Taxonomy: Who is in my family?
Teacher Version

In this lesson, we will find out more about how organisms are classified into various groups by learning how to use a dichotomous key to identify specific species in a collection of different organisms.

California Science Content Standards:

- **<u>Note</u>**: There are no specific California State Science Content Standards that address taxonomy, binomial nomenclature, and the other concepts presented in this lab activity. General standards that can be aligned to this lab are as follows:
- **6. Ecology: Stability in an ecosystem is a balance between competing effects.**
- 6a. Students know biodiversity is the sum total of different kinds of organisms and is affected by alterations of habitats.
- **8. Evolution: Evolution is the result of genetic changes that occur in constantly changing environments.**
- 8e. Students know how to analyze fossil evidence with regard to biological diversity, episodic speciation, and mass extinction.
- **8f. Students know how to use comparative embryology, DNA or protein sequence comparisons, and other independent sources of data to create a branching diagram (cladogram) that shows probable evolutionary relationships.

Learning Outcomes:

By the end of the lesson, students should be able to:

1. Appreciate the diversity of life on earth.
2. Appreciate how organisms can be very unique and yet similar to one another.
3. Understand that many different organisms can be sorted and categorized based on features that they share in common.
4. Understand how a dichotomous key can be used to identify and classify a given set of organisms.
5. Draw a dichotomous key to distinguish between related but distinct species based on their physical features and appearance.

Key Concepts/Vocabulary:

- **Biodiversity** is the variety (-diversity) of living organisms (bio-) in the world
- A **dichotomous key** is a flow chart with branches based on either/or decisions that can be used to arrive at distinct results at the ends
    - "Dichotomous" refers to the branching nature of the key, with each branch point splitting off into only 2 branches each time.

    - When used in the classification of organisms, either/or decisions are usually based on distinguishing physical features of the organisms being studied.
- The different levels of the **Linnaean classification system** are (in order of decreasing size): Domain/Kingdom/Phylum/Class/Order/Family/Genus/Species Domains are the highest level. Within domains are kingdoms, and within kingdoms are phyla, etc. Each unit/group at any level is called a **taxon** (e.g. Homo is a taxon at the genus level).
- A two-part naming system for organisms in Latin is known as **binomial nomenclature**. The first part of the name is the genus, and the second the species. An organism's name is usually italicized, with only the first letter of the genus capitalized - for example, the binomial nomenclature for humans is Homo sapiens.

Materials & Preparation:

In Class Materials (per student):

- 1 x student worksheet
- 1 x set of photographs (20 cut-outs from appendix A)
- 1 x cartoon animals set A (cut-outs A1 to A8 from appendix B)
- 1 x set A dichotomous key (appendix C)
- 1 x cartoon aliens set B (cut-outs B1 to B8 from appendix D)
- 1 x plain drawing paper

Note to teachers: Cartoon animals may be replaced by toy animals using various art materials (popsicle sticks, colored paper parts, etc.). Toy animals that are prepared should follow a similar scheme to the cartoon animals in having 8 different animals with shared characteristics.

Introductory Mini-lecture:

Our earth is inhabited by many different types of organisms (living things), from trees and grasses to all sorts of birds, insects, bacteria and more. Different organisms come in all sorts of shapes, sizes and colors, with each one having a unique form. Despite the great diversity, there is much unity in life as well, and organisms can be grouped together based on how closely related they are.

In order to have a better understanding of the organization of life on earth, scientists in the past developed various ways of classifying (or grouping) the different organisms on earth, and to assign each organism and their groups specific names. In the 18th century (about 300 years ago), a scientist named Carolus Linnaeus developed a ***Binomial nomenclature***, or naming system, that is still in use today. In this binomial system, organisms are given scientific names with two parts: the ***genus*** of the organism, which is the name given to a group of very similar organisms, and the second the species, which is specific to that one organism. For example, humans would have the scientific name *Homo sapiens* (where *Homo* is the ***genus*** and *sapiens* is the ***species***), and the African lion has the scientific name *Panthera leo*.

