Critical Analysis of Evolution – Grade 10

Ohio Standards Connection:

Life Sciences

Benchmark H
Describe a foundation of biological evolution as the change in gene frequency of a population over time. Explain the historical and current scientific developments, mechanisms and processes of biological evolution. Describe how scientists continue to investigate and critically analyze aspects of evolutionary theory. (The intent of this benchmark does not mandate the teaching or testing of intelligent design.)

Indicator 23
Describe how scientists continue to investigate and critically analyze aspects of evolutionary theory. (The intent of this indicator does not mandate the teaching or testing of intelligent design.)

Scientific Ways of Knowing

Benchmark A
Explain that scientific knowledge must be based on evidence, be predictive, logical, subject to modification and limited to the natural world.

Indicator 2
Describe that scientists may disagree about explanations of phenomena, about interpretation of data or about the value of rival theories, but they do agree that questioning,

Lesson Summary:
This lesson allows students to critically analyze five different aspects of evolutionary theory. As new scientific data emerge, scientists' understandings of the natural world may become enhanced, modified or even changed all together. Using library and Internet sources, groups of students will conduct background research for one of the aspects of evolution in preparation for a critical analysis discussion. Students also will listen to, and take notes on, their classmates' critical analyses of evolution theory.

Estimated Duration*: Four to six hours*

Commentary:
This lesson should be used midway or toward the end of a unit on evolution. This will allow students to "carry over" their knowledge of basic evolutionary concepts into this lesson. The strength of this lesson lies in having students research topics that interest them about evolutionary biology. Students are encouraged to consider the research and discuss their findings with fellow students.

Pre-Assessment:

- The following items can be used to stimulate dialogue with the students.
- Instruct students to copy the following items from the chalkboard in their science lab notebook.
  1. Describe what constitutes an anomaly.
  2. Why do anomalies exist in science?
  3. Are there any benefits to exploring scientific anomalies?
  4. How do scientists critically analyze conflicting data?
  5. Define the following terms in your own words:
     - Theory
     - Critical analysis
     - Natural selection
     - Biological evolution
     - Macroevolution
     - Microevolution
- Direct students to respond to the questions in their science notebook in as much detail as possible leaving space to record information from the ensuing dialogue to add to their notes.

response to criticism and open communication are integral to the process of science.

Indicator 3
Recognize that science is a systematic method of continuing investigation, based on observation, hypothesis testing, measurement, experimentation, and theory building, which leads to more adequate explanations of natural phenomena.

Scoring Guidelines:
Collect pre-assessments and evaluate for indication of prior knowledge and/or misconception. Sample definitions for question five in the pre-assessment include, but are not limited to, the following:

- Theory
  A supposition or a system of ideas intended to explain something, especially one based on general principles independent of the thing to be explained.
- Critical analysis
  The separation of an intellectual idea into its constituent parts for the purpose of a careful, exact evaluation and judgment about those parts and their interrelationships in making up a whole. (This definition combines the definition for critical and analysis.)
- Natural selection
  The principle that in a given environment, individuals having characteristics that aid survival will produce more offspring, and the proportion of individuals having such characteristics will increase with each succeeding generation.
- Biological evolution
  Changes in the genetic composition of a population through successive generations.
- Macroevolution
  Large-scale evolution occurring over geologic time that results in the formation of new taxonomic groups.
- Microevolution
  Evolution resulting from a succession of relatively small genetic variations that often cause the formation of new subspecies.

Post-Assessment:
- Describe why scientific critical analysis of evolution is important.
- Describe three major pieces of evidence used to support evolution and explain why these pieces are important.

- Describe three major pieces of evidence used to challenge evolution and explain why these pieces are important.
- Compare and contrast the supporting and challenging information regarding the aspect of evolution you studied.
- Evaluate the scientific data supporting and challenging areas of evolution in light of the scientific method. In other words, is the data that is used to support or challenge evolution consistent or inconsistent with the scientific method? Are there any limitations? (NOTE: steps of scientific method: Observation, hypothesis, test, retest and conclusion)

Instructional Procedures:
Instructional Tip:
Scientists make a distinction between two areas of evolutionary theory. First, scientists consider mutation, natural selection, genetic drift and gene flow (immigration and emigration) as the processes that generate evolutionary changes in organisms and populations. Second, the theory of universal common descent describes the historical pattern of biological change. This theory maintains that all living forms have descended from earlier living forms and ultimately from a single common ancestor. Darwin envisioned the theory of universal common descent as a necessary result of evolutionary changes in organisms and populations, and represented it in his branching tree of life. Students will investigate and analyze these two areas of evolutionary theory in this lesson.

