic photosynthesis ceases at night, the upper layers of the mat become highly reduced and sulfidic (Jørgensen et al., 1979) (page 384).

This is an example of a word, reduced, that has multiple meanings and may be used in an unfamiliar way. The context clues in the sentence show that the common definition, to make smaller, is not the best one, because reduced is linked with the word sulfidic through the use of the word “and”. Earlier in the sentence, the statement is made, “When oxygenic photosynthesis ceases...” providing the clue that removing oxygen from a substance would be the correct definition.

Another approach would be to look up the unfamiliar word, reduced, in the dictionary and substitute the meanings until one makes sense in the context of the passage.
Unmarked Think-Aloud: Prefixes, Suffixes, and Roots

(Use knowledge of Greek or Latin prefixes, suffixes, and roots to help break down the word into parts to determine meaning.): Questions: 2 and 5

Selections from:

Question 2:

Because these microbial mats are considered to be useful analogs of ancient marine communities, they offer insights about evolutionary events during the >3 billion year time interval wherein mats co-evolved with Earth’s lithosphere and atmosphere (page 383).

Question 5:

Photosynthetic microbial mat communities were obtained from marine hypersaline saltern ponds, maintained in a greenhouse facility, and examined for the effects of salinity variations (page 383).
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Question 2:

Because these microbial mats are considered to be useful analogs of ancient marine communities, they offer insights about evolutionary events during the >3 billion year time interval wherein mats co-evolved with Earth’s lithosphere and atmosphere (page 383).

Breaking the word, lithosphere, into parts helps determine its meaning. Litho is a Greek prefix meaning stone, sphere means round. Literally, the lithosphere is the stone sphere around the earth or the earth’s crust and mantle.

Question 5:

Photosynthetic microbial mat communities were obtained from marine hypersaline saltern ponds, maintained in a greenhouse facility, and examined for the effects of salinity variations (page 383).

Break down each of the word parts to find the meaning of this word: hyper is a Greek prefix used before nouns and adjectives meaning excessive, overly, too much, or unusual. The word part, sal is Latin for salt and ine is a Latin suffix meaning of or relating to. Hypersaline would be mean excessively salty.
Unmarked Think-Aloud: Syntactic Context Clues using Grammar and Prefixes, Suffixes, and Roots

(A grammar or punctuation rule helps determine word meaning when combined with a knowledge of Greek or Latin prefixes, suffixes, and roots helps to break down the word into parts to determine meaning.): Questions 3, 6 and 10

Selections from:

**Question 3:**

To understand the overall structure and function of mat communities, it is thus critical to determine the nature and extent of the interactions between phototrophic and non-photosynthetic microorganisms, including anaerobic microorganisms (page 384).
Unmarked Think-Aloud: Syntactic Context Clues using Grammar and Prefixes, Suffixes, and Roots

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Selections from:

Question 6:

As dominant components of our biosphere for at least 2 billion years of its >3.5 billion year history, microbial mats played a pivotal role in shaping the composition of Earth’s early atmosphere, including its eventual oxygenation (page 385).
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Selections from:

Question 10:

In this way, exposure of the deeper anaerobic layers of the mats to air and light was minimized (page 385).
To understand the overall structure and function of mat communities, it is thus critical to determine the nature and extent of the interactions between phototrophic and non-photosynthetic microorganisms, including anaerobic microorganisms (page 384).

The meaning of the word phototrophic can be determined through a combination of grammatical context clues and a study of prefixes, suffixes and roots. The grammatical structure, interactions between phototrophic and non-photosynthetic microorganisms, implies a contrast between microorganisms that are phototrophic and those that are non-photosynthetic. It can be inferred that phototrophic organisms are photosynthetic, since there is an interaction between those organisms that are phototrophic and those that are non-photosynthetic. A study of the word parts confirms this guess from context clues. Photo is a Greek prefix that means light. Troph is a Greek root means nourishment. The affix, ic, is Middle English suffix which means relating to. If a phototroph is a microorganism that relates to getting nourishment from light, then a phototrophic organism is photosynthetic and able to obtain energy through light.
Unmarked Think-Aloud: Syntactic Context Clues using Grammar and Prefixes, Suffixes, and Roots

(A grammar or punctuation rule helps determine word meaning when combined with a knowledge of Greek or Latin prefixes, suffixes, and roots helps to break down the word into parts to determine meaning.) Questions 3, 6 and 10 continued

Selections from:

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As dominant components of our biosphere for at least 2 billion years of its >3.5 billion year history, microbial mats played a pivotal role in shaping the composition of Earth’s early atmosphere, including its eventual oxygenation (page 385).