Besides developing a naming system, Linnaeus developed a hierarchical system for classifying all the organisms on earth. This system provided a structure with which we can group closely related organisms to better study them, and to identify new species of plants, animals and microorganisms that are still being discovered. The system is considered "hierarchical" since it consists of layers of groups, with a group (or ***taxon***) of a higher level encompassing several groups of lower levels within it. The main taxonomic levels, in order of decreasing size, are (with the example of the leopard given):

Domain *(Eukarya)*
↳***Kingdom*** *(Animalia)*
↳***Phylum*** *(Chordata)*
↳***Class*** *(Mammalia)*
↳***Order*** *(Carnivora)*
↳***Family*** *(Felidae)*
↳***Genus*** *(Panthera)*
↳***Species*** *(Panthera pardus)*

Organisms in the same group share various common features (such as having fur, a hard shell, scales, gills, etc.). Larger groups (such as domains, kingdoms, or phyla) have more generally shared features by many organisms, while smaller groups at the lower levels (species) have features that are very specific to just a small group of organisms.

In this lesson, we will find out more about how organisms are classified into various groups by learning how to use a ***dichotomous key*** to identify specific organisms in a collection of different ones.

References

1. Campbell, N. A., & Reece, J. B. (2009). *Biology*. 8th ed. San Francisco: Pearson Benjamin Cummings.

Part 1 – Who's More Closely Related?

Organisms that have greater similarities to each other are more closely related than those which share only a few characteristics. In this activity, we will look at pictures of various organisms and put them into groups based on how they look, and attempt to figure out which organisms are more closely related.

For this activity, you will need:

- 20 different photograph cut-outs.

Estimated duration: 30-45 minutes

Procedure:

1. Lay out all 20 photograph cut-outs on the table so that you can see all of them.

2. Pick one organism and find other organisms that seem most similar to it. Put the photographs in this first group together, clearly separated from the other photographs. Try and do this on your own first, because we will be comparing results later on.

3. Write down the names of these organisms in the row for group 1 of the table A below. Names are found at the bottom of each photograph.

4. Write down what features are shared by the organisms you have put in group 1 in the table A. Be as detailed as possible in listing out all the reasons for why you have put these organisms in the same group.

5. Continue making more groups and filling up the table until you have put all 20 organisms into a group. You do not need to fill up all the rows provided in the table.

Below is one possible grouping for the students. Let them create their own groupings based on their own criteria, then have them compare, contrast, and justify their choices with other groups.

Table A: Observations and Groupings

Group No.	Group members (names of organisms)	Shared features
1	*Escherichia coli, Helicobacter pylori*	*Single celled* *Rod shaped* *(Bacteria)*
2	*Bird's nest fern (fern – non flowering)* *Corn (angiosperm, monocot, C4 plant)* *Sequoia (gymnosperm)*	*Plants* *Green leaves* *Stationary (not moving)*
3	*Shiitake* *Enoki*	*Similar shape – "stalk" and "cap"* *(Fungi)*
4	*Monarch*	*Insect (6 legs)* *(Arthropods, mandibulata, insecta)* ***Closer to group 5 than 6.*
5	*Blue crab* *Barnacle **requires close up view of what is inside the shell.*	*Jointed legs* *Exoskeleton (hard outer covering, not a shell)* *(Arthropods, mandibulata, crustaceans)*
6	*Tarantula* *Tick*	*8 legs* *(Arthropods, chelicerata, arachnids)*
7	*Clam* *Snail* *Banana slug*	*Soft body* *Muscular foot* *(Molluscs)*
8	*Chimpanzee* *Long-tailed macaque* *Fruit bat*	*Fur* *Milk glands (may not be visible in photos)* *2 legs, 2 arms (4 limbs)* *(Mammals)*
9	*Hummingbird* *Peregrine falcon*	*Feathers* *Wings* *Beak* *(Birds)*

Questions:

Q1. Compare your list of groups with your friends. Do the groups that you have made match with everyone else?

No

If no, why do you think people got different results?
Different criteria for grouping.

Q2. Are there any big groups in your list which can be split into smaller groups?

Yes (depending on student's table)

If yes, which group can be split, and into what sub-groups? Do this for just one group which you think can be split.

A group that is a combination is most likely to have members of 4, 5, 6. Split the combined group into 4, 5 and 6.

Q3. Are there any small groups in your list which can be combined into one big group?

Yes (depending on student's table)

If yes, which groups can be joined, and what features do all members of the large group share? Do this for just one new large group which you think can be formed.

Combine groups with members of 4, 5, 6

Q4. Are there any organisms that are difficult to place in one group? Which organisms are they and which groups do they seem to belong to?

Organism

Clam, barnacle (Both have a hard shell.)
Fruit bat (Has wings. Likely to be grouped with birds instead of mammals.)

