GEO 302D: Age of Dinosaurs
Lab5: Systematics Part 2

Last week we discussed the basic principles of systematics. This week we will introduce methods and tools for creating cladograms using data matrices.

Why do we make cladograms?

The primary information that cladograms provide is a hypothesis of evolutionary relationships. From that hypothesis we can examine additional biological patterns, including geographic distribution, behaviors, stratigraphic occurrence, and functional morphology. Cladograms can also provide information on fossil taxa. Once the evolutionary relationships of your known taxa are established, you can make predictions about what other fossil taxa may be missing and what characters they should have.

Making a data matrix

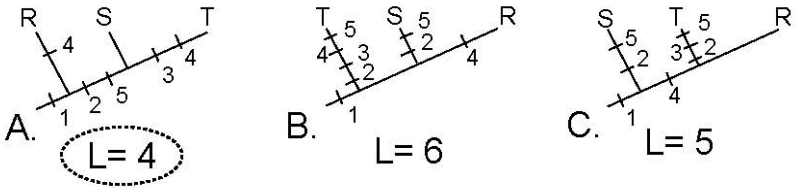
How does a cladist make a cladogram? First you pick your taxa of interest (called the **ingroup**). You also pick an **outgroup**. The outgroup is a taxon that you feel represents the likely primitive condition for all of your taxa of interest. Then you pick characters that fulfill several criteria. The characters should be: 1) heritable; 2) independent of one another; 3) unambiguous; and 4) repeatable by other scientists. Your outgroup should have the effect of polarizing your characters in the matrix, or in other words, it lets you know which characters are actually primitive and which are actually derived.

Using your taxa and characters you can create a **data matrix**. Taxa go on one axis, and characters go on the other. Below is the matrix used to create the cladogram on page 4. On this particular data matrix, "0" stands for "character absent", and "1" stands for "character present". Some cladists use "0" to mean a character is primitive, and "1" to mean a character is derived with respect to the presence or absence of the character in the outgroup. However, researchers can define character states as they choose. You then examine the taxa and score the matrix based upon your observations. From this you can construct the cladogram by working your way up the tree by building parsimonious relationships of taxa.

	worm	shark	mammal	snake	lizard	croc	bird
1	0	1	1	1	1	1	1
2	0	0	1	0	1	1	1
3	0	0	0	1	1	1	1
4	0	0	0	1	1	0	0
5	0	0	1	0	0	0	0
6	0	1	0	0	0	0	0
7	0	0	0	0	0	1	1
8	0	0	0	0	0	0	1

Sometimes an analysis yields more than one possible set of relationships. In the example below there are three terminal taxa (R, S, and T), and five characters (1-5). There are only three possible combinations of relationships, and these are shown. The characters are mapped on the cladograms. Cladists use the **Principle of Parsimony** to decide which tree is most likely correct. Parsimony assumes that the least complicated path is more likely to be the correct one. Cladists determine which tree is least complicated by counting the number of character state changes or steps (the number of times characters must be added or removed from a tree) in each. The tree with the fewest changes is considered the most parsimonious, and it is chosen as the correct tree. **Remember, only synapomorphies define monophyletic groups and thus are the only characters used to determine relationships. Plesiomorphies and autapomorphies are not counted.**

	R	S	T
1	1	1	1
2	0	1	1
3	0	0	1
4	1	0	1
5	0	1	1



!! Do not count plesiomorphies nor autapomorphies !!

Exercises

The Great Clade Race
Part I

1. Working in groups of two or three, cut out the eight index cards on the last page of this exercise.

2. Organize these cards into distinct groups using any criteria you wish. You can make as few or as many groups as you want, but each card must be put into exactly one group. Be able to explain your organizational scheme to the rest of the class.

What criteria did you use to organize the cards?

Part II

3. Imagine a race through the woods. All participants in the race start at the same starting line at one end of the woods. As the race continues, the path through the woods repeatedly splits, and runners are free to take either fork. Each series of forks leads to a separate finish line at the other end of the forest. As the runners make their way through the woods, each carries a card that he/she must have stamped at check-in stations along the way. The cards you have in front of you are the same ones that were carried by the eight runners in this imaginary race.

Work with your groups to draw a map of the racecourse, complete with check-in stations. While doing so, you must follow these rules:

A. All runners must complete the race. They cannot stop part of the way down a path.

B. When the path branches, it only branches into two new paths, never three or more.

C. Once two paths have branched off from one another, they can never reunite.

D. Check-in stations are located along straightaways between the branching points.

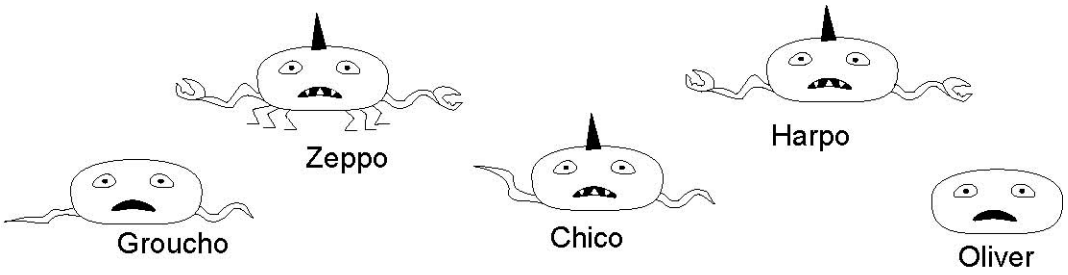
E. Although all the runners begin racing at a common starting point, they can exit the woods and finish the race at any point along the finish line.

Draw the path each runner took to complete the race. Include check-in stations, and draw the cards belonging to each runner at the point where they exited the woods.

FINISH

START

You are chief astrozoologist on a Mars mission. After prospecting for several days, you assemble a collection of life forms. It is now your job to determine the evolutionary relationships between these organisms. Use the list of characters given with the matrix below. You decide Oliver should be your outgroup, because it appears to be the least specialized, and therefore most primitive. Fill in the matrix. **Use "0" to represent the primitive state, as possessed by Oliver. "1" indicates a derived state**.



	Oliver	Groucho	Zeppo	Chico	Harpo
1.eyes					
2.mouth					
3.tentacles					
4.horn					
5.pincers					
6.legs					
7.teeth					

7. Construct a cladogram based upon your matrix. Map all your characters.

8. How many steps are there on your tree? Should you count steps 1 and 2?