

Modeling Evolutionary Relationships with Trees

Introduction

In this lesson, students will examine a beautiful tree of life poster by artist Ray Troll and use it as a launchpad to explore evolutionary, or phylogenetic trees. Students will take a pre-assessment to address misconceptions about phylogenetic trees before completing a modeling activity to give them a better understanding of how trees are used to model evolutionary relationships.

Upon completion of the activity, the pre-test is revisited and students have an opportunity to correct their thinking and demonstrate their newly built knowledge.

Related Resource

Tree of Life poster

Subject:

Modeling evolutionary relationships with trees

Grade Level: 7–12

Time

100–120 minutes (2 class periods)

Group size:

Individuals or small groups

Next Generation Science Standards	HS-LS4-1	Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. [Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]
	MS-LS4-2.	Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships. [Clarification Statement: Emphasis is on explanations of the evolu- tionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.]

Assessments

- Worksheets
- Model
- Class discussion

Learning Objectives

Students will construct and interpret phylogenetic trees and explain how trees are used to model evolutionary relationships. Students will also explore misconceptions related to phylogenetic tree models and build their own 3-dimensional model using pipe cleaners.

Materials and Preparation

- "Preconceptions about Evolutionary Trees" worksheet
- "A Pipe-cleaner Model of Animal Evolution" worksheet
- Pipe cleaners, at least six different colors per student (suggested: blue, red, orange, yellow, purple, and black)
- Pens, markers, or pencils in these same colors
- Copies of Ray Troll's Tree of Life

Resources and Sources

The University of California Museum of Paleontology has a wonderful resource on its Understanding Evolution webpage (evolution.berkeley.edu) called "The Tree Room." Here, you will find more information on misconceptions, tips for tree-reading, activities, and tips for teaching tree-thinking.

Many of the trees included in this lesson were adapted from their materials. The pipe cleaner modeling activity is based on an article originally appearing in The American Biology Teacher from April 2010.

Teacher's Background Material

Introduction:

Evolutionary trees are common sights in textbooks and museums. They come in all sorts of varieties: curved lines or straight, branches coming off at diagonals or right angles, some—like the one explored in this lesson—are drawn to look like a real tree. Charles Darwin famously drew a tree in his 1837 notebook with the words "I think" at the top.

Prior to Darwin, relationships among different forms of life were commonly drawn in a ladderlike formation. The Scalae Naturae, or ladder of life, dates back to Aristotle and originally modeled the entire universe: rocks and minerals on the lowest rungs, then plants, then animals, then man. The only beings sitting on higher rungs than man were angels and God itself.



Darwin's tree, drawn in his 1837 notebook. Source: Wikimedia Commons

After Darwin naturalists such as Ernst Haeckel adapted the Scalae Naturae to generate a slightly more nuanced model of the natural world. As you can see, though drawn as a tree with some branching, the central ladderlike ascension to man ("Menchen" in Haeckel's native German) is still very much in place. This view of evolution as being a linear, progressive march toward perfection is among the most common and persistent misconceptions about evolution today.



Haeckel's "Pedigree of Man" from an 1874 essay of the same name. Source: Wikimedia Commons

Evolution is of course not linear or progressive. A flowering plant is not somehow better or more evolved than a moss. A reptile is not superior to a fish. There is no universal yardstick by which we measure how "good" or "advanced" a species or group of species is. Yes, some species evolved later than others, but that does not make them any more evolved or well-adapted.

The core concept of evolution is that the lineage of any two species can be traced back to a point of common ancestry. Every species alive today is equally evolved—their lineages can all be traced back to the same point in time, some three plus billion years ago when life began on Earth.

Teacher's Introduction to Misconceptions

Evolutionary trees model the common ancestry of species or groups. By cultivating robust tree-thinking, we can address and overturn many common misconceptions about evolution. Described below are a few of the many persistent misconceptions related to evolutionary trees. Exploring and debunking these misconceptions will be the focus of the lesson.

Tree Misconception 1:A species' or group's position on the tree is a measure of how evolved, or advanced it is.

In particular, there is a tendency to think that species or groups ("taxa") at the ends of branches up and to the right (on a vertically oriented tree) are the most evolved/advanced. This misconception is intuitively satisfying because we read from left to right, and because we tend to think that "up" is better than "down." The misconception is reinforced by the tendency to organize trees in such a way that they branch from left to right in the order in which the species/groups evolved, such as the tree below.



