Biology Instructional Segment: Patterns in Living Systems—Clades

<table>
<tr><td colspan="2">This 5E model for instruction may be useful in connecting the concepts of clades and the endosymbiont theory to kinship among groups of organisms.</td></tr>
<tr><td colspan="2" align="center">Student Science Performance</td></tr>
<tr><td>Grade: 9-12 Biology</td><td rowspan="2" align="center">Title:
All in the Family Tree</td></tr>
<tr><td>Topic: Clades</td></tr>
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Performance Expectation for GSE:
Primary:
SB4. Obtain, evaluate, and communicate information to illustrate the organization of interacting systems within single-celled and multi-celled organisms.
a. Construct an argument supported by scientific information to explain patterns in structures and function among clades of organisms, including the origin of eukaryotes by endosymbiosis. Clades should include archaea, bacteria, eukaryotes, fungi, plants, animals.

(<u>Clarification statement</u>: This is reflective of 21st century classification schemes and nested hierarchy of clades and is intended to develop a foundation for comparing major groups of organisms. The term 'protist' is useful in describing those eukaryotes that are not within the animal, fungal or plant clades but the term does not describe a well-defined clade or a natural taxonomic group.)

b. Analyze and interpret data to develop models (i.e., cladograms and phylogenetic trees) based on patterns of common ancestry and the theory of evolution to determine relationships among major groups of organisms.

Secondary:
SB1. Obtain, evaluate, and communicate information to analyze the nature of the relationships between structures and functions in living cells.
a. Construct an explanation of how cell structures and organelles (including nucleus, cytoplasm, cell membrane, cell wall, chloroplasts, lysosome, Golgi, endoplasmic reticulum, vacuoles, ribosomes, and mitochondria) interact as a system to maintain homeostasis.

e. Ask questions to investigate and provide explanations about the roles of photosynthesis and respiration in the cycling of matter and flow of energy within the cell (e.g., single-celled alga).
(<u>Clarification statement:</u> Instruction should focus on understanding the inputs, outputs, and functions of photosynthesis and respiration and the functions of the major sub-processes of each including glycolysis, Krebs cycle, electron transport chain, light reactions, and Calvin cycle.)
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Performance Expectations for Instruction:
Investigate how a population with variations may shift over time in response to external factors.
Group Performance:
● Students analyze and interpret data collected to develop models of evolutionary trees.
● Students construct an argument using evidence from samples and information online to show family relationships between groups of organisms.
● Students analyze and interpret data by reading an article to collect evidence supporting the theory of endosymbiosis.
● Students construct an argument using evidence to support the theory of endosymbiosis.
Individual Performance:
● Students construct an explanation, based on evidence, to show relationships between protists and other clades of organisms.
● Students write a paragraph citing evidence used to support relationships between ancestral prokaryotes
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and eukaryotes.

Group Discussion:

- Student groups should share model of kinship with the class.
- Students share individual writings about ancestral prokaryotes and eukaryotes with the class.

Additional notes on student supports

Materials

Materials needed per group:
Pond water (or other source of live protists - ordered from online, moss), microscope, concave slides, plastic pipettes

Materials needed for class size of 30:
Samples of groups of different organisms: Plants, Animals, Fungi, and Bacteria or bacteria prepared slides, microscopes, hand lenses or stereo microscopes

Students will continuously be obtaining, evaluating, and communicating information. This is not a linear process. Students should be communicating through writing and discussions to allow for formative assessment. This benefits the teacher, student, and whole group to guide instruction to clarify misconceptions or extend content.

Engaging Learners	**Phenomenon** Protists are considered the first eukaryotic cells to have developed on the planet. Protists have always been a challenging group to classify. An amazing variety of patterns in structure and function are found in these organisms.
	Obtaining Students obtain background information by viewing a three-minute video: Introduction to the Protists about a variety of Protists in pond water. Students carry out an investigation to observe structure and function in organisms in pond water and collect evidence to support general patterns of kinship between protists and other eukaryotes (plant-like, animal-like, fungus-like). Students should observe things like the presence or absence of a nucleus, unicellular or multicellular, autotrophic or heterotrophic (look for green pigment generally), Cell Wall/No Cell Wall, *Motile/Non-Motile*, etc. *Teacher Notes: Students are supposed to plan and carry out this investigation so this should not be the teacher's idea. Ask students what they would need to look at in order to collect evidence to support patterns of kinship between protists and eukaryotes. Gently lead them down the road to directly observing protists and comparing them to available samples of plants, animals, and fungi, if after some discussion, they do not come to this. Have pond water sources available or have ordered some protists from a biological supply store. Give students a pond water (or other protist) source, microscopes, slides, and plastic pipettes to investigate characteristics of protists. Students write down characteristics based on their observations and group protists as plant-like, animal-like, or fungi-like. An optional student guide for this investigation is given below.* Additional notes on topic, focus, and phenomena.
	Evaluating Individually, students construct an explanation of characteristics based on evidence gathered from protist samples showing relationships between protists and other clades of organisms.