Q5. Are there organisms that have some similarities but have been placed in different groups? List down some of these organisms and their shared feature.

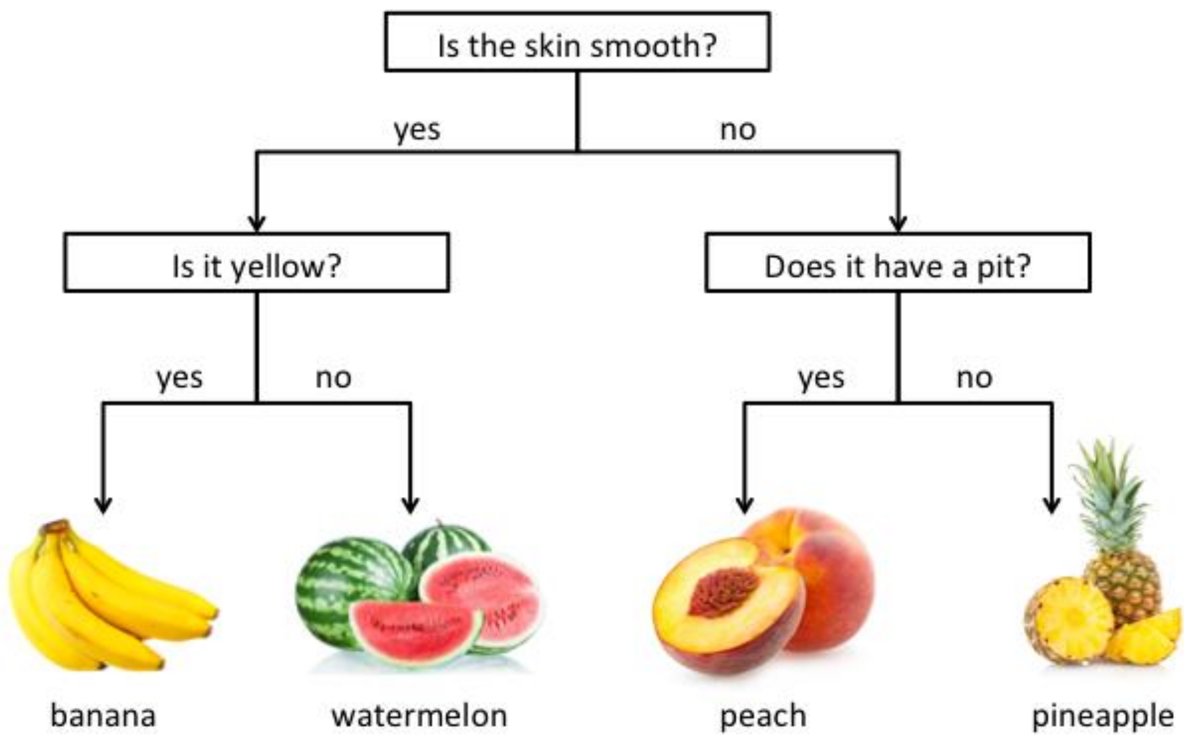
Shared Feature	*Organisms (and Group No.)*
Wings	*Fruit bat, hummingbird, peregrine falcon, monarch*
Hard outer shell	*Clam, snail, barnacle*
Many legs (6 or more)	*Monarch, blue crab (and barnacle), spider, tick*

Why do you think organisms in different groups can be distant from each other and yet have shared features?
(Convergent evolution)
Different ancestors; use similar resources/face similar challenges from the environment, and hence developed structures that look alike because the structures solve the same problems.

Q6. What do you think all 20 organisms share in common?
DNA as hereditary material
Reproduction
Ability to respond to the environment

Part 2a – Using a Dichotomous Key

In this activity, we will learn how to identify cartoon animals using a ***dichotomous key***. A dichotomous key is a reference chart that allows us to identify an organism through a series of questions about the organism with either/or answers (hence the term dichotomy, since it is a choice between two distinct options). A dichotomous key may be represented in various ways, the first of which is a tree diagram, where every branch point is a question, and it splits off into two branches depending on which of the two answers you choose. Here is an example of a dichotomous key for some types of fruit. (Note: you could build many different keys to identify the same four fruits):



A dichotomous key may also be represented in the form of a "choose your own adventure" book, where a choice to one question brings you to either another question, or arrives at an answer. This does essentially the same thing as a tree diagram, but represents it in a very compact form. Here is a simple example of how it would compare with the tree diagram above:

1a. Skin of fruit is smooth ……………………………………….(2)
1b. Skin of fruit is not smooth……………………………………(3)

2a. Fruit is yellow…………………………………………………Banana
2b. Fruit is green …………………………………………………Watermelon

3a. Fruit has a pit…………………………………………………Peach
3b. Fruit does not have pit………………………………………..Pineapple

Since our cartoon animals have already been discovered and characterized earlier, we will now use the dichotomous key provided to identify the set of cartoon animals that we have.