This way of drawing trees may give the impression that there is one main evolutionary path, or lineage, leading up to, in this case, mammals and relatives, and everything else reads like a secondary or lesser route. While a tree may be mapping out the evolution of a particular trait, it is important to remember that no one trait is a universal measure of how evolved or advanced an organism is.

Perhaps the person drawing the tree was interested in the evolution of mammals—but four limbs and fur are not somehow superior to fins and scales.

To help break up your students' intuition about trees, show them how nodes (branching points) in a tree model can be rotated to generate equivalent phylogenies, such as the trees below.

The pipe cleaner tree model that is part of this lesson should help your students with this misconception. Figures throughout this lesson have been drawn in ways other than the typical to help as well.



Evolutionary trees are often drawn branching up and to the right, as shown on the left. This can give the false impression that there is one "main" lineage with multiple "side" lineages. Drawing equivalent trees by rotating around nodes can help dispel this misconception.

Source: adapted from UCMP's Understanding Evolution http://evolution.berkeley.edu

Tree Misconception 2: How close together two species or groups are to each other on the tree is a measure of how related they are.

This idea is intuitively satisfying because we tend to associate proximity in space to similarity—after all, in many charts and tables, similar things are grouped together. But the reality is that evolutionary trees are read from root to tip (or tip to root)—not from left to right across the tips.

The more recently two taxa shared a common ancestor (represented by a shared node), the more closely related they are. In the model below, triangle and circle are on adjacent tips, but the triangle is more closely related to the oval than to the circle because the triangle and oval share a more recent common ancestor than the triangle and the circle. Here again, rotating trees around their nodes can be helpful.



Proximity does not correlate to relatedness on evolutionary trees. The only reliable means to determine relative relatedness is to compare the time to a recent common ancestor. Pairs of taxa that share a deeper node (a node closer to the root of the tree) are more distantly related than taxa that share a node closer to the tips.

Source: Adapted from UCMP's Understanding Evolution (http://evolution.berkeley.edu)

Also, look out for your student's thinking that a shorter branch represents a more evolved taxa because it evolved more recently in time. In the tree above, the triangle might be erroneously assumed to be more evolved than the circle because it sits at the end of a shorter branch. But remember that any two branches can be traced back along their lineages to a common node. Therefore, the evolutionary histories, or lineages, of the triangle and the circle are an identical duration.

It doesn't matter that you have to go back three nodes in the triangle lineage and back just one node for the circle lineage—all that tells us is that in this model, more branching points are included for the triangle lineage than for the circle lineage.

Broadly stated: Any two living taxa—whether two living individuals, two living species, or two living groups of species—have identically long evolutionary histories.

Tree Misconception 3: Evolutionary change only occurs at branching points.

Branching points represent the time when a common ancestor population splits into two separate lineages. However, evolutionary change can and does occur at all points along a lineage. Changes that make a given group or species distinct could have happened before or after a modeled splitting event.

In the tree below, many of the characteristics that make birds birds occurred after their split from Archaeopteryx. Another reason not to equate branching with evolutionary change is that evolutionary trees are models that can be simplified.

In the model below, "living birds" represents thousands of species—a model could show a branch for each species but has collapsed it down to one branch because the focus of the model is not relationships among living birds, but the relationships among living birds and extinct ancestors.



Evolutionary change is not limited to lineage splitting events. Changes happen all along the lineages.

Source: Adapted from UCMP's Understanding Evolution (http://evolution.berkeley.edu)

Procedure:

I. Pass out the worksheet "Preconceptions about Evolutionary Trees" and a copy of Ray Troll's "Tree of Life" illustration.

Ask students to complete the Preconceptions worksheet. Reassure them that they are not supposed to know all the answers—the point is to get a sense of what they think they know about evolutionary trees. They will have a chance to revise their answers after the lesson.

2. Pass out the "A Pipe-Cleaner Model of Animal Evolution" worksheet. Then explain that the worksheet has two parts. As individuals, in pairs, or in small groups, have students complete the "A Pipe-Cleaner Model of Animal Evolution" worksheet.

To complete Part A of the worksheet, students will need to have access to pipe cleaners—at least six pipe cleaners of different colors. The instructions call for blue, red, orange, yellow, purple, and black, but can be changed to match whatever colors you have. Students will also need access to colored markers, pencils, or pens in these colors.

