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# K-12 Partnership Lesson Plan

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# *Building Evolutionary Trees*

# *How did New World Oriole colors evolve?*

## Overview

Evolutionary trees are incredibly useful tools for evolutionary biologists. However, students often struggle with interpreting even simple evolutionary trees. The AP biology exam frequently asks students to interpret evolutionary trees or even build their own cladogram (simple evolutionary tree). This lesson is designed to prepare students for this exercise. At the beginning of this lesson students receive an introduction to the concepts of common ancestry, parsimony, and how evolutionary trees can be used to address evolutionary hypotheses. Students then use a simplified data set from a real scientific paper on the evolution of color in orioles to build their own evolutionary tree. At the end of the lesson students discover that the simplest tree based on color changes is slightly different than the published tree based on genetic sequences. This emphasizes the point that evolutionary trees are hypotheses and that more data can change the picture. Students get hands on experience using evolutionary trees to the answer the question: how did the female get her colors?

**Objectives**

At the conclusion of the lesson, students will be able to:

* Explain the concept of common ancestry and identify the common ancestor of any two species using an evolutionary tree
* Use an evolutionary tree to predict when a given trait first appeared
* Use an evolutionary tree to make associations between physical (aka phenotypic) traits and ecological variables
* Explain the concept of parsimony
* Use a data table with physical characteristics to build the most parsimonious tree
* Explain why trees built with physical characteristics might differ from trees built with gene sequences
* Generate a hypothesis on the evolution of a particular characteristic supported by data from an evolutionary tree.

**Length of Lesson**

Total lesson: 90 min; introductory material: 30 min; tree building exercise: 45-60 min

**Grade Levels**

Upper level high school (AP biology)

**Standards covered (NGSS)**

Disciplinary Core Ideas:

* **HS-LS3-1**: ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring
* **HS-LS4-1**: communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence
* **HS-LS4-5**: evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species

Cross Cutting Concepts:

* Patterns
* Stability and change of systems

Science and Engineering Practices

* Developing and using models
* Analyzing and interpreting data
* Engaging in argument from evidence

***Phylogenetic (aka evolutionary) trees are mentioned in the AP biology exam materials as a way to illustrate Essential knowledge 1.4.A: “biological evolution is supported by scientific evidence from many disciplines, including mathematics” and addresses the following learning objectives:***

* **LO.1.11**: the student is able to design a plan to answer scientific questions regarding how organisms have changed over time using information from morphology, biochemistry and geology
* **LO.1.13**: the student is able to construct and/or justify mathematical models, diagrams or simulations that represent processes of biological evolution

**Materials**

* Introductory powerpoint
* Building evolutionary trees worksheet, part 1 and part 2 (one per student)
* Blank tree (one per working group)
* Species cards, printed in color (one per working group)

**Background**

### Evolutionary trees are incredibly useful tools for evolutionary biologists. However, many students struggle with how to understand these tools. For instance, students may mistakenly believe that modern chimpanzees turned into humans, instead of understanding that both chimps and humans shared a common ancestor sometime in the past that no longer exists. The introductory material takes students through 5 basic points: (1) evolutionary trees are similar to family trees and show descendants from a common ancestor; (2) evolutionary trees show which species are most closely related; (3) evolutionary trees are used by biologists to determine when particular traits evolved; (4) trees built using more data are more accurate- gene sequences are the best; (5) evolutionary trees can be combined with environment or lifestyle data to test hypotheses for why traits might have evolved. The powerpoint included on the website provides extensive notes to guide students through these concepts.

### *Tree Building Exercise*

### To practice building trees, students are given a data set from a published article on color in New World Orioles. New World Orioles are a fascinating bird family. Some species show the pattern we have grown to expect- flashy colorful males and drab dull females. However, in some species females are just as bright as males. Evolutionary biologists, Hofmann, Cronin, and Omland, wanted to know which came first: dull females or bright females? At the end of this lesson students will discover that the female ancestor was somewhat dull but females have undergone some very dramatic changes over evolutionary time- in fact they’ve changed much more than males! This is exciting to biologists since most of the research up to this point has been focused on males. Females are actually a really important part to the color story.

### In this exercise students are asked to brainstorm how colors could be an adaptation and how colors could be costly. There are many possibilities in this section. For instance, bright colors could help birds attract mates, could help them look intimidating to their rivals, might tell predators they are toxic, or could just be a byproduct of the bird’s diet. On the other hand, colors might make birds stand out to predators or might be expensive to make. At the end of the lesson the students observe that all the species in this data set with bright colors also do not migrate. The end of the powerpoint provides information on one of the current hypotheses to explain this pattern: the “social competition hypothesis”.

