Environmental Science Institute
UNIVERSITY OF TEXAS AT AUSTIN

Lesson Module: Tree of Life

Grades: Pre-AP Science, 7th

Purpose: This lesson module is designed to be used in conjunction with extracted slides from Dr. Hillis's lecture on DNA. The intent is to give teachers a group of related lessons to use in their classrooms, post-lecture. In this module, students will begin with basic classification practice, participate in a lab that requires them to use Linnaean classification, learn about phylogenetic analysis and its place in modern classification schemes, and practice making their own cladograms.

Materials:
Classification document
Caminalcules lab document
Tree of Life Powerpoint
Cladistics Document
How to Make a Cladogram Document

Lesson Duration: Recommended 2 days

TEKS Objectives: See individual lessons for objectives

Activity:

Engagement:
Have the students begin with the Classifying Shoes Activity, outlined in the "Classification [1]" document.

Exploration:
Proceed with the Caminalcules Discovery Lab, outlined in the "Caminalcules" document.

Explanation:
Use Lesson Module PowerPoint "Tree of Life". Give an explanation of classification schemes, phylogenetic analysis, and evolutionary history.

Elaboration:
Conclude with lesson on making a cladogram, outlined in the "Cladistics [1]" document and "How_to_Make_a_Cladogram [1]" document.

Evaluation:
Teacher determined form of assessment. Recommended: grade lab conclusion questions, class discussion, post-quiz, test on classification.

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Classifying Shoes

Subject: Science

Grades: 6th

Rational or Purpose: Students and teacher will come together and group their shoes to see how classifications work. They also will learn the way organisms are classified today.

Materials:

- Students and their shoes

Lesson Duration: 30 minutes

Source:
http://www.teachers.net/lessons/posts/1228.html

TEKS:
112.22 Science, Grade 6: (2a) (3c)

Background:
Classification is a way scientists categorize different organisms so that others will be able to find what they are looking for and how different organisms are closely related to one another. We classify organisms by a hierarchy of groups, constructed by Charles Linnaeus. These groups are Kingdom, Phylum, Class, Order, Family, Genus, and Species. As organisms are classified into each successive group, their differences become more apparent. By classifying their shoes, students are able to better understand the process of classification and the variety of ways this can be accomplished.

Activity:
Students will be able to group shoes or other objects by various traits. Using these groupings, students should recognize that a classification system is an easy way to relate things to each other. They will also recognize the rules of classification for organisms.

Procedure

1. Take students into the middle of the classroom or the hallway. Have them stand in a circle facing the center.

2. Ask all the students to remove their right shoes, and toss the shoe in a pile in the middle of the circle. (Teachers are encouraged to join in this activity and take off a shoe as well. This would encourage all students to participate, especially those who are shy.) This pile of shoes will represent organisms that need to be classified.

3. Select three students to be the "Organizers"; they should enter the middle of the circle. They are the only students who are allowed in the center of the circle. These "Organizers" will make three groups of shoes based on the suggestions the other students in the circle give.

4. All other students should take notes on how the groups of shoes are created to share with the class. Have them report their notes on the board for everyone to see the process used to classify the organisms.

5. Students in the circle will give their suggestions to the "Organizers" to classify these shoes into groups. Remind them to be careful when classifying because in this activity, they will only make three groups out of the pile of shoes.

6. Once the three groups are classified, tell the class that they have just made three separate "Kingdoms." Kingdoms are the largest group of organisms and the highest level on the classification scheme. Have the students make Kingdom names for these groups and make note of them to share with the class.

7. Have the "Organizers" take one of these groups and make more groups, or sub-categories, with the help of the class. This sub-grouping is called "Phylum." Phylum is the next level down in the classification scheme which further differentiates the organisms.

8. Encourage students to consider generally shared characteristics, rather than specifics while doing this type of grouping, because they will have to make several more sub-groups from their new piles. Remind them to write down the names of their new Phyla and consider what the phylogenetic tree, or cladogram, would look like.

9. Continue this process of breaking the group into smaller sub-groups (Phylum, Class, Order, and Genus) until every shoe is in a group, or species, of its own. At the breakdown of each new sub-group, tell the students what level of classification they are on. Explain that each level down the classification scheme describes the organism in a little more detail.

10. After the grouping activity is done, review with the class how the groups were created and why they classified the organisms in this way. Make sure the classification scheme is written on the board so the students can identify the hierarchal levels. Asks the students to write down the classification of the shoe organisms in their notebooks.

Name: _____ Class Section: _____
Date: _____

Classification Quiz

1. What were the names of the first three groups of shoe organisms that the class created and what are these groups called in the classification scheme?

2. Name the seven levels of the classification scheme from largest to smallest.

3. What happens to the description of the organisms as we move further down the classification scheme? (Hint: Does it become more specific or more general?)

4. Give the full classification scheme for the class's shoe organisms.

KINGDOM:

PHYLUM:

CLASS:

ORDER:

FAMILY:

GENUS:

SPECIES:

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Caminalcules Discovery

Classifying Imaginary Animals by Analysis of Shared Characteristics

OBJECTIVE
Students reinforce the concept of classification by grouping imaginary organisms with similar characteristics. Students will also assign scientific names to the organisms to indicate the degree of relatedness based on similarities and differences in their physical traits.