3. Upon completing the "A Pipe-Cleaner Model of Animal Evolution" worksheet, instruct students to revisit their "Preconceptions about Evolutionary Trees" worksheet and make any changes to their original answers.

4. Have a class discussion to go over the "Preconceptions about Evolutionary Trees" worksheet. Ask volunteers to share how their answers changed after completing the "A Pipe-Cleaner Model of Animal Evolution" worksheet.

5. As a final wrap-up, have students compare their trees from Part B with Ray Troll's tree. Have a discussion about the similarities and differences. Do they show the same relationships among the taxa (beetle, crab, jellyfish, snail, sponge, starfish)? Which tree is easier to understand? What do they like about each, etc.



Name(s):

_ Date: __

Preconceptions about Evolutionary Trees

Student Edition Worksheet



Introduction:

Have you ever seen a branching diagram, like the one shown here? You probably have, in a textbook or at a museum. These diagrams are called evolutionary trees because, well, they are shaped kind of like trees and they tell us something about evolution! You have likely seen many examples of evolutionary trees in museums, school, or books. But what do you know, or think you know about how to read evolutionary trees? Today, you will be working through a lesson on how to build and "read" evolutionary trees.

Instructions

Read each of the statements below and decide whether it is a true statement or a false statement. Circle the appropriate letter (T or F) and jot down your reasoning. It is completely fine if you are only guessing—you are not expected to know these answers yet.

As you work through the lesson, note any of your answers that change. Do not erase or cross out your original answers. Instead, take notes in the appropriate space after each question. Be prepared to discuss your answers with the class.

I. Evolutionary trees are models. T/F

Reasoning:

Questions 2–5 are about Ray Troll's Tree of Life, shown to the right. (To answer the questions, you will find it easier to look at the full-size version your teacher has provided.)

2. According to Ray Troll's Tree of Life, sea cucumbers are more evolved than sea stars. (Both groups can be found near the top of the tree.) T/F

Reasoning:



Ray Troll's Tree of Life

Did your answer change? Y/N

3. In Ray Troll's Tree of Life, Eukaryotes are more evolved than prokaryotes. T/F

Reasoning:

Did your answer change? Y/N

4. In Ray Troll's Tree of Life, time runs from the roots to the leaves. T/F

Reasoning:

Did your answer change? Y/N

5. In Ray Troll's Tree of Life, each leaf represents an unchanging, un-evolving group of organisms. T/F *Reasoning:*

Questions 6–10 are about the Arthropod Tree shown to the right.



6. According to the Arthropod Tree, beetles are more closely related to crabs than they are to flies. T/F *Reasoning:*

Did your answer change? Y/N

7. The node (branching point) labeled "C" on the Arthropod Tree represents the common ancestors of flies and butterflies. T/F

Reasoning:

8. The tree to the right gives the same information as the Arthropod Tree above even though it looks different. T/F *Reasoning:*



Did your answer change? Y/N

9. According to the Arthropod Tree, flies are move evolved than crabs. T/F

Reasoning:

Did your answer change? Y/N

10. According to the Arthropod Tree, crabs haven't changed at all since they showed up on Earth. T/F Reasoning:

Preconceptions about Evolutionary Trees

Teacher Edition Worksheet

I. Evolutionary trees are models.

This is true. Evolutionary trees, no matter what style they are drawn in, are models of evolutionary relationships. Before you begin the lesson, it might be helpful to review the basic anatomy of a tree, as summarized below.



Questions 2–5 are about Ray Troll's Tree of Life, shown to the right. (To answer the questions, you will find it easier to look at the full-size version your teacher has provided.)

2. According to Ray Troll's Tree of Life, sea cucumbers are more evolved than sea stars. (Both groups can be found near the top of the tree.)

This is false. Your students might think that the model suggests sea cucumbers are more evolved because they are located at the very top of the tree, whereas sea stars are located a bit down and to the left. It is important that your students come to understand that no one living group is in any way more evolved



Ray Troll's Tree of Life

or better than another. Evolutionary trees show which taxon evolved earlier or later in time, but relative order of evolution is not a measure of how advanced or evolved a group is. Sea cucumbers and sea stars can both trace their ancestry back to a common point in time, making them (and every other living group of organisms) equally evolved.

3. In Ray Troll's Tree of Life, Eukaryotes are more evolved than prokaryotes.

This is false. Again, no living taxon is more evolved than another. In Ray Troll's tree, eukaryotes appear to be above prokaryotes near the base of the tree, which may cause some students to think that eukaryotes are more evolved. They are more recently evolved, but that does not make them more evolved.