In addition to the distinctions between different areas of evolutionary theory, scientists also find it helpful to distinguish amounts of biological change or evolution. Microevolution refers to evolution resulting from a succession of relatively small genetic variations that often cause the formation of new subspecies. Macroevolution refers to large-scale evolution occurring over geologic time that results in the formation of new taxonomic groups. These terms are helpful distinctions in the course of analyzing evolutionary theory. These terms have appeared in OhioLink research databases, numerous Internet sites, and biology and evolution textbooks. Though "micro" and "macro" are prefixes, it is quite clear that the scientific community recognizes and acknowledges the distinction between the words. There is more research on microevolution than there is on macroevolution. To help ensure academic clarity, this lesson distinguishes between microevolution and macroevolution. Teachers may need to provide support to students to help them understand this distinction throughout the lesson.

Student Engagement

1. Write the following statement on the chalkboard or overhead:
   Anomalies are ideas in science that depart from the general consensus of the time. Many anomalies occur in science. In an effort to determine the cause of this deviation, scientists conduct research to collect data that will explain the phenomena. As the evidence mounts by careful analysis of the data, original ideas may change from one scientific understanding to another.
2. Ask students to think through the following science topics and discuss where anomalies led to the collection of data that further explained the phenomena and contributed to changing scientific understandings.
   - Spontaneous generation versus biogenesis
     Several pieces of data could be used. One example is Francesco Redi's observation that flies must contact meat in order for maggots to appear on the meat.
   - Geocentric versus Heliocentric
     Several pieces of data could be used. One example is the observed phases of Venus.
   - Global warming versus non global warming
     Several pieces of data could be used. One example is the observed increasing size of the hole in the ozone layer.
3. Ask students to cite additional areas where critical analysis is needed by the scientific community.

Teacher Presentation

4. Present supporting and challenging information for five aspects of evolution found in Attachment A. This will give students background information concerning both supporting and challenging evidence. Students can use this information to focus their research.

Instructional Tip:

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Alternative strategies for beginning this lesson could be to engage students in a Socratic discussion or a mini-lecture. See the Web site for student research at the Los Alamos National Laboratory for guidelines on the Socratic method. The Web address is listed in the Technology Connections section.

Student Research

5. Form groups consisting of two to four students. Assign each group a number to help monitor their activities and assignments during the lesson.
6. Allow the groups to pick (or assign) one of the five aspects of evolutionary theory. Assign two groups to research each aspect. The aspects are:
   Aspect 1: Homology (anatomical and molecular)
   Aspect 2: Fossil Record
   Aspect 3: Anti-Biotic Resistance
   Aspect 4: Peppered Moths
   Aspect 5: Endosymbiosis
7. Distribute Attachment B, Investigative Worksheet, to help guide research. Allow time for the two groups assigned the same aspect to research their topic by answering questions on the Investigative Worksheet. Have groups use the worksheet as a guide to help them research supporting and challenging data on their particular aspect of evolution. The worksheet will help students organize their ideas and facilitate their critical analysis.

Instructional Tip:
Attachment B, Investigative Worksheet, has questions that can be applied to all five aspects. This will help students become familiar with the data, and therefore be able to critically analyze the evidence for either the supporting side or the challenging side. As they complete the worksheet, the group members may all work together on each question, or divide the questions among themselves and then share their findings as a group.

8. After the groups have completed their research, collect the Investigative Worksheets and review them. Return the worksheet to them prior to the next step of the instructional procedures; the critical analysis activity. The Investigative Worksheet is a formative assessment which will enable the teacher to check the student work and if necessary, assist in any

way to help ensure student success on his or her critical analysis activity.