LEVEL
Middle Grades: Life Science

NATIONAL STANDARDS
UCP.1, UCP.2, UCP.4, UCP.5, A.1, A.2, C.3, C.5

TEKS
6.1(A), 6.2(B), 6.2(C), 6.2(D), 6.2(E), 6.3(C), 6.10(A), 6.10(C), 6.11(A)

7.1(A), 7.2(B), 7.2(C), 7.2(D), 7.2(E), 7.3(C), 7.10(B)

8.1(A), 8.2(B), 8.2(C), 8.2(D), 8.2(E), 8.3(C), 8.11(B)

IPC 2(C), 2(D)

CONNECTIONS TO AP
AP Biology:
III. Organisms and Populations: A. Diversity of Organisms 1. Evolutionary patterns 2. Survey of the diversity of life 3. Phylogenetic classification 4. Evolutionary relationships

III. Organisms and Populations: B. Structure and Function of Plants and Animals 2. Structural, physiological, and behavioral adaptations

TIME FRAME
90 minutes

MATERIALS
(For a class of 28 working individually)

28 photocopies of 29 imaginary organisms (Caminalcules)	glue sticks
scissors	colored pencils

TEACHER NOTES

The imaginary organisms presented here are called Caminalcules, named after evolutionary taxonomist, Joseph Camin, who created them. *Caminalcules Discovery* is a complex inquiry activity where students devise a system of classification for a group of imaginary organisms. The students divide the Caminalcules into groups of families, genera, and species and create scientific Latin-sounding names for each group. Because there are 29 different individual Caminalcules, there are many potential ways to organize them into different classification schemes. *Caminalcules Discovery* requires a good deal of higher order thinking and should follow an introductory classification activity. Introductory classification activities may be found in most textbook ancillaries or on the Internet.

As an introduction to this activity you may wish to walk the students through a simple classification scheme using their shoes as objects. Have all students remove their left shoes and place them on the floor in the middle of the room. Have the students look at the shoes in terms of characteristics. "What are some characteristics we see in all those shoes?" The characteristics observed could be: leather, shoelaces, Nikes, athletic, white, red, black, etc… Ask the question, "What is one way that we could divide the shoes into two large groups?" Students could suggest something like athletic shoes and non-athletic shoes. Have two or three students come up to the front and put all the athletic shoes in one pile and all the non-athletic into another pile. Suggest a Latin-sounding name for the athletic pile, perhaps "Athletica" or something similar and "Dressupica" for the non-athletic shoes. Then within the "Athletica" have students suggest another characteristic to further sub-divide the shoes, such as: has laces or not; ("Laceia" and "Velcroa"), leather or non-leather ("Leatherum" and "Nonleatherum", by brand name, or some other way that your students create. Within one of the subdivisions, such as "Laceia", have students suggest further subdivisions based on characteristics: "Whiteus" versus "Blackeus" and so on, again assigning Latin-sounding names to these sub-groupings. Then continue with the non-athletic and further subdivide into the smaller groups, to where you eventually have the smallest group of division.

Once the groups of shoes have been subdivided, ask students to describe characteristics of the groups of shoes and how those characteristics are different from other subgroups. If time permits, pile all the shoes back together in a pile, pick 2 or 3 different students, and have them come up with another classification scheme, this time using different characteristics to divide the groups of shoes. The idea can then be presented that all the students in the Caminalcules activity can come up with logical, yet different schemes of classification.

The method of subdividing the shoes by shared characteristics can be then expanded to include how all living species are classified and subdivided in biology, referred to as cladistics, which hypothesizes relationships among organisms.

The pictures of the Caminalcules are copyrighted by the journal *Systematic Biology* and Robert R. Sokal. They are used here with permission.

SAMPLE DATA

A sample of a student's work appears in Figure 1. The student work represents just one way of classifying the 29 Caminalcules. Perhaps you could show students this example on an overhead to give them a concrete idea of how to begin classifying the Caminalcules into different groups. This student has divided all her Caminalcules into 4 families (from top to bottom): Dotsidae, Blobidae, Potatodae, and Wingidae. Within the Dotsidae family, she has subdivided her Caminalcules into 2 genera, which contain 1 species each: *Wavidae feettogetherum* and *Bentidae feetapartum*. These names reflect the characteristics of the Caminalcules in those groups as well. Blobidae family is represented by 5 different species (also 5 genera): *Smallheadidae roundtailum*, *Longneckidae pointum*, and *Neckfoldidae antennum*, *Forktailidae armsuppum*, and *Mermaidtailidae bulging eyesum*. Again the names reflect the physical characteristics. (An alternative way of classifying these would be to put the *Smallheadidae roundtailum*, *Longneckidae pointum*, and *Neckfoldidae antennum* into one genus, all three being different species. The names could perhaps be *Roundplainbodium roundtailum, Roundplainbodium pointium, Roundplainbodium antennum* as these 3 groups have similar enough characteristics that they could be possibly be grouped together in one genus.) Her family division, Potatodae, has been divided into *Smalltailidae* and *Bigtailidae* genera, again, with each genera being a separate species. She has finally divided the last family, Wingidae, into 3 genera: *Normalidae*, *Longidae* and *Shortidae*. This is not the perfect student assignment but represents a very well thought-out classification scheme. All her genus and species names are underlined, her family names end in –idae. One criticism for this particular student's work is the use of -idae in her genera naming scheme, as opposed to –a, -us, or –um, as –idae is the Latin ending for family names. Included on the sample student example is the list of characteristics that describe each one of her species groups. Figure 2 summarizes the previous written explanation into an organizational flow chart.

