Dinosaur Problem: Hints and an Example Tree

If you are having difficulty with the dinosaur practice problem, read through these pages, especially the example tree we filled out.

Step #5: Determine which character states are ancestral and which are derived using outgroup data.

	Ancestral	Derived
1. armored plates:	no	yes
2. predentary		
3. pubis ext. post.		
4. rostral		
5. skull shelf		
6. symphysis		
7. enamel		

To fill out the table in Step #5, look at the data in Step #4: if the character state for *Allosaurus*, the outgroup, is "no," then that state is ancestral (and "yes" is derived). Remember that this is by definition: we chose *Allosaurus* as the outgroup because we know that it has relatively ancestral character states in comparison with these other dinosaurs. Basically, we are using *Allosaurus* as a tool in this step.

Step #6: Fill out character matrix.

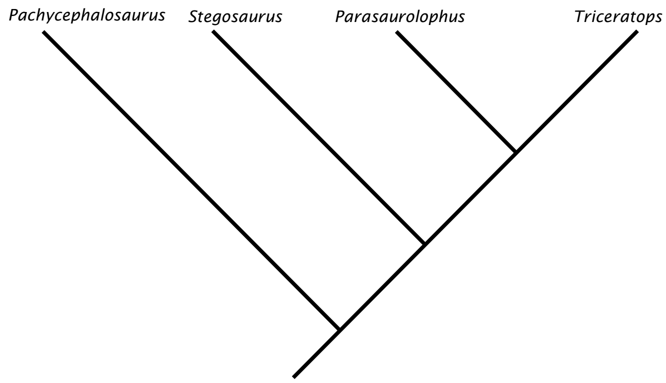
Character:	1	2	3	4	5	6	7
Pachycep.	A						
Parasaur.	A						
Stegosaur.	D						
Tricerat.	A						

A=ancestral, D=derived

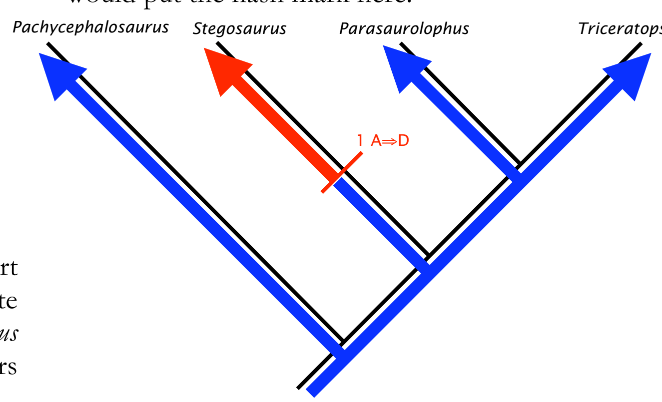
If your answers in Step #5 are correct, this chart should be fairly straightforward to complete. Note that the genera are now listed in a column, *Allosaurus* is missing, and we begin referring to the characters by number for shorthand.

Step #7: Use character matrix to analyze possible trees.

Before going on to Step #7, or if you are having trouble with Step #7, we suggest you check your answers to Steps #5 and #6 below. Once you are sure your answers for #5 & #6 are correct, you'll need to be very methodical about placing hash marks on your trees. Remember that in Step #7 of the dinosaur problem, we are only asking you to evaluate 5 of the 15 possible trees which describe the relationship between these dinosaurs. This example tree is merely a sixth tree from the 15 possible:



To begin placing hash marks on the tree, start with one character and look at the pattern in Step #6. For example, character 1 is ancestral for Pachycephalosaurus, Parasaurolophus, and Triceratops, but derived for Stegosaurus. This means you will need to place a hash mark such that only Stegosaurus is derived. The hash mark represents an evolutionary change from the ancestral to the derived state (i.e. this is where armored plates arose, for character 1). On the example tree, you would put the hash mark here:

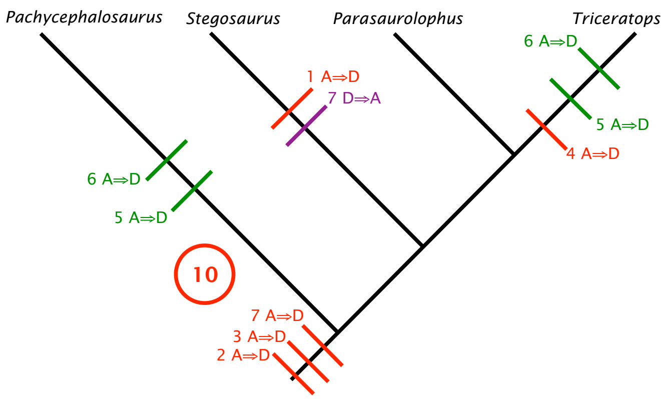


We've added blue arrows to represent the ancestral state, and after the red hash mark, the red arrow represents the derived state.

It does not matter where along this branch you place the hash mark. You should realize that placing the mark on any other branch will increase the number of changes required (it will require reversals). Always choose placement such that it invokes the fewest changes on the tree. In some cases, there may be multiple ways to handle hash mark placement with the same number of changes: choose your favorite.