Critical Analysis Activity

9. Allow the students to spend time researching and preparing for the critical analysis activity on both the supporting and challenging information. Prior to the activity, randomly determine which of the two groups will present supporting information and which will present challenging information. You may have groups draw cards to help objectively determine if they will research the supporting or challenging information.

Instructional Tip:
Encourage all students to participate in the critical analysis activity because the experience will be a learning opportunity. Be prepared, however, to distribute alternate assignments to students who do not want to participate.

10. Hand out Attachment C, Critical Analysis Rubric, to help students understand the materials they need to prepare and how they should conduct their presentations.
11. Ask each group to write out their introduction, outline their presentations and write their conclusions. Have students practice their presentations to be sure that they are concise.
12. Have two pairs of students address each aspect. Have one group present the data that support an aspect and the other group present the data that challenge the aspect. Flip a coin to decide which group begins the critical analysis activity. Instruct each side to present its research. The teacher will serve as facilitator to assure that the groups remain on task and on time. There are no winners or losers in this critical analysis activity. This is a sharing of the results of their research concerning evolution.
13. Encourage students to actively participate as they critically analyze their assigned aspect. To ensure that they remain engaged as they watch and listen to the other groups, distribute copies of Attachment D, Critical Analysis Worksheet, and have them take notes. At the conclusion of the lesson, this worksheet will be turned in for a grade.
14. Use Attachment C, Critical Analysis Rubric, to evaluate each group's presentation.
15. Proceed to the post-assessment to evaluate students' understanding.

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Differentiated Instructional Support:
Instruction is differentiated according to learner needs, to help all learners either meet the intent of the specified indicator(s) or, if the indicator is already met, to advance beyond the specified indicator(s).

- Make a copy of the post-assessment available to all students at the beginning of the lesson. This will allow students to clearly understand what is expected from them.
- Have students submit an outline of their presentation, including introductory remarks and conclusion, to assist in their organizational skills. This allows the teacher to give feedback to the students and to help prepare them for the critical analysis activity.

Extension:
Have students consider other aspects of evolutionary biology that are critically analyzed by scientists. Possible topics include:

- Hox (homeotic) genes
- Biogeography
- Vestigial organs
- Four winged fruit fly
- Galapagos finches

Interdisciplinary Connections:
Social Studies Skills and Methods Standard

Benchmark A	Evaluate the reliability and credibility of sources.
Indicator 1	Determine the credibility of sources by considering the following: a. The qualifications and reputation of the writer; b. Agreement with other credible sources; c. Recognition of stereotypes; d. Accuracy and consistency of sources; e. The circumstances in which the author prepared the source.

English Language Arts Research Standard

Benchmark B	Evaluate the usefulness and credibility of data and sources.

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Indicator 3	Determine the accuracy of sources and the credibility of the author by analyzing the sources' validity (e.g., authority, accuracy, objectivity, publication date and coverage, etc.).
Benchmark C	Organize information from various resources and select appropriate sources to support central ideas, concepts and themes.
Indicator 2	Identify appropriate sources and gather relevant information from multiple sources (e.g., school library catalogs, online databases, electronic resources and Internet-based resources).
Indicator 4	Evaluate and systematically organize important information, and select appropriate sources to support central ideas, concepts and themes.

Materials and Resources:
The inclusion of a specific resource in any lesson formulated by the Ohio Department of Education should not be interpreted as an endorsement of that particular resource, or any of its contents, by the Ohio Department of Education. The Ohio Department of Education does not endorse any particular resource. The Web addresses listed are for a given site's main page, therefore, it may be necessary to search within that site to find the specific information required for a given lesson. Please note that information published on the Internet changes over time, therefore the links provided may no longer contain the specific information related to a given lesson. Teachers are advised to preview all sites before using them with students.

For the teacher: attachments, resource materials such as the Internet, World Wide Web, library resources
For the student: attachments, resource materials such as the Internet, World Wide Web, library resources

Vocabulary:
- Biological evolution
- Critical analysis
- Evolutionary theory
- Macroevolution

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- Microevolution
- Natural selection
- Theory

Technology Connections:

- Have students use the Internet to search for resources on evolutionary biology.
  http://www.stephenjaygould.org
  http://www.arn.org
  http://www.objectivityinscience.org
  http://www.origins.org
  http://genetics.nbii.gov
  http://www.ucmp.berkeley.edu/history/evolution.html

- Access the Web site for student research at the Los Alamos National Laboratory, at http://set.lanl.gov, for guidelines to the Socratic Method. From the homepage, navigate to Programs, and then Critical Issues Forum.