Also included is her taxonomic tree, in the student sample, which was done correctly and awarded extra credit.

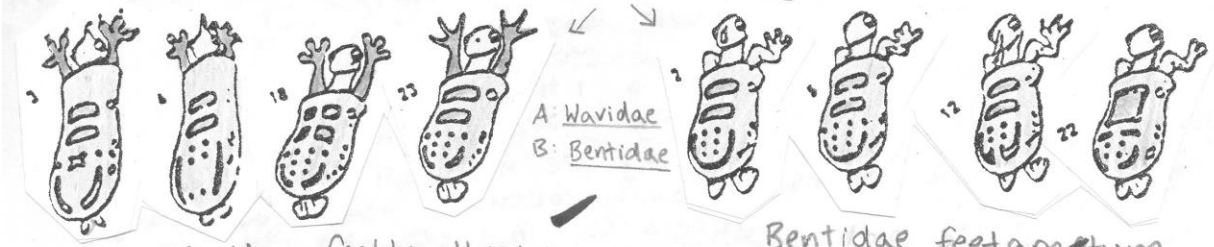
The obvious "gray area" in this activity is deciding where the variation ends and begins between different species and genera. As long as the student can explain and justify their scheme, then full credit should be awarded.

Figure 1:

CLASSIFYING ANIMACULES

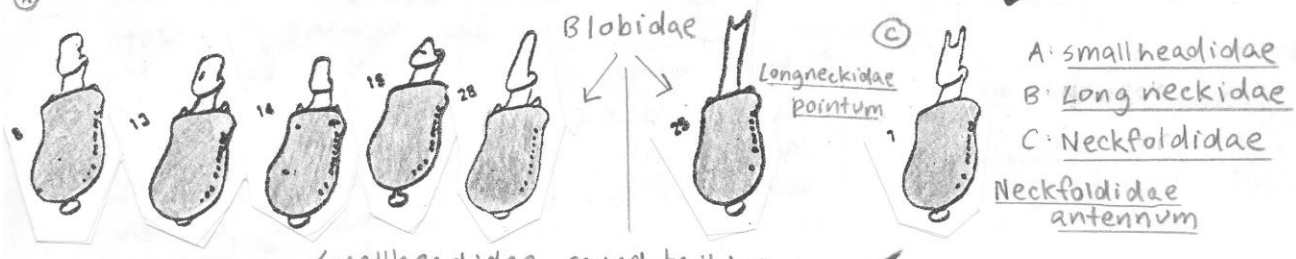
Dotsidae

A: Wavidae
B: Bentidae



Waridae feettogetherum

Bentidae feetapartum



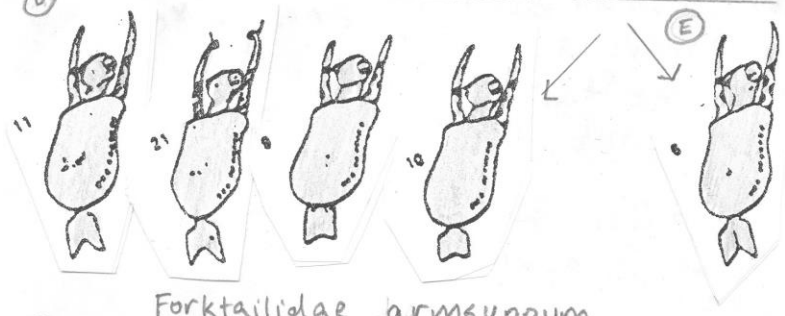
Blobidae

Longneckidae pointum

A: smallheadidae
B: Long neckidae
C: Neckfoldidae

Neckfoldidae antennum

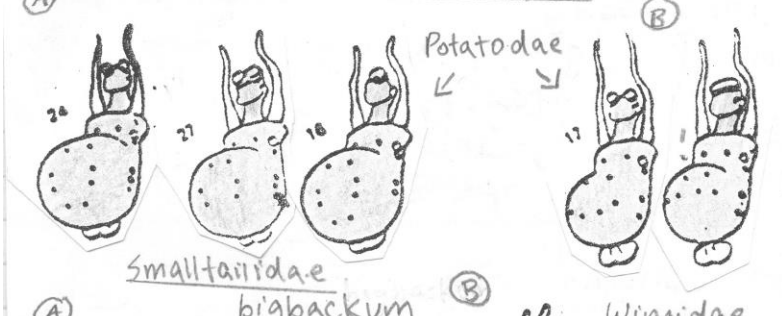
Smallheadidae roundtailum



A: Forktailidae
B: Mermaidtailidae

Mermaidtailidae bulgingeyesum

Forktailidae armsuppum

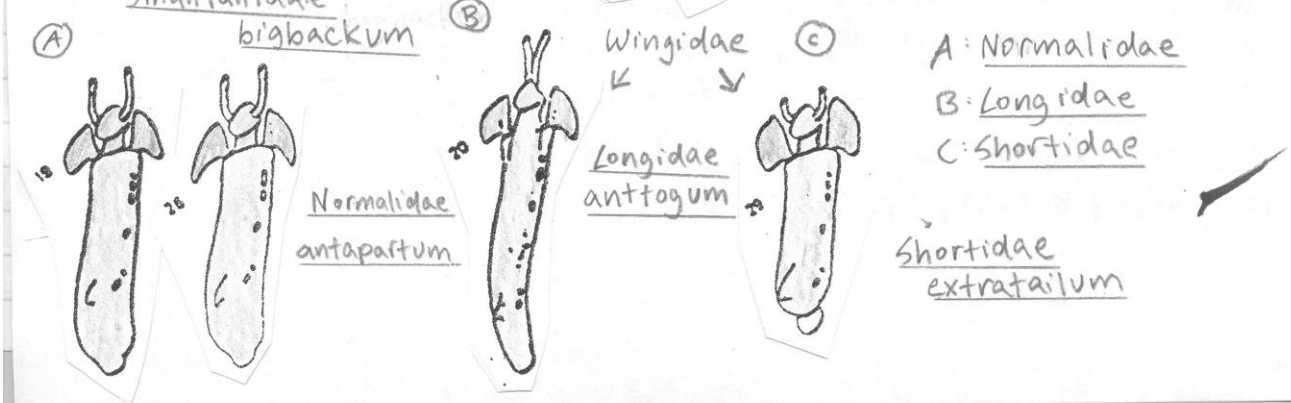


Potatodae

A: Smalltailidae
B: Bigtailidae

Bigtailidae smallbackum

Smalltailidae bigbackum



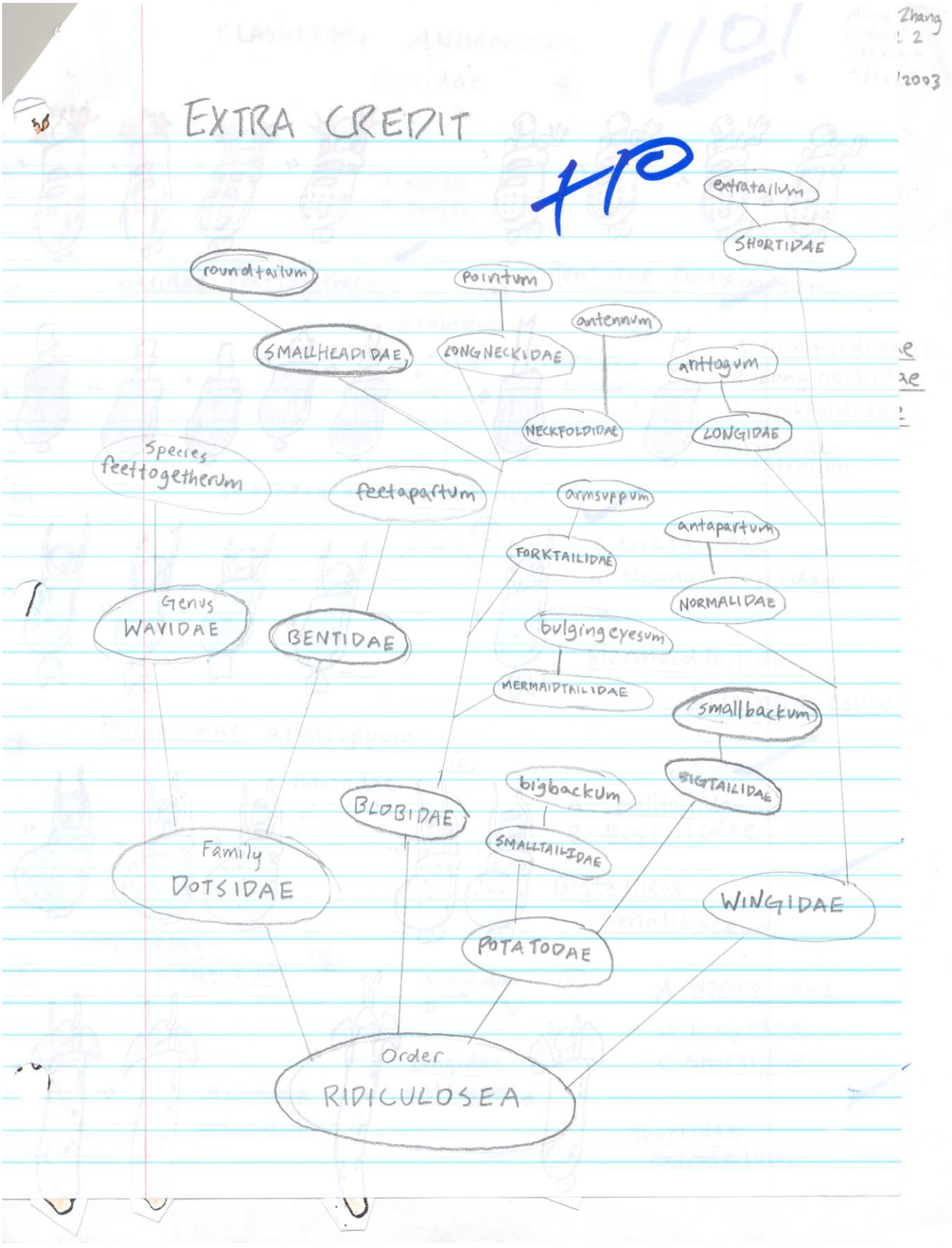
Wingidae

Normalidae antapartum

Longidae anttogum

A: Normalidae
B: Longidae
C: Shortidae

Shortidae extratailum


EXTRA CREDIT
+10
extratailum
SHORTIDAE
roundtailum
Pointum
antennum
SMALLHEADIDAE
LONGNECKIDAE
antlogum
NECKFOLDIDAE
LONGIDAE
Species
feettogetherum
feetapartum
armsuppum
antapartum
FORKTAILIDAE
NORMALIDAE
Genus
WAVIDAE
BENTIDAE
bulging eyesum
MERMAIDTAILIDAE
smallbackum
bigbackum
BLOBIDAE
SMALLTAILIDAE
Family
DOTSIDAE
WINGIDAE
POTATODAE
Order
RIDICULOSEA

Possible answers to the conclusion questions

1. What difficulties did you experience in developing your classification system? Describe at least two.

- Probably the greatest difficulty is deciding how to differentiate the variation between a genus and a species. The variation among a group of individuals could represent several different species within the same genus, it could represent the variation that is naturally present within one species, or it could possibly be interpreted as more than one genera.

- Another difficulty that students find is naming the groups with Latin-sounding names.

2. Explain why all Caminalcules are not placed in the same family.