Context clues and word part analysis help one to determine the meaning of this word. If one knows that the atmosphere is composed of oxygen and other gasses, then one can guess that oxygenation has something to do with oxygen. When one looks at the word parts, one finds that the oxy or ox-prefix means oxygen, gen is a Greek root which means origin or source, and ion is a suffix which means condition or action. Put it together and one has the condition or action of the origination of oxygen.
Unmarked Think-Aloud: Syntactic Context Clues using Grammar and Prefixes, Suffixes, and Roots

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Selections from:

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Word parts and context clues reveal the meaning of the word anaerobic. The context clues “exposure” and “deeper anaerobic layers of the mats to air and light was minimized” indicate that the anaerobic layer does not have contact with air and light. No air present means an environment without oxygen. Also, the absence of light does not allow photosynthesis. A break down of the word parts confirms this guess: a and an are Greek prefixes meaning not, without, or lacking. The Greek prefix aero or aer means air, atmosphere, or gas. The Middle English suffix, ic, is used after nouns to form adjectives meaning of or relating to or it is used after nouns to form adjectives meaning having some characteristics of or in the style of. When you combine the definitions of the word parts, something anaerobic exists without oxygen.
Unmarked Think-Aloud: Semantic Context Clues

(The words, phrases or sentences around an unfamiliar word that help determine its meaning.): Question 7 and 9

Selections from:

Question 7:

Normal in situ daily water column temperature variations were simulated in the greenhouse by (1) controlling the temperature increase (attributable to solar heating) during the daytime to stay below the maximum temperature observed in situ and (2) turning off temperature control at night to allow the water temperature in the flow boxes to decrease slowly with the decrease in greenhouse air temperature (page 387).

Question 9:

Furthermore, many mat microorganisms are motile, utilizing light and/or UV radiation as a cue to adjust their position in the mats vertically (Castenholz, 1994; Bebout and Garcia-Pichel, 1995) (page 398).
Unmarked Think Aloud: Semantic Context Clues

(The words, phrases or sentences around an unfamiliar word that help determine its meaning.): Question 7 and 9

Selections from:

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**Normal in situ daily** water column temperature variations were simulated in the greenhouse by
(1) controlling the temperature increase (attributable to solar heating) during the daytime to stay below the maximum temperature observed in situ and
(2) turning off temperature control at night to allow the water temperature in the flow boxes to decrease slowly with the decrease in greenhouse air temperature (page 387).

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The context clue, adjust their position in the mats vertically, indicates that motile refers to movement.

Latin Phrase information about in situ
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What clues help determine the meaning of the highlighted word?

Oxygen microelectrode signal output was calibrated to oxygen concentrations using a two-point calibration. Because the water circulating through the flow boxes was constantly aerated through the action of the pumps and through contact with the atmosphere across a large surface area of water, the electrode current at any point in the water overlying the mats was taken to be equal to the current produced in air-saturated water at that particular temperature and salinity. The exact value of this oxygen concentration can then be identified using published values (Sherwood et al., 1991).
Marked Think-Pair-Share: Syntactic Context Clues Using Grammar

(A grammar or punctuation rule helps determine word meaning): Pretest Reference: Questions 1 and 8

Selection from:

What clues help determine the meaning of the highlighted word?

Oxygen microelectrode signal output was calibrated to oxygen concentrations using a two-point calibration. Because the water circulating through the flow boxes was constantly aerated through the action of the pumps and through contact with the atmosphere across a large surface area of water, the electrode current at any point in the water overlying the mats was taken to be equal to the current produced in air-saturated water at that particular temperature and salinity. The exact value of this oxygen concentration can then be identified using published values (Sherwood et al., 1991).

Explanation:

Several clues help determine the meaning of the word aerated. First, the sentence indicates that the water is circulating. Second, the sentence explains how the water was aerated, “through the action of the pumps and through contact with the atmosphere across a large surface area of water.” The word through indicates grammatically how the aeration happens for it signals an explanation. The words in the sentence that follow through explain that the water is being circulated with air. This meaning is confirmed by comparing the “current produced in air-saturated water,” indicating that aeration involves adding air to something.
Marked Think-Pair-Share: Multiple Meanings and Context Clues

(Context clues, the words, phrases or sentences around an unfamiliar word, help to determine the meaning of a word that has multiple meanings): Pretest Reference: Questions 4

Selection from:

What words, phrases or sentences help you determine the meaning of the highlighted word below?