### According to the social competition hypothesis, migration has several important impacts. First, migration is difficult and risky and many birds die in the process. Second, migration can help “level the playing field”, so to speak, each year. Every spring migrants must compete for territories all over again. If a young bird happens to catch a lucky wind current or stronger competitors get delayed by a chance storm, they might be able to snag a good territory before the population is full. In comparison, non-migrants often hold territories for multiple years, which can make it harder for a new bird to find its way in. Third, migrants more often live in the temperate zone (because of winter!). As a general pattern, tropical birds tend to have lower adult mortality, longer lifespans, and tend to hold on to territories for a much longer time. All three of these factors increase the amount of social competition for territories, breeding resources, and possibly mates for tropical/non-migratory birds. Female colors are thought to act as a social signal to other competitors that can be used to assess the condition/quality/fighting ability of the female. In the temperate zones/migratory birds the competition is less, and these signals are not as necessary for females, and thus these colors have been lost. This is a great place to emphasize that science is an active on-going process! This is just one hypothesis scientists are investigating and we don’t know the answer yet.

### Activities of the session

### *Introduction: Exploring Evolutionary Trees*

1. Introduce the concept of evolutionary trees using the powerpoint, slides 1-9. Slide notes provide extensive notes and possible questions to prompt student discussion.
2. Practice building a simple evolutionary tree using the data on slide 10. For less advanced students, this can be done as a class. For more advanced students, you can provide the basic skeleton of the tree and have them work in groups.

### *Tree Building Exercise*

### Note: This exercise is purposefully designed as a challenging puzzle to get students to think about real data. There are several possible approaches students might take. Students should work in groups to brainstorm possible trees. The goal should be to come up with the best (aka fewest changes) tree in the class. To help students get started on this challenging puzzle, and skeleton tree has been provided.

1. Introduce the scientific question (slides 12-13)
2. Have students brainstorm how colors could be adaptive and how colors could be costly. List these on the board to assist student thinking when they reach the end of the exercise.
3. Pass out **ONLY PART 1** of the exercise (if you hand out part 2 & 3 you will spoil the answer!), the species cards (one per group), and the tree skeleton (one per group). Students will be asked to use the data table on the worksheet and the colored species cards to arrange the birds on the tree in the most parsimonious fashion (aka fewest changes). Once students have decided on a final arrangement, they should write the species names on the end of the branches and use a labeled dash to mark each time a color trait from the table changed.
4. Help the students get started: looking at the data in the table, what was the back color of the male common ancestor? (only one option)
5. Help the students get started: then look at the next simplest trait (female back color). First ask how many times the trait changed (one change is most likely). Point out that this divides the birds into two nice groups- gray group and black group (which is why it is a good place to start). Ask them the best place to put this trait on the tree skeleton (there is just one good place that divides the birds in a group of 3 and a group of 4)
6. Students work through the rest of the data in groups. Let them know that they may have to play around with things to find the fewest number of changes.
7. Student answer part 1 questions based on their own tree.
8. When the group thinks they have an answer, they should turn to a nearby group and compare trees. Whichever group has the fewest number of changes should draw their tree on the board. When all groups are finished, the instructor picks a class winner.
9. Hand out **PART 2 & 3.** Use slide 15 to introduce the idea that parsimonious trees built with morphological data might change when genetics are introduced. Show colored published tree (slides 16-17).
10. Students answer questions in part 2 as individuals or groups (answer to question 1 is on slide 18).
11. Introduce the last section (using trees as tools for testing why traits evolved). Students answer questions in part 3.
12. If desired, use slide 20 to discuss one hypothesis for why we see these patterns (do this only after students have a chance to answer the question for themselves).

**Resources**

* Powerpoint, exercise worksheet, species cards, and the blank tree skeleton are all available on the “Building evolutionary trees” lesson page on the KBS GK-12 website
* The oriole color exercise is based on simplified data from the following publications:
	+ Hofmann, CM, Cronin, TW, Omland, KE. 2008. Evolution of sexual dichromatism 1. Convergent losses of elaborate female coloration in New World Orioles. *The Auk*. 125:778-789
	+ Friedman, NR, Hofmann, CM, Kondo, B, Omland, KE. 2008. Correlated evolution of migration and sexual dichromatism in the New World Orioles (*Icterus*). *Evolution* 63:3269-3274.
* The domesticated cat phylogeny is based on the following work:
	+ Driscoll, CA et al. 2007. The near east origin of cat domestication. *Sciencexpress*. doi: science.1139518
	+ Driscoll, CA et al. 2009. The taming of the cat. *Scientific American* 300:68-75. doi:10.1038/scientificamerican0609-68

**Assessment**

 The student worksheet can be used for assessment.