- The number of differences in the characteristics between all the Caminalcules is too great to represent just one biological family.

3. Explain how this activity illustrates the concept: "Classification is the grouping of objects based on similarities and differences."

- The students organize the groups of Caminalcules on the basis of shared characteristics (and differences). The characteristics that are present in an individual Caminalcule determine how closely related it is to another individual.

4. What is one inherent problem with a classification scheme based only on different physical characteristics?

- Different scientists could see different ways to organize and classify the same group of organisms.

5. The technique of DNA sequencing has enabled scientists to create large data bases of genomic sequences for different organisms. How do you think the ability to sequence an organism's entire genome could help to more accurately classify groups of organisms?

- Genome sequencing of biological groups of organisms has revolutionized the field of classification. Now entire DNA sequences can be analyzed by computers to determine, mathematically, which organisms are more closely related, by comparing the number of shared nucleotide bases. Using DNA sequence comparisons between different species can tell a much more accurate story of relatedness and evolutionary history than just observing external characteristics.

Caminalcules Discovery

Classifying Imaginary Animals by Analysis of Shared Characteristics

PURPOSE

In this activity you will reinforce the concept of classification by grouping imaginary organisms with similar characteristics.

MATERIALS

28 photocopies of 29 imaginary organisms	glue sticks
scissors	colored pencils

Safety Alert
1. Always use care when handling scissors.

The imaginary organisms presented here are called Caminalcules, named after evolutionary taxonomist, Joseph Camin, who created them. *Caminalcules Discovery* is a complex inquiry activity where you devise a system of classification for a group of imaginary organisms. You will divide the Caminalcules into groups of families, genera, and species and create scientific Latin-sounding names for each group.