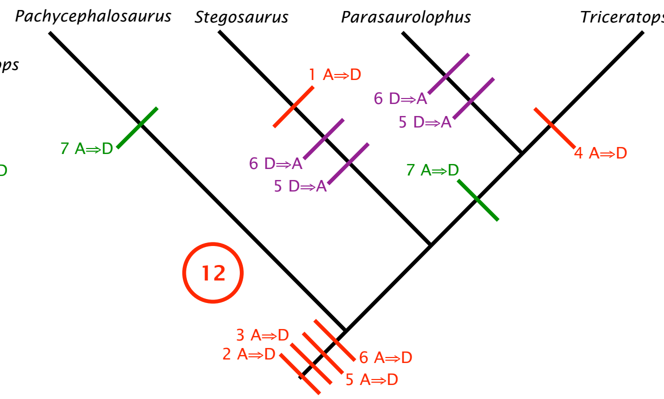
Continue looking at each character individually and placing hash marks on the tree; repeat this process for each of your trees. You may find that some trees require you to draw multiple "A⇒D" hash marks (these represent convergence), and at other times you will need to make a "D⇒A" change (this represents a reversal).

We completed the example tree so you can see what it looks like:



Red represents a single change from ancestral to derived.
Purple represents a reversal from derived to ancestral.
Green represents a convergence: multiple changes from ancestral to derived.
The total number of changes required in the tree is in circled, in red.

You do not need to color code your answers; we just wanted to emphasize what is occurring in the tree. Note that this is drawn with a reversal in character 7 and two converging characters: 5 and 6. The reversal could be diagrammed equally effectively as a convergence, with no effect on the total number of changes required. The convergences could be drawn as reversals, but this adds changes to the tree. Below is the same tree with those adjustments:



Good luck with the rest of the practice problem!

Dinosaur Practice Problem: Key for Steps 5 and 6

Step #5: Determine which character states are ancestral and which are derived using outgroup data.

	Ancestral	Derived
1. armored plates:	no	yes
2. predentary	no	yes
3. pubis ext. post.	no	yes
4. rostral	no	yes
5. skull shelf	no	yes
6. symphysis	yes	no
7. enamel	no	yes

Step #6: Fill out character matrix.

Character:	1	2	3	4	5	6	7
Pachycep.	A	D	D	A	D	D	D
Parasaur.	A	D	D	A	A	A	D
Stegosaur.	D	D	D	A	A	A	A
Tricerat.	A	D	D	D	D	D	D

A=ancestral, D=derived

Dinosaur Practice Problem: Key for Steps 7 and 8

Step #7: Use character matrix to analyze possible trees.

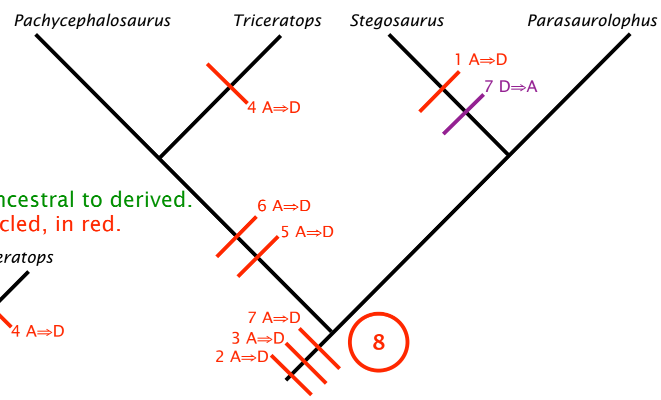
In this example, rather than making you analyze all 15 possible trees, we have drawn a subset of 5 trees to analyze. You should get the idea from these, but you can always set up the other 10 trees on your own if you like.

For each tree, you will need to determine where state changes must have occurred. In some cases, you will need to decide whether a convergence or a reversal is necessary; choose the option which puts fewer changes on the tree. (If the number of changes is identical, it doesn't matter which you choose.)

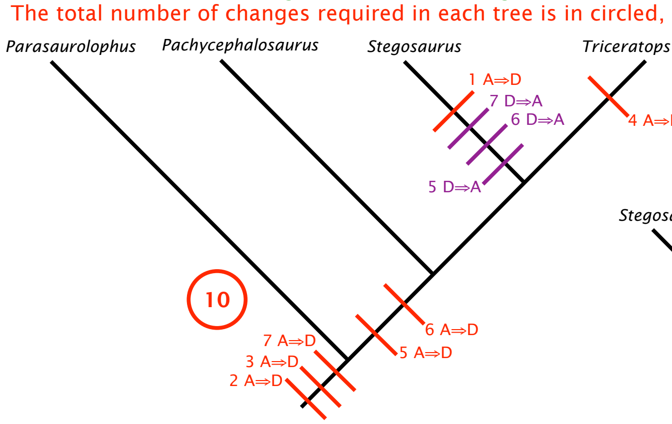
Review the trees in Figure 2 if you have questions.

