Lesson Title: Constructing a Dichotomous Key and Exploring Its Relationship to Evolutionary Patterns

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Grade Level: 4th and 5th grade

Type of Lesson: STEM

Objectives: The objectives of this lab are to learn to use a **dichotomous key**, identify variation in physical characteristics among closely and distantly related species, and recognize the relationship between dichotomous keys and patterns of evolution. This activity addresses the following Boulder Valley School District Essential Learnings for fourth graders in describing that each organism has different structures that serve different functions in growth, survival, and reproduction and for fifth graders in explaining how nonliving components of ecosystems can affect living components.

Background Information: A dichotomous key is a set of couplets of mutually exclusive **physical characteristics** that are used to identify organisms in a scientifically reproducible way. Dichotomous keys are the most widely used method in the scientific community for classification of organisms into different groups such as family, genus, or species. Dichotomous keys are used by deciding between two exclusive characteristics and following a path to the correct group or answer. They begin with general characteristics and slowly lead to more specific traits and ultimately into a single category identifying the organism (a more formal and scientific version of the kid's game 20 questions to identify a person, place, or thing). Dichotomous keys are typically organized around **family trees**. Family trees, also known as **cladograms**, are trees diagraming the evolutionary relationships between different taxa. Historically, these trees were based on physical characteristics, and this particular type of family tree is also known as a **phenogram**. Although not always correct, as we now know from DNA analysis, phenograms show relatively accurate trees. One of the goals of this activity is to create a tree that will be incorrect based on physical characteristics in order to help the students understand the benefits of using new techniques like DNA analysis.

This lab will encourage students to discover how variations in structures on animals can be used to identify them and reveal information about their relationships to each other. In this lab students will first learn to create a dichotomous key for a small group of different organisms. The students will then, with your assistance, create a dichotomous key for all the organisms in the class. Next, they will realize that the key they created can be used to describe the evolutionary history of the organisms. Again, trees created using physical

characteristics are typically nearly correct with a few pitfalls; the tree you create is nearly, but not completely, correct. I have found that students love the drama of using a method that has been used by scientists for centuries, but sometimes they come to an incorrect conclusion. This nicely illustrates that scientists are still making major discoveries about something as seemingly simple as the relationships between organisms. Finally, when students recognize the inaccuracies of this method, you can explain that DNA is now used to create relationship trees among organisms. DNA is much more accurate because instead of using a few physical characteristics, scientists are able to use thousands of base pairs. DNA is still very cost prohibitive and so as a result, as previously described, dichotomous keys are the most commonly used method of identifying species.

References: Vocabulary and general lesson structure were adapted from the following websites:

http://www.mhhe.com/biosci/pae/zoology/cladogram/

http://www.biologyjunction.com/dichotomous_keying.htm

Lesson Vocabulary:

Family tree (cladogram if older students) – an upside down tree showing how closely or distantly different organisms are related according to physical features or DNA analysis.

Physical characteristic – Feature or features used to describe the way something looks or feels

Dichotomous key – a tool for categorizing species or objects using logical choices.

DNA – **D**eoxyribo**n**ucleic **a**cid is a molecule that encodes the genetic instructions for creating all living organisms. It is made up of nucleotides given the letters ATCG; our entire genetic code is made up of a four-chemical base structure.

Materials Required: This lab works best with the following small plastic animals but will also work with pictures substituted for the plastic animals if they aren't available (both described here after as animal models). Both types of models, plastic and pictures, can work interchangeably if one is not available. Animals in parentheses can substitute for animals.

1. Octopus, five starfish, and squid (jellyfish, cuttlefish, oyster, mussel)
2. Butterfly, lady beetle, and cockroach (crab, lobster, bumble bee, spider)
3. Trout, grouper, whale (any form of fish for trout and grouper and dolphin or seal for whale)
4. Frog, snake, lizard (toad, newt, dinosaur)

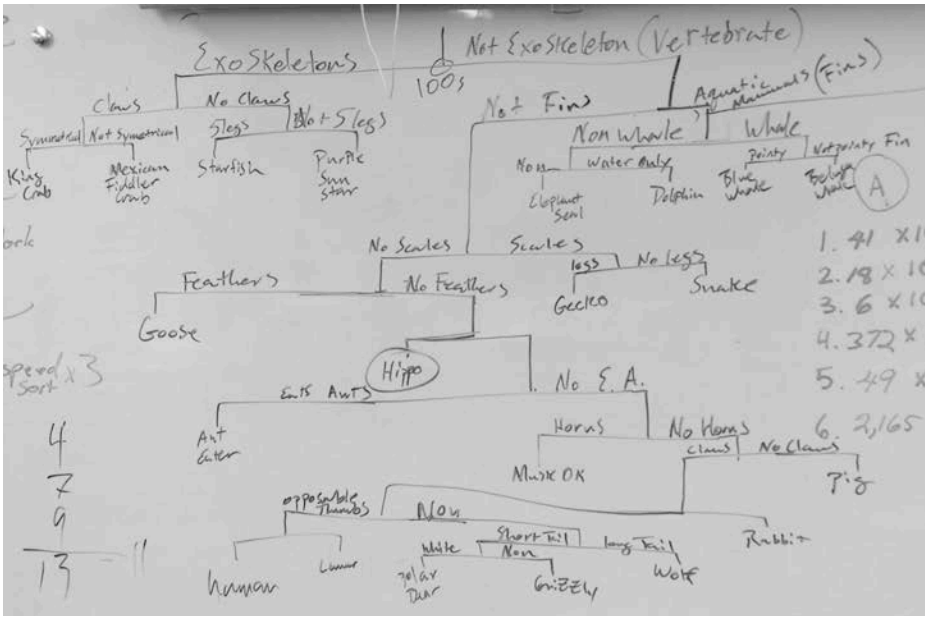
5. Eagle, duck, bat (any bird will substitute well for the eagle and duck)
6. Lion, tiger, bear (wolf, mountain lion, coyote)
7. Rabbit, deer, squirrel (buffalo, elk, giraffe)
8. Lemur, chimp, human (any tailed monkey will substitute for lemur and any untailed monkey will substitute for chimp)

Preparation: (15 minutes)

Animal models should be separated into small groups before class.