	Teacher Notes: A simple background reading for students can be found at [Learner.org: Protists] *More detailed background information for students can be found at [Basic Biology: Protists]* Students construct an explanation in writing that will form the basis for their group performance. *Questions to encourage student thinking and discussing:* Q: Are the organisms you are observing prokaryotes or eukaryotes? How do you know? Q: Are the organisms you are observing single celled or multi-celled? How do you know? Q: Are the organisms you are observing autotrophs or heterotrophs? How do you know? Q: Are the organisms you are observing motile? Q: Do the organisms you are observing have cell walls? Q: How could you group these organisms based on similar characteristics? Q: What is a clade?
	Communicating Using chart paper, student groups develop models showing ancestry of protists based on evidence collected (through research) and design a simple phylogenetic tree showing bacteria giving rise to 3 general types of protists. Student groups share their models with the class.
Exploring Revising Model	*Obtaining* Students obtain information by observing samples of organisms including Plants, Animals, Fungi, Archaea, and Bacteria. *Teacher Notes: Have student groups rotate through stations of samples (or other sources) to collect data on characteristics of these groups. Characteristics include criteria such as Prokaryotic/Eukaryotic, Unicellular/Multicellular, Autotrophic/Heterotrophic, Cell Wall/No Cell Wall, Motile/Non-Motile, etc.*

	Evaluating
	Student groups construct an argument using evidence from their samples and information obtained online to show patterns of relationships between these groups of organisms.
	
	Teacher Notes: Students should be able to explain the phenomenon using the following concepts:
	● *Protists are eukaryotic and are thought to have evolved through the process of endosymbiosis.*
	● *Protists vary greatly in structure and function. Examples include:*
	    ○ *Algae are more closely related to plants because they have a cell wall and can perform photosynthesis (as evident by green pigments/chloroplasts).*
	    ○ *Water molds are more closely related to fungi because they have a cell wall but cannot perform photosynthesis (visible wall but no green pigmentation).*
	    ○ *Amoebas are more closely related to animals because they lack a cell wall and cannot perform photosynthesis (no visible wall and no green pigmentation).*
	● *Protists share a few common structures and functions:*

	○ *Nucleus that differentiates them from prokaryotic bacteria* ○ *Obtain ATP energy required cellular process through respiration* ○ *Plasma cell membrane that regulates the passive or active passage of material in and out of the cell to maintain homeostasis* A phylogenetic tree showing our current understanding of relationships between clades is found at OpenStax: Groups of Protists, but this is an extensive tree that students are not expected to derive on their own. A tree showing bacteria giving rise to animal-like, plant-like, and fungus-like eukaryotes is enough to show understanding of the big ideas. Q: What structural similarities do the plants, animals, and fungi you are observing share with the organisms in the pond water? Q: What differences do you observe? Q: How do the structural similarities you observe show kinship? Q: How could you show these relationships using a phylogenetic tree?
	Communicating Student groups expand their models to include organisms observed and information found after looking at patterns in organisms in all clades. Students share models with the class.
Explaining Finalizing Model	*Evaluating* Students evaluate their models based on shared information from class discussion.
	Communicating Students revise models to add or remove information following their conclusions. ***Formative Assessment of Student Learning*** Students may peer assess each other's models and reflect on their own learning. Reflections include what students already know, what they learned, and what they still do not understand. Instructor reviews models and reflections and gives feedback on these reflections.
Elaborating Applying Model to Solve a Problems	**Phenomenon** Eukaryotes have internal structures that are like prokaryotic ancestors.
	Obtaining Students view a 7-minute video: Bozeman Science Endosymbiosis to collect evidence supporting the Theory of Endosymbiosis. *Teacher Notes: Have students find evidence that shows that cellular structure of eukaryotes supports an endosymbiotic origin. Eukaryotes have internal structures that work together to carry out functions that allow the cell to function as a unit. These internal structures have their own internal membranes, DNA, and are energy converters.*
	Evaluating Students analyze and interpret data by reading an article, such as OpenStax: Endosymbiont Theory, to collect evidence supporting the theory of endosymbiosis. Students construct an argument using evidence of structure and function in cells to support the theory of endosymbiosis. Q: What are the similarities and differences between prokaryotic cells and eukaryotic cells?