When compared with previous efforts to maintain microbial mats, our results indicate that two factors—water flow and the light regime—are likely to be more important than others in simulating the field environment.
What words, phrases or sentences help you determine the meaning of the highlighted word below?

When compared with previous efforts to maintain microbial mats, our results indicate that two factors—water flow and the light regime—are likely to be more important than others in simulating the field environment.

Explanation:

The common meaning for regime is a type of government. However, when one reads the sentence, this does not work. If one turns to the sentence, one finds some clues that hint at the meaning of regime. The sentence has several words that help one put together a meaning for regime. The sentence starts out “When compared with previous efforts to maintain microbial mats, our results indicate that two factors...” and then goes on to state that light regime is one of the factors. We can conclude that light regime is an effort to maintain a mat. Next, the sentence states that these factors “are likely to be more important than others in simulating the field environment.” The field environment is where the mats live in nature. Light is a requirement for the life of the mat. The light regime must be a regular cycle of light like in the field. When one compares this idea with the dictionary, one finds this is true. One of the definitions that Merriam Webster’s Collegiate Dictionary, Eleventh Edition has for regime is, “A regular pattern of occurrence or action.” Thus, the light regime is a regular pattern of light given to the mats in the greenhouse community.
Unmarked Think-Pair-Share: Prefixes, Suffixes, and Roots

(Use knowledge of Greek or Latin prefixes, suffixes, and roots to help break down the word into parts to determine meaning): Pretest Reference: Questions 2 and 5

Selection from:

How can your knowledge of Greek or Latin prefixes, suffixes and roots help you determine the meaning of the highlighted word below?

More specifically, the major populations of cyanobacteria did not seem to change, and M. chthonoplastes remained the dominant *phototroph* in all of the sections of mat characterized microscopically.

Explanation:
Use knowledge of Greek or Latin prefixes, suffixes, and roots to help break down the word into parts to determine meaning): Pretest Reference: Questions 2 and 5

Selection from:

How can your knowledge of Greek or Latin prefixes, suffixes and roots help you determine the meaning of the highlighted word below?

More specifically, the major populations of cyanobacteria did not seem to change, and M. chthonoplastes remained the dominant phototroph in all of the sections of mat characterized microscopically.

Explanation:
Photo is the Greek prefix meaning light and troph is a Greek root meaning food. Combine the two word part definitions to mean light food or an organism that produces food using light.
**Unmarked Think-Pair-Share: Syntactic Context Clues using Grammar and Prefixes, Suffixes, and Roots**

(A grammar or punctuation rule helps determine word meaning when combined with a knowledge of Greek or Latin prefixes, suffixes, and roots helps to break down the word into parts to determine meaning.) Pretest Reference: Questions 3, 6 and 10

Selection from:

Oxygen **microprofiles**, measured using microelectrodes, and oxygen and carbon fluxes, measured using flux chambers, were found to be comparable in greenhouse and freshly collected natural mats.
Unmarked Think-Pair-Share: Syntactic Context Clues using Grammar and Prefixes, Suffixes, and Roots

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Selection from:

Oxygen microprofiles, measured using microelectrodes, and oxygen and carbon fluxes, measured using flux chambers, were found to be comparable in greenhouse and freshly collected natural mats.

Explanation:
The meaning of the word microprofile can be determined from the Latin prefix micro, which means small and the word profile means the graphical presentation of measurements. If one looks at the words in the sentence around microprofile, one finds that oxygen is measured. One can draw the conclusion that the microprofiles portray the oxygen measured.
Therefore, flow variations around the 5 cm s\(^{-1}\) value will minimally affect the fluxes in and out of the mat.
Therefore, flow variations around the 5 cm s\(^{-1}\) value will minimally affect the fluxes in and out of the mat.

**Explanation:**

Around the word fluxes are the words “in and out of the mat” indicating a rate of change in flow variations and giving the meaning of the word, flux.
Posttest

Posttest of words used in Bebout, Brad M. et al. (2002), Long-Term Manipulations of Intact Microbial Mat Communities in a Greenhouse Collaboratory: Simulating Earth’s Present and Past Field Environments, Astrobiology 2, 383-402.

A. one who is authorized to act for another  
B. the process of using light as an energy source to make food  
C. organisms that have more than one cell  
D. the cycling of chemicals into the living and nonliving parts of an ecosystem  
E. organisms that have one cell  
F. a taste in fine arts  
G. a layered community of microorganisms  
H. loose fluffy material  
I. a program designed to gather information  
J. to grow in a prepared mixture

Match the highlighted words in each passage on the left, with the letter of the correct definition located at the top of the page. Underline the words or parts that give a clue to the meaning of the bold word in the sentence.

1. Within the collaboratory, intelligent software agents will assist in the experimentation process controlling the hardware, troubleshooting, recording results, and reporting back to collaborating experimenters.

2. A microbial mat is a highly complex assemblage of organisms possessing many different modes of metabolism, all of which are interacting with each other at some level in beneficial and/or competitive ways.

3. Measurements of rates of biogeochemical cycling in greenhouse mats were similar to rates measured on freshly collected mats (Table 2).

4. In photosynthetic microbial mats, all of the energy necessary for growth and maintenance of the community is ultimately derived from the sun.

5. 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 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.

6. Nonquantitative microscopic observations revealed an increase in the abundance of unicellular cyanobacteria that resembled the Halothece type at the surface of the HIGH salinity mats relative to those maintained at NORMAL salinity.

7. Either some microbial processes do not occur in culture [eg., anaerobic methane oxidation (Reeburgh, 1980) and sulfate reduction under aerobic conditions (Canfield and Des Marais, 1991)], or they occur at rates vastly different than rates observed in nature. In addition, relatively few (<1%) of the total number of microbes present in nature are available in culture (Ward et al., 1990; Amann et al., 1995).
A combination of these affix and word meanings indicates living and nonliving changes.
or ground and chemical means the composition, structure and properties of a substance and the changes it makes.
the hint that culture is not nature and culture is growing something by artificial means.
what is happening in culture with “or they occur at rates vastly different than rates observed in nature” this contrast provides
sentence, the statement is made, “When oxygenic photosynthesis ceases…” providing the clue that removing oxygen from a
smaller, is not the best one, because reduced is linked with the word sulfidic through the use of the word “and”. Earlier in the
_____7. Either some microbial processes do not occur in culture [eg., anaerobic methane oxidation (Reeburgh, 1980) and
sulfate reduction under aerobic conditions (Canfield and Des Marais, 1991)], or they occur at rates vastly different than rates observed in nature. In addition, relatively few (<1%) of the total number of microbes present in nature are available in culture (Ward et al., 1990; Amann et al., 1995). Multiple Meanings and Context Clues: If culture is something associated with the arts, then one will soon learn that culture as used in this sentence does not fix this meaning. However, the context clues contrast what is happening in culture with “or they occur at rates vastly different than rates observed in nature” this contrast provides the hint that culture is not nature and culture is growing something by artificial means.
Question: What is a microbial mat?

Answer:
A microbial mat is a community of microorganisms that is only a few millimeters thick. Within the community, each organism produces chemical compounds, (gases, sugars or other organic substances) used by other members of the community to gain energy. Different types of microbes are located at different depths within the mat, based on their own chemical and light requirements. This creates the distinctive layered appearance of mats. If one slices a mat and looks at it from the side, it can be seen that the upper brown layer contains diatoms, cyanobacteria conducting photosynthesis compose the green layer, and the pink layer, contains purple sulfur bacteria. The dark areas, where oxygen is not present, is inhabited by fermenters, and sulfate reducing bacteria. Colorless sulfur bacteria are always at the interface of the oxygen containing, and anoxic layers. When light and chemical conditions change, at night for example, colorless sulfur bacteria move to the top of the mat, since oxygen is not present in the lower layers.
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Rephrasing Activity for Narrative Retelling

<table>
<thead>
<tr>
<th>Words from the Article</th>
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### Rephrasing Activity for Narrative Retelling

**NAME:**

1) Rephrase main ideas in your own words.
2) Number the ideas in the order you want to write about them.
3) Write your narrative.

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<td>only a few millimeters thick.</td>
<td>lots of microorganisms live in a mat that work together</td>
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<td>microbial mat is a community of microorganisms</td>
<td>mats are small –millimeters deep</td>
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<td>each organism produces chemical compounds, (gases, sugars or other organic substances)</td>
<td>Microorganism gain energy by materials produced by organisms living in the mat. Mat organisms produce organic substances, sugars, and gases.</td>
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<tr>
<td>used by other members of the community to gain energy.</td>
<td></td>
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<tr>
<td>Different types are located at different depths within the mat, based on their own chemical and light requirements.</td>
<td>Mat organisms live where they have the light and chemicals they need. Different organisms need different things,</td>
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<td>layered appearance of mats.</td>
<td>Mats are layered like lasagna.</td>
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<td>brown layer contains diatoms</td>
<td>Diatoms live in brown layer.</td>
</tr>
<tr>
<td>cyanobacteria conducting photosynthesis compose the green layer</td>
<td>Cyanobacteria the green layer—they take light and water and produce oxygen through photosynthesis</td>
</tr>
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<td>pink layer, contains purple sulfur bacteria.</td>
<td>Purple sulfur bacteria live in the pink part of the mat.</td>
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<td>dark areas, where oxygen is not present, are</td>
<td>Oxygen is not produced in the dark areas of the mat.</td>
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<tr>
<td>inhabited by fermenters, sulfate reducing bacteria.</td>
<td>dark layers without oxygen contain sulfate reducing bacteria and fermenters(What is this? Look it up.)</td>
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<td>Colorless sulfur bacteria are always at the interface of the oxygen containing, and anoxic layers.</td>
<td>Living at areas where there is oxygen and no oxygen are colorless sulfur bacteria.</td>
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<td>interface of the oxygen containing, and anoxic layers.</td>
<td>Anoxic doesn’t contain oxygen</td>
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<td>light and chemical conditions change, at night for example, colorless sulfur bacteria move to the top of the mat, since oxygen is not present in the lower layers.</td>
<td>Colorless sulfur bacteria need oxygen since they move to the top of the mat at night when oxygen is not lower in the mat. CSB are microbes that move to find what they need in the mat.</td>
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INTRODUCTION

MODERN MICROBIAL MATS are thought to be extant representatives of Earth’s most ancient ecosystems (Walter, 1976). Geochemical evidence of the existence of photosynthetic microbial mats, and their mineralized counterparts, stromatolites, has been identified in rocks as old as 3.0 Ga (Beukes and Lowe, 1989). As a living repository of genetic, physiological, isotopic, and biogeochemical information on the co-evolution of a planet and the only known biosphere, modern microbial mats are invaluable objects of study. Modern microbial mat studies have provided important insights on rates of biological activity (Revsbech et al., 1983; Canfield and Des Marais, 1993; Des Marais, 1995), genetic diversity (Ward et al., 1990; Garcia-Pichel et al., 1998; Nübel et al., 2001), stable isotopic fractionation (Schidlowski, 1988; Des Marais and Canfield, 1994), and organic (Boon, 1984; Ward et al., 1985) and atmospheric (Visscher and Van Gemerden, 1991; Visscher and Kiene, 1994; Hoehler et al., 2001) biomarkers, as well as minerals (Reid et al., 2000), that have been used to interpret the fossil record of these communities over geologic time.
**Rephrasing Activity for Narrative Retelling**

NAME ____________________________________________

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<td><strong>Content from Article</strong></td>
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</tr>
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<td><strong>Genre</strong> Select the appropriate genre for scoring.</td>
<td>Story has clearly defined plot and character development. Writing masterfully captures attention and sustains interest. Word choice vividly conveys details of character development, setting and plot.</td>
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<td>• Narration</td>
<td>Story clearly utilizes the same structure as the original text. Writing masterfully captures attention and sustains interest. Word choice vividly conveys details and effectively contributes to the fluency of the text.</td>
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<td>• Picture Book</td>
<td>Poem clearly portrays images that are vivid and detailed. Line breaks and rich creative word choice emphasize meaning. Clearly defined flow or rhythm draws readers into the content of the poem.</td>
</tr>
<tr>
<td>• Poem</td>
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References


Bebout, Brad M. (2005) Microbes @ NASA. http://microbes.arc.nasa.gov

Beers, Kylene. When Kids Can’t Read What Teachers Can Do. Portsmouth, NH: Heinemann, 3003.


Lanier, Judy. The Monotillation of Traxoline.