Research Connections:

Marzano, R. et al. *Classroom Instruction that Works: Research-Based Strategies for Increasing Student Achievement*. Alexandria: Association for Supervision and Curriculum Development, 2001.

- Identifying similarities and differences enhances students' understanding of and ability to use knowledge. This process includes comparing, classifying, creating metaphors and creating analogies and may involve the following:
  - Presenting students with explicit guidance in identifying similarities and differences.
  - Asking students to independently identify similarities and differences.
  - Representing similarities and differences in graphic or symbolic form.
- Summarizing and note taking are two of the most powerful skills to help students identify and understand the most important aspects of what they are learning.

General Tips:

- Students should use school library resources such as InfOhio's Access Science and EBSCO to locate information on aspects of evolutionary theory.

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- See the following resources for information that supports or challenges different aspects of evolution.

1. Ayala, Francisco, "The Mechanisms of Evolution." *Scientific American*, 239:3 (1978): 68.

2. Brickhouse, Nancy. "Diversity of Students' Views about Evidence, Theory." *Journal of Research in Science Teaching*. 37:4 (2000).

3. Carroll, Robert L. (1997/98). "Limits to Knowledge of the Fossil Record". *Zoology*. 100 (1997/98): 221-231.

4. Carroll, Robert L. "Towards a New Evolutionary Synthesis." *Trends in Ecology and Evolution* 15 (2000): 27-32.

5. Cherfas, J. "Exploring the Myth of the Melanic Moth." *New Scientist*. (1986): 25.

6. Chinn, Clark. "An Empirical Test of a Taxonomy of Responses to Anomalous Data in Science." *Journal of Research in Science Teaching*. 35:6 (1998).

7. Chinn, Clark. "The Role of Anomalous Data in Knowledge Acquisition: A Theoretical Framework and Implications for Science Instruction." *Review of Educational Research*. 63:1 (1993): 1-49.

8. Darwin, Charles. *On the Origin of Species: A Facsimile of the First Edition*. Cambridge: Harvard UP, 1975.

9. Denton, Michael. *Evolution: A Theory in Crisis*. Bethesda: Adler and Adler, 1986.

10. Doolittle, W. Ford "Uprooting the Tree of Life," *Scientific American* (2000): 90-95.

11. Erwin, Douglas. "Macroevolution is More Than Repeated Rounds of Microevolution," *Evolution & Development* 2 (2000): 78-84.

12. Erwin, Douglas. "Early Introduction of Major Morphological Innovations," *Acta Palaeontologica Polonica* 38 (1994): 281-294.

13. Evans, Margaret E. "The Emergence of Beliefs About the Origins of Species in School-Age Children." *Merrill-Palmer Quarterly*. 46:2 (2000): 221-253.

14. Faust, David. *The Limits of Scientific Reasoning*. Minneapolis: University of Minnesota Press, 1984.

15. Fitch, W., and E. Margoliash, "Construction of Phylogenetic Trees." *Science* 155 (1967): 281.

16. Gilbert, Scott F., et al. "Resynthesizing Evolutionary and Developmental Biology," *Journal of Developmental Biology* 173 (1996): 357-372.

17. Gould, Stephen J. "Abscheulich (Atrocious), Haeckel's Distortions did not Help Darwin. *Natural History*. (2000).

18. Jeffares, D. "Relics from the RNA World." *Journal of Molecular Evolution* 46 (1998): 18-36.

19. Lee, Michael. "Molecular Phylogenies become Functional" *Trends in Ecology and Evolution*. 14 (1999): 177-178.

20. Levinton, Jeffrey S. "The Big Bang of Animal Evolution." *Scientific American* 267 (1992): 84-91.

21. Lewin, Roger. "Evolutionary Theory Under Fire." *Science*. 210 (1980): 883.

22. Lowenstein, J. and A. Zihlman. "Unreliable trees." *Nature*, 355 (1992): 783.

23. Mahoney, Michael. "Publication Prejudices: an Experimental Study of Confirmatory Bias in the Peer Review System." *Cognitive Therapy and Research*. 1:2 (1977): 161-175.