	Q: What is endosymbiosis? Q: What evidence do we have for the origin of eukaryotes? Q: What is the function of chloroplasts and mitochondria? Q: What is DNA?
	Communicating Students individually write a paragraph, create a storyboard, or illustrate a drawing citing their evidence used to support relationships between ancestral prokaryotes and eukaryotes. Students share their findings with the class. Student groups then construct a cladogram using their data from endosymbiosis and their prior lab work that includes the evolutionary relationships between archaea, bacteria, plants, fungi, and animals. Protists are placed appropriately with their subgroups. Groups share their cladograms with the class. *Teacher Notes: Subgroups are only intended to include plant-like protists, animal-like protists, and fungi-like protists. Alternatively, students may be given a set of data to interpret in order to create a cladogram.* *Information on phylogenetic trees and cladograms can be found at Khan Academy: Building a phylogenetic tree or at OpenStax: Phylogenetic Trees.*
Evaluation	***Assessment of Student Learning***
	Students use the theory of endosymbiosis and cell structure and function to build a cladogram that includes archaea, bacteria, plants, fungi, and animals.
SEP, CCC, DCI	**Science Essentials**
Science and Engineering Practices	• Construct explanations • Engage in argument from evidence • Plan and carry out Investigations
Crosscutting Concepts	• Patterns • Structure & Function • Matter & Energy
Disciplinary Core Ideas	From ***A Framework for K-12 Science Education:*** LS4.A: Evidence of Common Ancestry and Diversity LS1.A: Structure and Function LS1.C: Organization for Matter and Energy Flow in Organisms

Protists: The World's Largest Group of Misfits

Protists are a group of single celled organisms which appeared on the planet not long after bacteria. This group of organisms is incredibly diverse, and very difficult to classify. Scientists once considered the protists a separate kingdom, but now see they are more related to other kingdoms than they are to each other! Protists have been separated into a few general groups.

Given samples of plants, animals, fungi, bacteria, and protists, how do you think the protists should be grouped? Design an investigation with your team using the observation tables below.

Investigation:

Non-Protist Samples			
Sample Organism Observed	Kingdom	Observable Characteristics	Drawing of Cell(s) Under a Microscope

Non-Protist Samples			
Sample Organism Observed	Kingdom	Observable Characteristics	Drawing of Cell(s) Under a Microscope

Protist Samples			
Sample Number	Observable Characteristics	Drawing of Cell(s) Under a Microscope	Kingdom Resemblance?
Sample 1			
Sample 2			
Sample 3			
Sample 4			

Protist Samples			
Sample Number	Observable Characteristics	Drawing of Cell(s) Under a Microscope	Kingdom Resemblance?
Sample 5			
Sample 6			

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Additional Notes on Topic, Focus, and Phenomena Patterns in Living Systems GSE: SB1. a, c, d, e; SB4. a, b			
Anchoring Phenomenon: Protists have always been a challenging group to classify. An amazing variety of structure and function patterns are found in these aquatic organisms.			
Topic	**Focus**	**Lesson Phenomenon**	**GSE/Notes/Language**
Endo-symbiosis	Eukaryotes evolving from prokaryotes through the process of endosymbiosis	Chloroplasts and mitochondria are like prokaryotic cells.	SB4a Prokaryotic cells are thought to be the common ancestor for all living organisms. Eukaryotes evolved through endosymbiosis. Chloroplasts and mitochondria are organelles that have double-membranes.
Photo-synthesis and Cellular Respiration	Anaerobic Fermentation Emphasize that the first prokaryotes are thought to have lived in an environment that did not have enough oxygen but needed to produce energy to perform cellular functions which is a benefit of endosymbiosis. Overview of ATP may occur here with emphasis in aerobic respiration and active transport.	Many foods, like yogurt and cheese, are formed using bacteria.	SB1e/SB4a/SB5b/SB1c Use phenomena to describe how anaerobic respiration still occurs in some eukaryotes as well as prokaryotes. Extend: *Euglena* is an example of a protist that can do both photosynthesis in light conditions but can also consume food in the absence of light. Illustrate the cycling of carbon and water through the processes of photosynthesis and cellular respiration:

	Aerobic Cellular Respiration Benefits of engulfing an aerobic heterotrophic prokaryote; emphasize the process of cellular respiration along with the sub-processes of glycolysis, Krebs cycle, etc. Emphasize ATP energy with the connection back to fermentation.	Muscle soreness occurs in humans after a long run.	• Carbon (dioxide) and water enter the chloroplast and is converted to glucose (oxygen is released). • Glucose (and oxygen) enters the mitochondria and is converted to carbon (dioxide) and water. Revisit fermentation to compare the two processes (anaerobic and aerobic respiration) while emphasizing the benefits associated with the endosymbiotic engulfing of the mitochondria. Extend with macromolecule connection: Glucose is a carbohydrate with the main function to produce immediate energy (ATP). Extend: Algae are used in NASA's OMEGA Project (2009-2012) as an oceanic biofuel. CK-12: Autotrophs and Heterotrophs. Extend: Spotted salamanders and algae share a symbiotic relationship.
	Photosynthesis Benefits of engulfing a photosynthetic prokaryote; emphasize the process of photosynthesis along with the sub-processes of light reaction and Calvin cycle.	Algae are used to produce energy in this bioreactor house.	
Modeling Evolution	Scientists may model the evolution of modern organisms from ancient ancestors using cladograms and/or phylogenetic trees.	Dinosaurs and birds have structures that are similar.	SB4b Modeling theories of evolution (gradualism and punctuated equilibrium) in cladograms and/or phylogenetic trees may be useful in connecting with the instructional segment: Stability & Change in Populations Over Time.
Clades & Evolutionary Relationships	Compare structure and function of organelles between prokaryotes and eukaryotes that include nucleus, cytoplasm, cell membrane, cell wall, chloroplasts, lysosome,	Protists have always been a challenging group to classify. An amazing variety of structure and function patterns are found in these aquatic organisms.	SB1a/SB4a/SB4b Use key characteristics to differentiate among the five major clades before suggesting where protists (algae, amoebas, and slime molds) fit: • cells

	Golgi, endoplasmic reticulum, vacuoles, ribosomes, and mitochondria.		• extreme habitats • nucleus • not photosynthetic (may introduce the terms heterotrophic and autotrophic to make connections with ecology) • lack of cell wall Illustrate that organisms classified as protists do not fit into a single clade. Some have features that seem to make them more closely related to plants while others are more fungal-like or animal-like. Extend: Do viruses fit in the cladogram?
	Use the theory of endosymbiosis and cell structure and function to build a cladogram that includes: archaea, bacteria, plants, fungi, and animals.		

Anchoring Phenomenon:

Protists have always been a challenging group to classify. An amazing variety of structure and function patterns are found in these aquatic organisms.

Students will explain the phenomenon using the following concepts:

- Protists are eukaryotic and are thought to have evolved through the process of endosymbiosis.
- Algae, amoebas, and slime molds are commonly grouped together as protists but vary greatly in structure and function:
  - Algae are more closely related to plants because they have a cell wall and can perform photosynthesis.
  - Slime molds are more closely related to fungi because they have a cell wall but cannot perform photosynthesis.
  - Amoebas are more closely related to animals because they lack a cell wall and cannot perform photosynthesis.
- Protists share a few common structures and function:
  - Nucleus that differentiates them from prokaryotic bacteria
  - Obtain ATP energy required cellular process through respiration
  - Plasma cell membrane that regulates the passive or active passage of material in and out of the cell to maintain homeostasis

Additional Supports for struggling learners:

The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student's Individualized Education Program.

General supports for the following categories:

Reading:	Writing:	Math:
1. Provide reading support by reading aloud or doing partner reads 2. Have the teacher model what they are thinking when reading the text 3. Annotate the text with students so that they may refer to it as they work through the lab	1. The teacher can provide a sentence starter for the students. 2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic). 3. The teacher can provide constructive feedback during the writing process to help students understand the expectations.	1. The students may need assistance from the teacher at identifying the initial patterns. The teacher can use guiding questions to get the students started down the path of identifying patters.

Supports for this specific lesson if needed:

Performance expectations for instruction:

Group performance:

1. Teachers should be intentional in grouping students to ensure that students get the most out of the lesson. Data driven grouping based on a prior assessment is best practice.
2. Struggling students may need assistance as they begin identifying patterns. Some guiding questions may be helpful for students to determine what characteristics are important and what is just coincidence.
3. Teachers can lead a whole group read aloud or, if grouped appropriately, small group read aloud could be utilized. Make sure that student annotate articles to refer to as they move through the lesson.
4. Remind students of the definition of a scientific argument.

5. Provide choice in ways to express the argument such as written, verbal or a picture.

Individual performance:

6. Provide choice for creating an explanation such as written, verbal or image.
7. The activity above states that students should write a paragraph, but this may prove troublesome for some students that struggle with writing. So, provide choice to the students to get an accurate assessment of their knowledge. Several ways that students can express their knowledge are creating a cartoon, writing a paragraph, verbally explaining, drawing an image or designing a play. The teacher should remind students that this must contain evidence from the activity and information that they have gathered in class.
8. At the end of the lesson the teacher should reflect on the following topics:
   -The teacher should reflect on grouping of students. Was it beneficial and were all students able to contribute? Why or Why not?
   -The teacher should reflect on supports for struggling learners. Were the supports enough for the student population? Why or why not? Then make a list of other supports that the teacher can try in the classroom.

Engaging Learners:

Obtaining

1. Once students have completed their observations, they may require some guiding questions to get the students to clearly see similarities and differences. Many struggling students will focus on either the similarities or the differences and neglect the other.
2. The chart for recording observations is very open ended and this may be a stressor for some students. The teacher should be walking around, reviewing what the students are recording and helping when necessary.

Evaluating and Communicating

3. The activity above has links for simplified reading that can be used with struggling readers. The other supports that can be used for articles are read aloud, partner reads and videos rather than reading.
4. Students should have some choice in constructing their explanation such as in writing, drawing or verbally.

Exploring:

1. This is another very open-ended chart that may be a stressor for some students. The teacher should be walking around, reviewing what the students are doing and helping when necessary.

2. The teacher notes here have a very in-depth description of how students should be able to describe the phenomenon. The teacher may have to accept an abbreviated version of this description as the student decides to explain. Many students will shut down if they feel the expectations are too high, they do not see a purpose in the question or if it seems like too much work to the student. So, the teacher can use guiding questions to see if the student needs more assistance or if they do adequately understand the topic.
3. As students work on their cladogram or phylogenetic tree, this is a good time to do small group pull out for the students that are struggling to grasp the material.

Explaining:

1. Students may need additional time to revise their model and some may require guiding questions to help them identify problem areas.
2. The teacher can provide a rubric and guidance on self-assessing their cladograms to help facilitate the students finding errors and being ready to have a peer review it.
3. Students may need sentence starters to get their reflection started. Students may need additional time to provide a well thought out reflection on their work.

Elaborating:

1. The teacher may need to show the video more than once to allow the students to pick out the most important topics.
2. After the video, ask the students some questions about what they viewed. The teacher could do this using a question sheet or just verbally reviewing what they saw. The teacher should focus on material that might be used as evidence to support the student's argument later in the lesson.
3. The teacher can provide support for reading the article by leading a class read aloud or by having the students do a partner read.
4. The teacher should remind students of the definition of a scientific argument.
5. The teacher should provide choice to the students that are constructing an argument. Several ways that students can express their scientific argument are creating a cartoon, writing a paragraph, verbally explaining, drawing a picture or designing a play. The teacher should remind students that this must contain evidence.
6. The accommodation in the teachers notes of giving the students a set of data to then create a cladogram would be a good accommodation for students that struggled to gather data in the chart.

Evaluating:

1. Students may need additional time to construct a model of a cladogram.
2. Providing data to students to construct the cladogram will assist students that struggle with the data collection part of this activity.

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