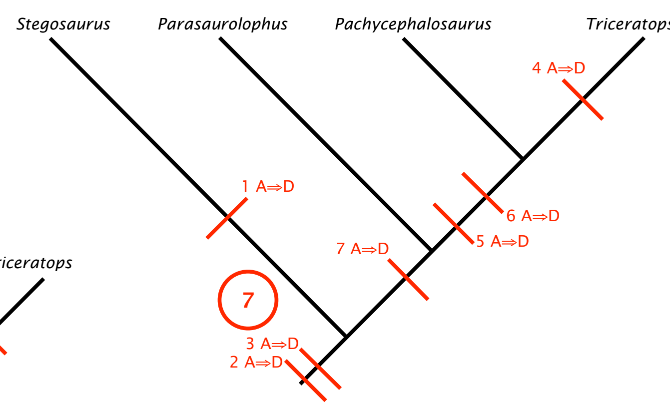
Step #8: Determine which tree is most parsimonious.

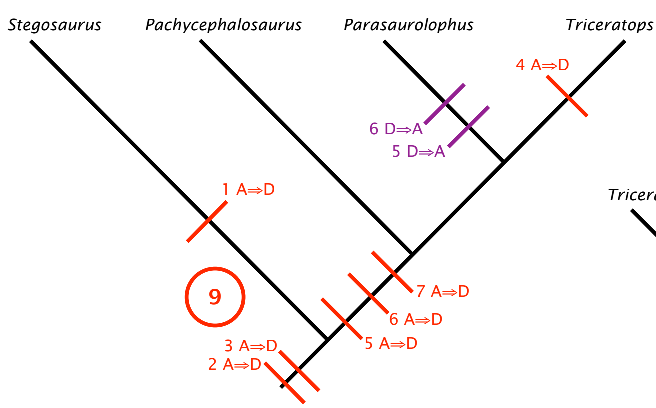
After you have counted up the changes required for each tree, find the tree with the smallest number. Congratulations! If you haven't already, step back and look at how much each character contributed to your selection of that tree. Were there characters that had the same effect on all the trees? What are the implications of characters like those? Which characters were the most important in determining your phylogeny?

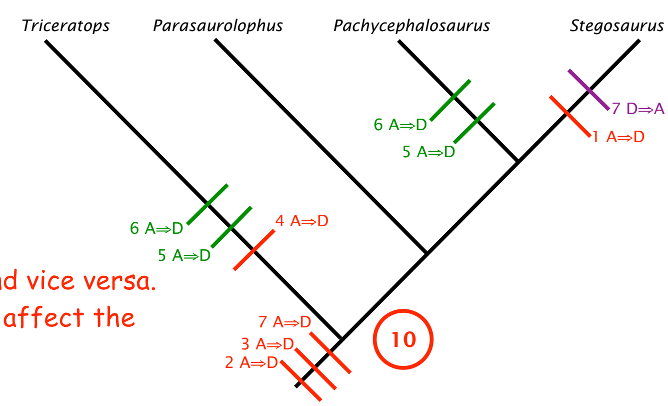


Red represents a single change from ancestral to derived.
Purple represents a reversal from derived to ancestral.
Green represents a convergence: multiple changes from ancestral to derived.
The total number of changes required in each tree is in circled, in red.



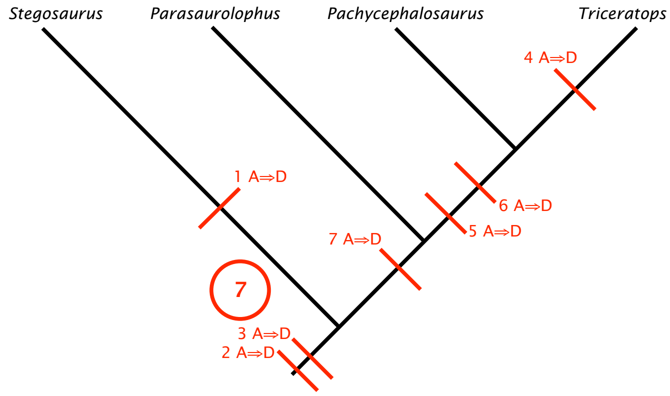






You could redraw the reversals as convergence, and vice versa.
You might try this for practice; it may or may not affect the total number of changes in the tree.

The most parsimonious tree is the one shown below. It requires only 7 changes, and no reversals or convergence.



You should quickly notice that including characters 2 and 3 on your trees did not affect the phylogeny. If you look back at the characer matrix in Step 6, you'll see that these characters are derived for all four organisms: this is why they are not useful.

Characters 1 and 4 were also not helpful in creating a phylogeny; since only one organism has the derived character state for each of these characters, it does not help us group organisms with shared derived characters. If you look over your trees, you'll see that characters 1 and 4 are always out on the ends of branches, and so do not affect the overall tree.

Characters 5 and 6 have the same pattern of derived and ancestral states across these organisms. This means they do not provide us with different information from each other, but they do effectively support the same tree. Overall, characters 5, 6, and 7 were the only characters which helped us distinguish between the different possible trees. Here's a revised version of this tree with only the distinguishing changes marked: