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Lesson Sequence Plans:
A Lab Examining Plant Adaptations, Common Ancestry, and Convergent Evolution

Next Generation Science Standards (NGSS) Performance Expectations:
- HS-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. (loosely addressed)
- HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

NGSS Disciplinary Core Idea: Biological Evolution (Unity and Diversity)
NGSS Crosscutting Concepts (loosely covered)**:**
- Patterns
- Cause and Effect

NGSS Science Practices:
- Practice 7: Engaging in Argument from Evidence
- Practice 8: Obtaining, Evaluating, and Communicating Information

Student Goals:
1) Examine the concepts of convergent evolution, shared common ancestry, and coevolution using plant specimens as representatives
2) Draw upon knowledge of natural selection to explain morphological adaptations in several groups of plants
3) Using morphological evidence and logical explanation, support a case for common ancestry or convergent evolution between two groups of plants
    a. Present claims for evaluation by classmates
4) Use classmate-provided evidence to determine instances of coevolution

<u>**Activity 1**</u> (*60 minutes)*
Student groups examine a plant specimen or two from a particular plant family at their lab bench. Groups create a list of observable adaptations exhibited by these plants. For each adaptation, students devise an explanation for evolution of that adaptation using their knowledge of natural selection. Both abiotic and biotic selective pressures should be considered. Students predict the type of environment in which they would expect to find such plants.
Students repeat this activity at each lab bench, in order to examine a total of 6 plant family representatives. Alternatively, students might work in pairs, but this would require a minimum of 10 plant family representatives.
Estimated time of 10 mins per plant family

Rationale: This first activity enables students to gather evidence from observation to support a conclusion regarding the geographic range of a plant species, as well as infer the selective pressures driving adaptations observed. NGSS Science Practices 7 and 8 emphasize the importance for evidence based claims and conclusions in science, so this initial activity will require students to base any conclusions they draw firmly on those morphological features of their plant specimens perceived to be adaptations. An interesting article by Paul Narguizian (2004), written for high school science teachers, examines the nature of science as understood through evolutionary concepts and coincides well with the NGSS focus on science practices. Narguizian emphasizes, in particular, the demand for empirical evidence in science, and he includes observational evidence in this discussion. For high school teachers, he recommends sharing with students historical evidence for evolution, such as the extensive observations made by Charles Darwin on his *Beagle* voyage, in an effort to emphasize science processes. However, as my students are already familiar with the basic tenets of natural selection, this first lab activity with ask them to collect observational evidence for evolution themselves.

Activity 2 (*10 mins max*)
Following observations of all plant specimens, students determine which of the others is most closely related to their original specimen. Students are given one of these alternative plants to bring to their table. At this point, I provide students with an example of convergent evolution. Students have the option to change their minds about the relationships between their plants, through re-examination of morphological features. Each plant will be accompanied by a card, which students may open at this point, displaying its native geographical region. This information can be factored in to students' conclusions.
Alternative format: Because groups may choose each other's plants, resulting in 8 students examining the same two families, groups may be assigned a "for" or "against" position, supporting either common ancestry or convergent evolution.

Rationale: This second exercise, essentially a short conclusion to the first activity, draws loosely from the crosscutting concepts of pattern and cause and effect. Using the morphological adaptations observed for each plant specimen, as well as their evolutionary reasoning employed to explain each adaptation, students will determine apparent relationships between their own plant specimen and another. To be successful, students must carefully compare and note patterns among the morphological features each plant exhibits. Cause and effect is then examined, as predicted evolutionary history attributed to one plant will be extended to a second plant. The students may suspect that common ancestry explains similar evolutionary history and resulting adaptations, but whether similar morphology is always a product of common ancestry becomes a topic of debate once convergent evolution is introduced and the geographic regions for each plant specimen are made known. This new information should encourage students to consider alternate explanations for seemingly homologous traits under suspicion.

Activity 3 (*~45 mins*)
Students construct a brief PowerPoint presentation using photos from their plant specimens, and the explanations they devised regarding evolutionary history, to support or refute a hypothesis of common ancestry between their specimens. Students give these presentations. Other groups determine whether they agree or disagree with each group's presentation, given the evidence provided. Should a group be the only group to present a particular hypothesis, disagreeing groups must defend their alternate claim with further evidence or contrary explanation. If two groups support opposite positions initially, the class will vote to determine which claim they feel is best supported.
PowerPoint construction: 15 minutes
Presentations: 20 mins
Counter arguments: 5-10 mins

Rationale: As a primary goal of my lesson is to engage students in communication of evidence-based scientific conclusions (a combination of both NGSS Practices 7 and 8), this third activity requires students to develop an argument for or against common ancestry and present this argument to their classmates. Joyce Shaw (2012), in an article examining the effectiveness of debate in a microbiology classroom, cites student improvement in critical thinking, practice with oral communication, and the careful analysis of arguments as impetus for testing such instructional methods at her institution. It is for similar reasons that I plan to use a debate format during Activity 3, although the topics of this activity do present some limitations. As the current classification scheme for each of the plant specimens included in this lab might be discovered through a quick Google search, my students must rely upon the morphological evidence they can gather themselves to support their arguments. This may limit, unfortunately, the degree of critical thinking students employ. As a possible solution, I may allow students to research specific morphological characteristics, necessitating students to evaluate the credibility of sources located online. Despite this potential limitation, students will still engage in analysis of their own evidence to develop logical explanations for morphological patterns, and their conclusions will be presented orally, for possible rebuttal, to their classes. Ultimately, this activity will expose students to the presentation of conclusions, defense of arguments, and revision of ideas often hidden, yet so essential in the scientific process, and as conclusions supported are of students' own devising, ownership of the activity may enhance motivation.

Activity 4 *(~ 30 mins*)
This final activity is primarily for fun, as this is the students' last lab of the semester, but it is also designed to examine coevolution. Students are provided with a picture of a pollinator (e.g. bee, butterfly, moth, bat, hummingbird, etc.). Student groups look up characteristics of their assigned pollinator, and determine the types of adaptations in plants that might attract such pollinators. Students then draw (or construct with PlayDo? Too juvenile?) a flowering plant that exhibits the adaptations determined by students. Once complete, all groups circulate around the room and match appropriate pollinators to the "flowers" designed by their classmates using a list provided in their lab manual.

Rationale: A older article MaryAnn Foote (1990) describes an exercise to help high school students understand why flowers produce smells, but she advocates doing so by allowing students to observe a variety of plants, take note of the insect pollinators visiting such plants, and through their observations, come to understand which insects are partial to particular smells. My students are well aware of the reasons for scent production in flowers, but there are a variety of adaptations other than scent that plants employ to attract pollinators, many of which are explained in Foote's article. These adaptations are great examples of coevolution, and at Drew, we had used a similar activity to Foote's in the past to examine these pollination syndromes. In past years, students played a pollination game, where given a list of pollinator characteristics and an array of flowering plants, they were tasked with matching pollinators to plants. A problem with this activity, however, is that so many plants are generalists and attract many pollinators. Activity 4, described above, draws on our previous activity at Drew, and Foote's ideas, to examine coevolutionary specialization, as well as summarize some of the day's activities. Students compile, through online research, their own set of pollinator characteristics and support a model of their own construction with their collected evidence. Classmates then test the effectiveness of each model in demonstrating a particular pollination syndrome. Although this final activity does not contain a communication component, it does emphasize the importance of evidence in support of evolutionary correlations, and it introduces an element of fun to the study of plants.

Allowing 15 minutes for pre-lab lecture and interruptions by me, total run time: 2 hours, 40 mins

Through the above activities, I hope to emphasize the collaborative and communicative nature of science. Further, as this lab requires students to amass evidence to support a claim of their own devising, their view of science as an evidence-based enterprise, forwarded through open communication of both complementary and contradicting ideas, will be reinforced.

Through my recent interviews to elicit student preconceptions and content knowledge, I found that many of the interviewees understood the relationship between common selective pressures and adaptation in unrelated organisms, with one student using the term "convergent evolution." After some deliberation, I decided that rather than risk potential confusion by introducing phylogeny during the last lab of the semester, I would keep convergent and coevolution as the focus of this lab. Students with adequate prior knowledge will be able to draw upon that understanding to support their groups' considerations, while other students will be introduced to the concept through an interactive, evidence-based activity without the complication of more complex principles of relatedness.

Assessment of student performance will be embedded within the lab activities. Students will be observed at each stage of the lab for their degree of participation, careful consideration of evidence at hand, and cooperation with group members. All students will be required to speak during their group presentations, and their peers, the TAs, and I will evaluate the effectiveness of their arguments for or against convergent evolution. During the final coevolution activity, evaluation of flower models will be dependent on the ability of classmates to provide an appropriate pollinator match. No assignments will be given to complete outside of class due to the timing of the lab activity, although I will provide students with an optional survey enabling them to give feedback regarding their perception of the lab's activities.

References

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Narguizian, P. (2004). Understanding the nature of science through evolution. *The Science Teacher 71*(9), 40-45.

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