PROCEDURE

1. Study the set of imaginary organisms on the “Caminicules” sheet and carefully cut out each individual organism with your scissors.

2. In this activity, you are the scientist that discovered a new group of animals, which you have named "Caminalcules." You have researched their physiology and behavior very thoroughly and have identified them as members of the following groups: Kingdom Animalia, Phylum Mollusca, Class Imaginata, Order Ridiculosea. It will be your responsibility to classify and create names for the family, genus and species levels for these organisms.

3. Organize the Caminalcules into families as you see fit. Within each family further subdivide the group into genus and species on the basis of similar characteristics. Even

though no two Caminacules are identical, remember there is wide variation within the human species as well.

4. Once you have sorted the organisms into their respective species, neatly glue each group of organisms onto your student answer page. Leave plenty of room to write in family and scientific names above each group and three shared traits below each group. To best organize your groups place different species of the same genus next to each other on your page.

5. You will need to invent family names for each family you created (Note: Family names always end in: "idae.") Write the family name above each family.

6. For each of the species groups create a "scientific name" in the form of *Homo sapiens* and write it below the family name on your paper. You should create six to ten scientific names, depending upon how many groups you have in your classification system. All individuals in the same species should have the same scientific name. In other words, even though there are some minor individual differences, all organisms in the same group should be enough alike to be placed in the same "species" When naming the species, try to make them "sound" Latin; e.g., *Burritos longus*. Remember, the genus name is capitalized, the species name is not, and the scientific name (genus + species) is underlined or italicized. Also, some Caminacule species may be closely related (very similar) and may be placed in the same genus.

7. Below each species grouping, list at least three characteristics that all organisms in the species have in common.

8. For extra credit, create an evolutionary tree with lines drawn between your species to show how your different species are related to each other. Your teacher will show you an example of an evolutionary tree that a student has drawn previously.

Name _____

Period _____

Caminalcules Discovery
Classifying Imaginary Animals by Analysis of Shared Characteristics

ANIMICULE CLASSIFICATION

Once you have organized and classified your Caminalcules into groups, use the glue stick to adhere the individuals to this page and the next. Be sure to glue the Caminalcules that share the most characteristics more closely together.

CONCLUSION QUESTIONS

1. What difficulties did you experience in developing your classification system? Describe at least two.

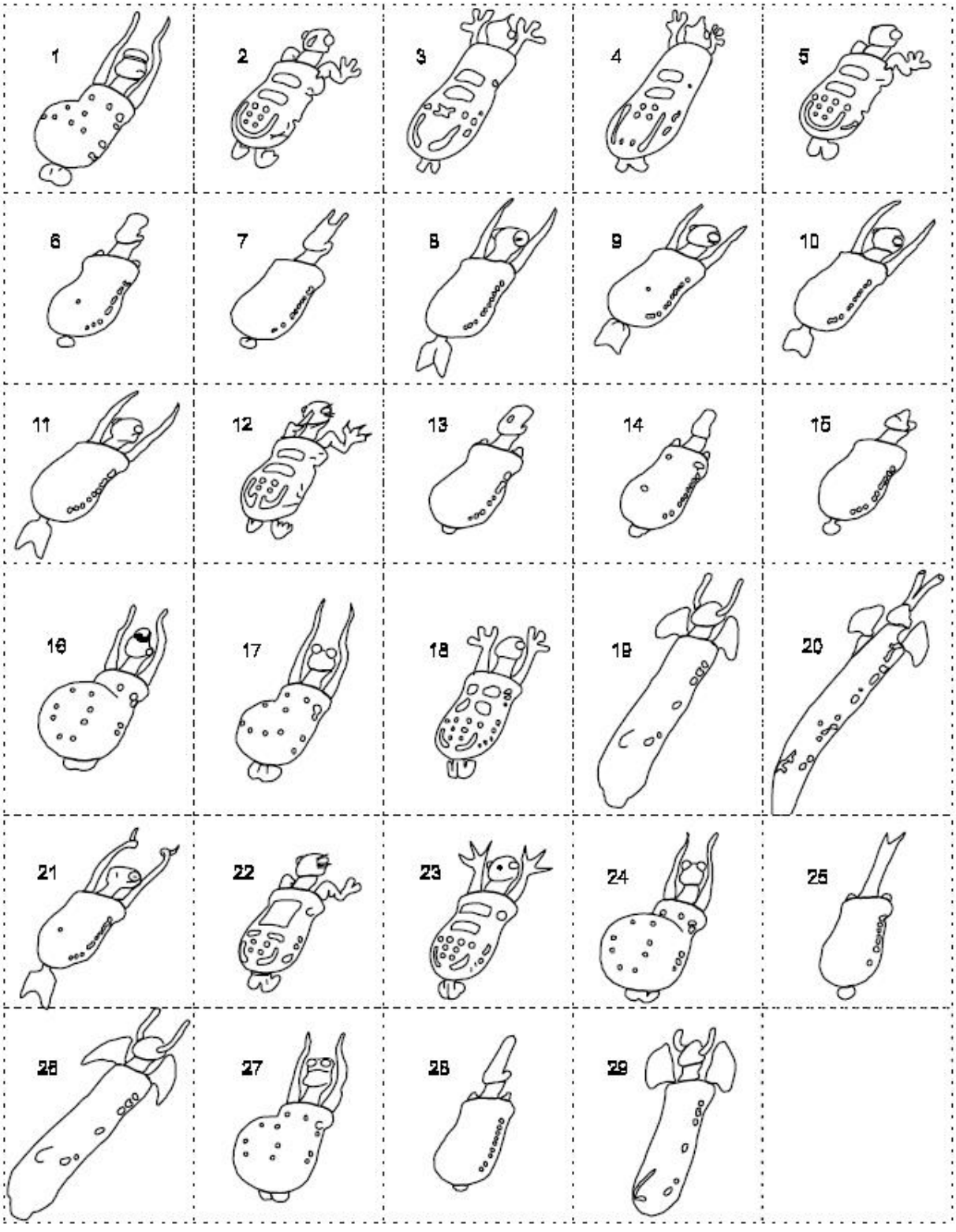
2. Explain why all Caminalcules are not placed in the same family.

3. Explain how this activity illustrates the concept: "Classification is the grouping of objects based on similarities and differences."

4. What is one inherent problem with a classification scheme based only on different physical characteristics?

5. The technique of DNA sequencing has enabled scientists to create large data bases of genome sequences for different organisms. How do you think the ability to sequence an organism's entire genome could help to more accurately classify groups of organisms?

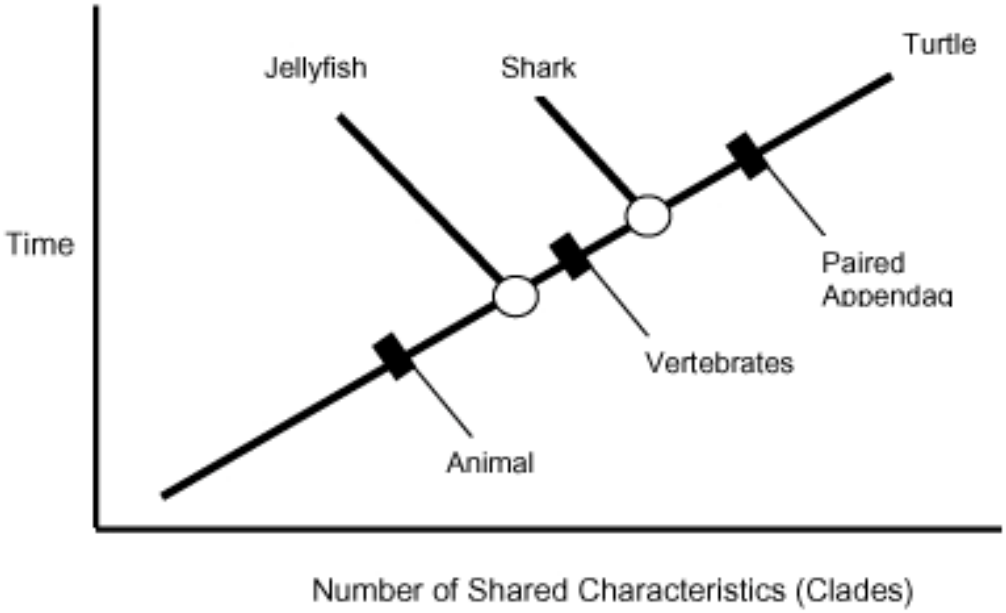
CAMINALCULES



How to Make a Cladogram

In the past, there have been various ways to classify organisms so that we are able to understand the diversity of organisms in this world, and how they relate to each other. Cladistics is a scheme that researchers have developed using physical characteristics to discover how groups of organisms are related to each other (phylogeny). Cladistics uses a diagram rather than groups to show the organism's phylogeny. These diagrams are called cladograms or phylogenetic trees.

Cladograms are used to organize different clades. A clade is one phlyogenetically related group. Clades are groups that have anatomical structures in common such as the jellyfish and a turtle. Both of these organisms can be organized into a clade labeled "Animals". Within the Animal clade, they can further be divided based on other characteristics. For example, the turtle would be classified in the vertebrate clade, while the jellyfish is in the invertebrate clade. When using cladograms, the more clades the organisms have in common, the closer they are to a common ancestor, and the two organisms can be found in closer proximity to one another in the cladogram. Here is an example of a cladogram:



This is a simple cladogram showing three organisms and how they relate to each other. Clades are represented by the black boxes. Clades are placed in the cladogram to divide the organisms in groups based on shared characteristics. For example, all organisms (Jellyfish, Shark, and Turtle) above the black box indicating "Animal" fall into that classification category. All organisms above the "Vertebrates" clade (Shark and Turtle) share the common characteristic of having backbones; those below the "Vertebrates" clade (Jellyfish) do not have backbones. Finally, all organisms above the

clade for “Paired Appendages” (Turtles) have that characteristic, while those organisms below (Shark and Jellyfish) that clade does not. Notice that the organisms are labeled at the top of each stem. These labels indicate the name of the organisms today. These stems are then connected together to the original lineage, indicated by a circle. These circles represent the organism’s common ancestors. For example, the shark and the turtle have a closer common ancestor than the turtle and the jellyfish because the shark and turtle have more clades in common. The shark and turtle share two clades while the turtle and jellyfish only share one; therefore, the turtle’s and jellyfish’s common ancestor is not very recent. The easiest way to develop a cladogram is by drawing a data table. An example is listed below:

Data Table				
Sets	Traits (Clades)	Jelly fish	Turtle	Shark
Set 1	Animal	X	X	X
Set 2	Backbone		X	X
Set 3	Paired Appendages		X	
	Total of X’s	1	3	2

By placing an X in the table where the clades match with the organism, we can see where the organisms would be located on the cladogram. For example, since the jellyfish only has one X, we know that it should be the first organism listed on the cladogram. Additionally, since the turtle has three X’s, it should be placed last. The clades then should separate the organisms. The label your cladogram correctly and indicate common ancestors where lines meet. Sometimes cladograms can be tricky, but this system is just one way people are able to visualize how organisms are related to each other.

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How to Make a Cladogram

Subject: AP Biology

Grades: 11th – 12th

Rational or Purpose: By introducing new ways of classifying organisms, students will get the chance to learn a new scheme of classification called Cladistics. The students will be able to see how organisms are related to each other and develop their own cladograms.

Materials: (For each student)

- Handout "How to Make a Cladogram"
- Cladogram Worksheet (For Teacher)
- Solutions for Cladogram Worksheet and Example

Lesson Duration: 60 minutes

Source:
http://www.indiana.edu/~ensiweb/lessons/mclad.html

TEKS Objectives:
111.43 Biology (c) (7a) (8a) (8b)

Background:
There are many systems today that classify organisms. One way is the Linnaean classification scheme with hierarchical levels (Kingdom, Phylum, Class, Order, Family, Genus, and Species). Another organization system is Cladistics. Organization in this system is based on similar physical characteristics. Cladistics uses a diagram called a cladogram to show how the organisms relate to each other, as well as ancestral lineages. More information is shown in the handout "How to Make a Cladogram."