For this activity, you will need:

- 8 cartoon animals (Set A)
- Set A dichotomous key

Estimated duration: 15-30 minutes

Procedure:

1. Using the dichotomous key starting at 1a/b, determine whether 1a or 1b gives a better description of animal A1, and then follow the closer match to the next number specified.

2. Continue following the key in the same way, moving to subsequent numbers until you reach a name instead of a number.

3. Write down the scientific name you have arrived at for A1 in the space provided in table B. You have now identified A1 to be this particular species.

4. Repeat steps 1 and 2 with the other 7 animals to identify all 8 of them. Remember to always start using the key at step 1a/b.

Table B: Identities of Cartoon Animals in Set A

Cartoon Animal	Scientific Name
A1	*Rotundopedus bipede*
A2	*Octocrus mirum*
A3	*Palma thyrsus*
A4	*Chelicerus stipula*
A5	*Rotundopedus unipede*
A6	*Chelicerus longacrus*
A7	*Octocrus archetypum*
A8	*Palma magnocauda*

Questions:

Q7. Which animal do you think A8 is most related to and why?
A3. They share the most number of characteristics, and only differ in 1 (tail shape)

Q8. Do you think a different key could be made to achieve the same end result of identifying all the cartoon animals?
Yes. The key can be rearranged to begin the comparison using different characteristics.

Q9. What do you think makes a good dichotomous key?
Good descriptions that are not ambiguous (based on characteristics that are easily distinguished into distinct types)
Fewer steps – simpler and easier

Image sources:
Football: http://johnclay.bloginky.com/category/college-football/
Rugby ball: http://sportige.com/rugby-ad/
Soccer ball: http://us.7digital.com/cms/USEvents/World-Cup-2010.aspx
Basketball: http://www.principalspage.com/theblog/archives/tag/basketball

Part 2b – Drawing a Dichotomous Key

Having learned how to use a dichotomous key, we will now learn about how the dichotomous keys are made based on our observations. In this activity, we will use the skills we have learned from the previous two activities to construct our own dichotomous key for a new set of cartoon aliens.

For this activity, you will need:

- 8 cartoon aliens (Set B)
- Plain drawing paper

Estimated duration: 30 minutes.

Procedure:

1. Lay out the cut outs of cartoon aliens B1 to B8 on the table.

2. Examining all the aliens and their characteristics, divide the animals into two groups based on differences in one feature (e.g. number of legs). The groups do not need to be equal in size. Groups with only 1 alien in them are fine as well.

3. Draw a box for the feature at the top of your drawing paper, and show two branches coming out of it.

4. Label each branch (e.g. 6 legs or 8 legs).

5. Take one group to work on first. Find another feature that allows you to divide this group into 2 smaller groups (e.g. wings).

6. Draw in the next box for the second feature (e.g. if you took the 6 legs group, draw a box for “wings” that is joined to the branch for “6 legs” in your chart).

7. Continue doing this until you have each alien in its own group. You now have the honor of giving your newly classified cartoon aliens their own unique names!

8. When you are done, compare your key with a friend, or let a friend identify the aliens with your key.

Questions:

Q10. How many boxes have you drawn in your chart?

Answer depends on student's chart. 7 in example given.

Q11. Do you think you can draw your chart with fewer steps/boxes?

Answer depends on student's chart. Compare with example in teacher's version.

Q12. Is it better to have more boxes or fewer boxes? Why?

Fewer boxes; arrive at the solution faster; fewer boxes is simpler to use and understand

Q13. According to your chart, is B1 more closely related to B3 or B8?

Depends on the student's chart. In answer given, it is B3.

Q14. Are physical features sufficient for determining which aliens are most related to each other?

No.

Q15. What are some other methods or things that we can compare to find out how closely related two animals, aliens or people are?

Compare DNA sequences, protein sequences.

Example of one possible dichotomous key that can be drawn from Set B. Note that several variations of the key can be drawn.