Engagement: Tell the students that dichotomous keys are the most frequently used method of identifying different organisms in the scientific community, and if they learn how to use them correctly they can use them to identify almost any creature on Earth. Show them animal models of a lion, a bear, and a snake and ask them which one is *least* like the others. The students should answer the snake, which is a reptile. Ask the students what physical characteristic of the mammals makes the reptile different. Have the students fill out the first couplet together as a class for question #1. Do this again with the second couplet. If they are struggling, it can be helpful to tell students that for each couplet they should come up with a trait that some of the animals have and some don't (essentially yes and no traits). For example, for in the first question about, the snake, the lion, and the bear, the snake has *scales* and the lion and the bear have *no scales*.

Exploration: Hand out the animal models to the students in the previously described groups. Have the students create a small family tree, like the one in question 1, for question 2 using the animal models for their group.



Next, allow the students to discuss in their groups the characteristics that *all* of the animals in the tree they just created share. One member of each group should briefly describe these to the class. Create a dichotomous key, with the help of the students, on the board incorporating all of the groups (see example board). If the students have trouble getting started try to lead them by asking which one group is most different and then the same question among the rest.

Explanation: Lead the students in a discussion on the relationships between different species; the closer the species being compared are on the **family tree** the more likely they are closely related evolutionarily. Hopefully, one or two of the students will point out the errors of this cumulative tree, notably that the positions of the whale and the bat are incorrect and that they should be positioned with the mammals and not with the fish and birds. This may confuse some of the students. A good way to help students that are confused is by telling them how different groups can evolve to have similar structures *if* that structure is beneficial in a particular environment (such wings for bats and fins for whales).

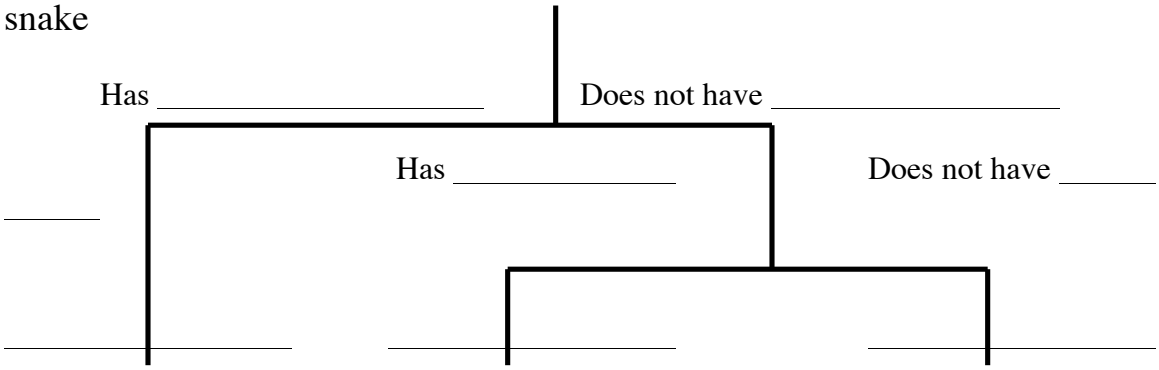
Elaboration, Extension: The students will have created a tree using only one set of external physical characteristics. Have them fill out question 4 asking how they might make a more accurate tree (*comparing trees with more features, internal anatomy in addition to external anatomy, and DNA*).

Evaluation: For question five, have the students come up with a three couplet dichotomous key including flowers, insects, and mammals.

Wrap-up: Ask the students to think about dichotomous keys and evolution on their way home, could they create a key for things such as shoes, books, or computers?

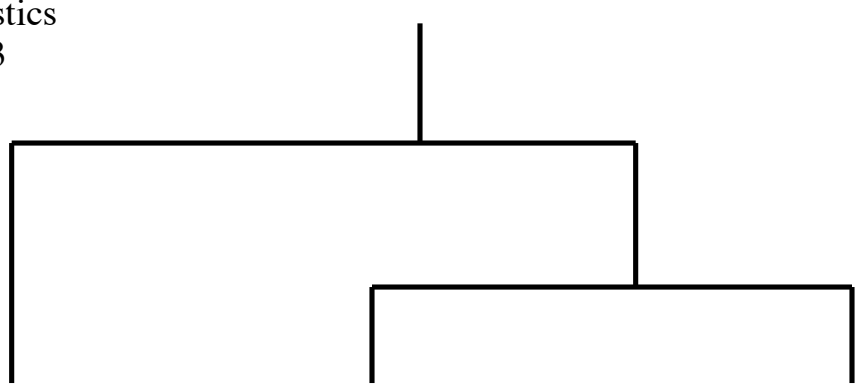
Dichotomous Key Student Handout
Name_____
Date_____

Question 1
Create a dichotomous key for the following organisms: a lion, a bear, and a snake



Question 2
Create a dichotomous key for your groups of animals using physical characteristics

Question 3



Create a dichotomous key of all the animal groups for the whole class (complete this with the whole class)

Question 4
How could you make a more accurate family tree?

Question 5
Come up with a four couplet dichotomous key including a maple tree, a flower, a bumble bee, and a polar bear