Activity:
Students will be able to identify what a Cladogram is and how it is used. They will explore different methods of classification and compare similarities and differences. They will use this understanding to develop a cladogram of groups of animals. Based on this knowledge, they will understand the significance of using Cladistics as well as other forms of Classification.

Procedure:

1. Ask the students how they classify different organisms. Also remind them about the Linnaean Hierarchical Levels if they have forgotten.

2. Today the students will learn a new way of classifying organisms. Pass out the handout to each student and ask them to read quietly. Wait for all the students to finish reading.

3. As a class, come together and discuss the use of Cladograms. Set up an example with 5 species such as a Brittle Star, a Sea Bass, a Salamander, a Horse, and a Human. Ask the students which clades to use.

4. Ask students to draw a data table on the board and fill it out. If the students are unsure, allow them to ask the class to be sure their clade is correct.

5. Discuss why each cladogram is drawn, other factors that play into the classification of these animals, and how they relate to each other.

6. At the end of class, give the students the cladogram worksheet to finish. Ask them to draw the cladogram on the back of the worksheet. This can be used as a quiz. Ask them to label one clade, one organism, and one common ancestor.

When the students finish the worksheet, develop a more advanced cladogram with forks that branch off the original lineage and ask them to explain what they think happens at each new branch.

Name: _____ Class Section: _____

Date: _____

Cladogram Worksheet

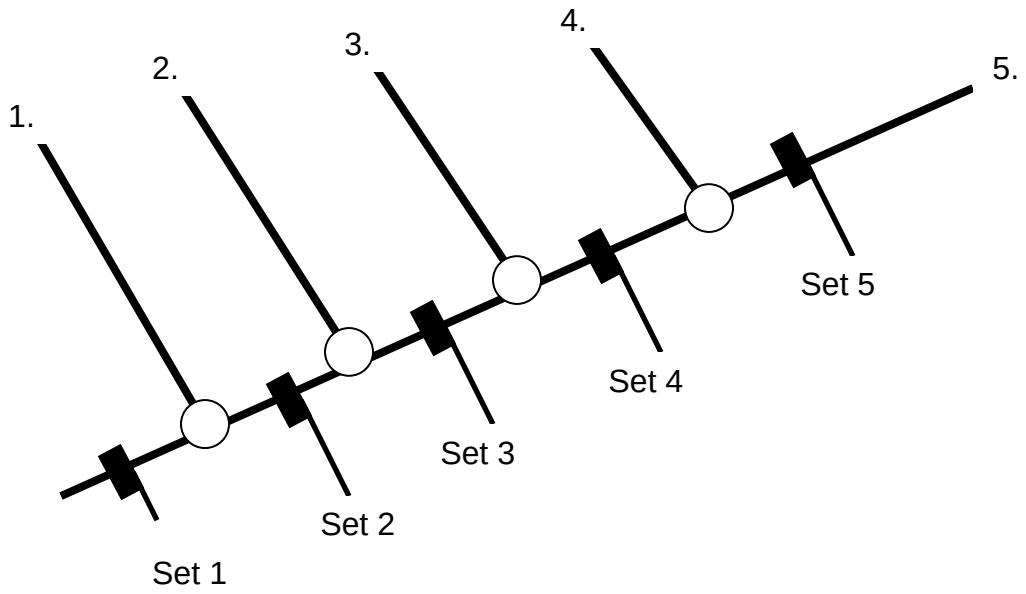
Step 1: DATA TABLE

SETS	TRAITS	Animals: Kangaroo	Lamprey	Rhesus Monkey	Bullfrog	Human	Snapping Turtle	Tuna
SET 1	Dorsal Nerve Cord Notochord							
SET 2	Paired Appendages Vertebral column							
SET 3	Paired legs							
SET 4	Amnion (Amniotic sac)							
SET 5	Mammary Glands							
SET 6	Placenta							
SET 7	Canine teeth short Foramen magnum fwd							
	TOTALS of Xs------->							

Solutions for Worksheet and Example

Example:

Set	Clade	1. Brittle Star	2. Sea Bass	3. Salamander	4. Horse	5. Human
Set 1	Notochord	X	X	X	X	X
Set 2	Vertebrate		X	X	X	X
Set 3	Paired appendages			X	X	X
Set 4	Mammary Glands				X	X
Set 5	Canine teeth short					X
	Total of X's	1	2	3	4	5



Worksheet (Data Table Only):

Set	Trait	Kangaroo	Lamprey	Monkey	Bullfrog	Human	Turtle	Tuna
Set 1	Notochord	X	X	X	X	X	X	X
Set 2	Vertebral column	X		X	X	X	X	X
Set 3	Paired Legs	X		X	X	X	X	
Set 4	Amnion	X		X		X	X	
Set 5	Mammary Glands	X		X		X		
Set 6	Placenta			X		X		
Set 7	Canine teeth Short					X		
	Total of X's	5	1	6	3	7	4	2