24. Margoulis, L., and D. Sagan. "Bacterial Bedfellows." *Natural History* 96 (1987): 26-33.

25. Martin W., and M. Muller. "The Hydrogen Hypothesis for the First Eukaryote." *Nature* 392 (1998): 37-41.

26. Mikkola, K. "On the Selective Forces Acting in the Industrial Melanism of *Biston oligia* Moths." *Biological Journal of the Linnean Society* 21 (1984): 409-421.

27. Monastersky, Richard. *National Geographic* (1998): 58-81.

28. Mynatt, Clifford. "Confirmation Bias in a Simulated Research Environment: An Experimental Study of Scientific Inference." *Quarterly Journal of ExperimentalPsychology*. 29 (1977): 85-95.

29. National Academy of Science. *Teaching About Evolution and the Nature of Science*. Washington: National Academy Press, 1998.

30. National Academy of Science. *National Science Education Standards*. Washington, National Academy Press, 1996.

31. Pennisi, E. "Direct descendants from an RNA world." *Science* 280 (1998): 673.

32. Philippe, Herve, and Patrick Forterre. "The Rooting of the Universal Tree of Life is Not Reliable." *Journal of Molecular Evolution* 49 (1999): 509-523.

33. Plous, Scott. *The Psychology of Judgment and Decision Making*. New York: McGraw Hill, 1993.

34. Richardson, Michael K. "There is no Highly Conserved Stage in the Vertebrates: Implications for Current Theories of Evolution and Development," *Anatomy and Embryology* 196 (1997): 91-106.

35. Samarapungavan, Ala. "Children's judgment in theory choice tasks: Scientific rationality in childhood." *Cognition.* 45 (1992): 1-32.

36. Shubin, Neil H. and Charles R. Marshall. "Fossils, Genes, and the Origin of Novelty." *Deep Time* (2000): 324-340.

37. Smith, John M., and Eörs Szathmáry. *The Major Transitions in Evolution.* Oxford: Oxford UP, 1995.

38. Smith, Mike U. "Counterpoint: Belief, Understanding, and Teaching of Evolution." *Journal of Research in Science Teaching*. 3:5 (1994): 591-597.

39. Sokal, R., and P. Sneath. *Principles of Numerical Taxonomy*. San Francisco: Freeman, 1963.

40. Thagard, Paul. Mind, Society, and the Growth of Knowledge. *Philosophy of Science*. (1994): 61.

41. Thomson , Keith S. "Macroevolution: The Morphological Problem," *American Zoologist* 32 (1992): 106-112.

42. Thomson, Keith S. "The Meanings of Evolution." *American Scientist*. 70. (1982): 529-531.

43. Towe, Kenneth M. "Environmental Oxygen Conditions During the Origin and Early Evolution of Life." *Advances in Space Research* 18 (1996): 7-15.

44. Wells, Jonathan. *Icons of Evolution*. Washington: Regency Publishing, 2000.

Attachments:
Attachment A, Five Aspects of Evolution
Attachment B, Investigative Worksheet
Attachment C, Critical Analysis Rubric
Attachment D, Critical Analysis Worksheet

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Attachment A
Five Aspects of Evolution

Aspect 1: Homology
Citations #8, 9, 15 and 39 in the General Tips Section may provide a starting point for student research. It is suggested that students employ additional resources in their research.

Brief Supporting Sample Answer: Different animals have very similar anatomical and genetic structures. This suggests that these animals share a common ancestor from which they inherited the genes to build these anatomical structures. Evolutionary biologists call similarities that are due to common ancestry "homologies." For example, the genes that produce hemoglobin molecules (an oxygen carrying protein) in chimps and humans are at least 98% identical in sequence. As another example, bats, humans, horses, porpoises and moles all share a forelimb that has the same pattern of bone structure and organization. The hemoglobin molecule and the "pentadactyl limb" provide evidence for common ancestors. Also, the genetic code is universal, suggesting that a common ancestor is the source.

Brief Challenging Sample Answer: Some scientists think similarities in anatomical and genetic structure reflect similar functional needs in different animals, not common ancestry. The nucleotide sequence of hemoglobin DNA is very similar between chimps and humans, but this may be because they provide the same function for both animals. Also, if similar anatomical structures really are the result of a shared evolutionary ancestry, then similar anatomical structures should be produced by related genes and patterns of embryological development. However, sometimes, similar anatomical structures in different animals are built from different genes and by different pathways of embryological development. Scientists can use these different anatomical structures and genes to build versions of Darwin family trees that will not match each other. This shows that diverse forms of life may have different ancestry.

Aspect 2: Fossil Record
Citations #8, 10, 11 and 29 in the General Tips Section may provide a starting point for student research. It is suggested that students employ additional resources in their research.

Brief Supporting Sample Answer: The fossil record shows an increase in the complexity of living forms from simple one-celled organisms, to the first simple plants and animals, to the diverse and complex organisms that live on Earth today. This pattern suggests that later forms evolved from earlier simple forms over long periods of geological time. Macroevolution is the large-scale evolution occurring over geologic time that results in the formation of new taxonomic groups. The slow transformations are reflected in transitional fossils such as *Archaeopteryx* (a reptilelike bird) and mammal-like reptiles. These transitional fossils bridge the gap from one species to another species and from one branch on the tree of life to another.

Brief Challenging Sample Answer: Transitional fossils are rare in the fossil record. A growing number of scientists now question that *Archaeopteryx* and other transitional fossils really are transitional forms. The fossil record as a whole shows that major evolutionary changes took place suddenly over brief periods of time followed by longer periods of "stasis" during which no significant change in form or transitional organisms appeared (Punctuated Equilibria). The "Cambrian explosion" of animal phyla is the best known, but not the only example, of the sudden appearance of new biological forms in the fossil record.

Aspect 3: Antibiotic Resistance
Citations in the General Tips Section may provide a starting point for student research. It is suggested that students employ additional resources in their research.

Brief Supporting Sample Answer: The number of strains of antibiotic resistant bacteria, such as of *Staphylococcus aureus*, have significantly increased in number over time. Antibiotics used by patients to eliminate disease-causing bacterial organisms have facilitated this change. When some bacteria acquire a mutation that allows them to survive in the presence of antibiotics, they begin to survive in greater numbers than those that do not have this mutation-induced resistance. This shows how environmental changes and natural selection can produce significant changes in populations and species over time.

Brief Challenging Sample Answer: The increase in the number of antibiotic resistant bacterial strains demonstrates the power of natural selection to produce small but limited changes in populations and species. It does not demonstrate the ability of natural selection to produce new forms of life. Although new strains of *Staphylococcus aureus* have evolved, the speciation of bacteria (prokaryotes) has not been observed, and neither has the evolution of bacteria into more complex eukaryotes. Thus, the phenomenon of antibiotic resistance demonstrates microevolution.

Aspect 4: Peppered Moths (*Biston betularia*)
Citations #5, 26 and 44 in the General Tips Section may provide a starting point for student research. It is suggested that students employ additional resources in their research.

Brief Supporting Sample Answer: During the industrial revolution in England, more soot was released into the air. As a result, the tree trunks in the woodlands grew darker in color. This environmental change also produced a change in the population of English peppered moths (scientifically known as

Biston betularia). Studies during the 1950s have suggested a reason for this change. It was observed that light-colored moths resting on dark-colored tree trunks were readily eaten by birds. They had become more visible by their predators compared to their dark-colored counterparts. This different exposure to predation explained why the light-colored moths died with greater frequency when pollution darkened the forest. It also explained why light-colored moths later made a "comeback" when air quality improved in England. This whole situation demonstrates how the process of natural selection can change the features of a population over time.

Brief Challenging Sample Answer: English peppered moths show that environmental changes can produce microevolutionary changes within a population. They do not show that natural selection can produce major new features or forms of life, or a new species for that matter—i.e., macroevolutionary changes. From the beginning of the industrial revolution, English peppered moths came in both light and dark varieties. After the pollution decreased, dark and light varieties still existed. All that changed during this time was the relative proportion of the two traits within the population. No new features and no new species emerged. In addition, recent scientific articles have questioned the factual basis of the study performed during the 1950s. Scientists have learned that peppered moths do not actually rest on tree trunks. This has raised questions about whether color changes in the moth population were actually caused by differences in exposure to predatory birds.

Aspect 5: Endosymbiosis (formation of cellular organelles)
Citations #24, 25, 31 in the General Tips Section may provide a starting point for student research. It is suggested that students employ additional resources in their research.

Brief Supporting Sample Answer: Complex eukaryotic cells contain organelles such as chloroplasts and mitochondria. These organelles have their own DNA. This suggests that bacterial cells may have become established in cells that were ancestral to eukaryotes. These smaller cells existed for a time in a symbiotic relationship within the larger cell. Later, the smaller cell evolved into separate organelles within the eukaryotic ancestors. The separate organelles, chloroplast and mitochondria, within modern eukaryotes stand as evidence of this evolutionary change.

Brief Challenging Sample Answer: Laboratory tests have not yet demonstrated that small bacteria (prokaryotic cells) can change into separate organelles, such as mitochondria and chloroplasts within larger bacterial cells. When smaller bacterial cells (prokaryotes) are absorbed by larger bacterial cells, they are usually destroyed by digestion. Although some bacterial cells (prokaryotes) can occasionally live in eukaryotes, scientists have not observed these cells changing into organelles such as mitochondria or chloroplasts.

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Attachment B
Investigative Worksheet

Name: ______________________________

This activity will help you to prepare for the critical analysis activity. Complete the following table by addressing the following points when you record supporting and challenging data for one aspect of evolution. Record your responses on the appropriate space on the chart.

- Write a brief summary of what you have read and discovered regarding your particular aspect and how it <u>supports</u> evolutionary theory.
- Write a brief summary of what you have read and discovered regarding your particular aspect and how it <u>challenges</u> evolutionary theory.
- Were any scientific tools, instruments or other forms of technology used by scientists to <u>support</u> this evidence and how it supports a key aspect of evolutionary theory? Briefly explain your answer.
- Were any scientific tools, instruments or other forms of technology used by scientists to <u>challenge</u> this evidence and how it challenges the key aspect of evolutionary theory? Briefly explain your answer.
- How do scientists critically analyze this aspect of evolution?
- Is the information you found supported by using the scientific method? Are there any limitations?
- Are there any other type(s) of research that scientists need to do in order to critically analyze evolution? Briefly explain your answer.

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Attachment B (cont'd)

Aspect of Evolution	Supports	Challenges
What comparisons can be made between the supporting and challenging information you have found? Briefly explain.		

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Attachment B (cont'd)

A. In the space below, write your introduction for the critical analysis activity.

B. In the space below, outline the body of your informational presentation.

C. In the space below, write your conclusion.

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Attachment C
Critical Analysis Rubric

1. Group was able to articulate and demonstrate knowledge of the aspect of evolution they presented.

3 2 1 0

2. Students were courteous and respectful toward their fellow students.

3 2 1 0

3. Students were able to effectively use research (scientific data) to support their presentation.

3 2 1 0

4. Students were logical in presenting their information.

3 2 1 0

5. Students used visual aids (e.g., graphs, tables, pictures, etc. displayed on posters, transparencies, chalkboard or presentation software) effectively.

3 2 1 0

6. Provide an opportunity for all group members to speak. Allowing for all group members to speak is very important for it will enable the students to verbally engage in the analysis of evidence.

3 2 1 0

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18 – 16	=	Excellent (mastery)
15 - 13	=	Good (acceptable)
12 - 9	=	Poor (needs revision)
8 - 0	=	Not acceptable (remediation required)

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Attachment D
Critical Analysis Worksheet

Directions: Fill in the following worksheet with information you have learned from the groups.

Aspects of Evolution	Supports	Challenges

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Attachment D (cont'd)

Student Reflection:

1. Why is it important for scientists to critically analyze evolution?

2. How has the information presented by the various groups added to your understanding of evolutionary theory? Cite examples.