4. In Ray Troll's Tree of Life, time runs from the roots to the leaves.

This is true. Time always runs from root to tips, no matter the style of tree.



5. In Ray Troll's Tree of Life, each leaf represents an unchanging, un-evolving group of organisms.

This is false. The tips of branches in an evolutionary tree simply represent the youngest lineages in the model. These taxa can be groups of species, as in Ray Troll's tree, or they can be single species, individuals, or even genes! Evolution is always occurring within populations, so the groups of species identified in the leaves of The Tree of Life—including humans!—are very much changing and evolving.

Questions 6–10 are about the Arthropod Tree shown to the right.

6. According to the Arthropod Tree, beetles are more closely related to crabs than they are to flies.

This is false. Students may be tempted to say this is true because when read across the tips, left to right, beetles and crabs are next to each other, while beetles and flies are separated by butterflies.



Evolutionary trees are not read across the tips, however. The only thing that can determine relative relatedness is tracing lineages back through time to a common ancestor. Tracing the lineages back in time from tips to root, it is clear that beetles and flies share a more recent common ancestor (represented by node B) than do beetles and crabs (represented by node A). Therefore, beetles are more closely related to flies than to crabs.

7. The node (branching point) labeled "C" on the Arthropod Tree represents the common ancestors of flies and butterflies.

This is true. Remind students that we commonly refer to "the common ancestor" when referring a node, but unless the tree has individuals at its tips, a more precise phrase would be "the common ancestor population." Nodes represent points in time when one ancestral lineage split into two or more descendant lineages through speciation events. This process occurs at the population level, so nodes represent populations not individuals.

8. The tree to the right gives the same information as the Arthropod Tree above, even though it looks different.

This is true. You can rotate branches around nodes without changing the evolutionary relationships depicted in a tree diagram. This has the effect of changing the order of terminal taxa, but not changing the information that the tree conveys. The tree presented in this question is identical to the athropod tree, it has just been rotated around Node A. All of the trees below are equivalent:





9. According to the Arthropod Tree, flies are move evolved than crabs.

This is false. The more often you can repeat this to your students the better: no one group, no matter is position on a tree or anything else, is more evolved than another.

10. According to the Arthropod Tree, crabs haven't changed at all since they showed up on Earth.

This is false. Students may be tempted to agree with this statement because the crab lineage is unbranched. Long, unbroken branches appear when one group on the tree is comprised of only a few lineages or because the tree designer opted to show only a few members of the group on the phylogeny. The long, unbroken branch is caused by the relative size of the groups on the tree and has nothing at all to do with the amount of evolutionary change a lineage has undergone. In this tree, the taxon "crabs" is representing the group known as crustaceans, which includes at least four distinct subgroups not individually represented in the model. Beetles, flies, and butterflies each represent a subgroup of insects, which is the sister group (or most closely related group) to crustaceans according to most analyses.

There was a choice on the part of the person drawing this model to show three of the insect groups while lumping together all crustaceans groups to one branch. It's important to remind your students often that trees are models that can be manipulated to emphasize different aspects of the relationships represented. So in this tree, we could assume that the tree designer was more interested in insect relationships than arthropod relationships.



Name(s):

_____ Date: __

A Pipe Cleaner Model of Animal Evolution

Student Edition Worksheet

Introduction:

The evolutionary tree shown here was drawn by Charles Darwin, a scientist who lived more than 150 years ago. It was Darwin, and another man named Alfred Russel Wallace that came up with the idea of natural selection, which is one of the ways that life evolves. Darwin wasn't the first person to suggest that life evolves, the idea had been around for a while, but he was one of the first to use evidence to explain his observations about life.

This lesson isn't about Darwin or natural selection, though—not directly, anyway! It's about the trees—trees like the one that Darwin drew in his notebook to model evolutionary relationships. What are evolutionary trees, how do you make one, and what can they tell us about evolution?

In the first part of this activity, you'll build an evolutionary tree using pipe cleaners. Then, in the second part of the activity, you'll use evidence to infer relationships among different groups of animals.



Darwin's tree, drawn in his 1837 notebook.

Source: Wikimedia Commons

Part A: Pipe-Cleaner Tree

Instructions:

I. Get six differently colored pipe cleaners from your teacher: blue, red, orange, yellow, purple, and black.

2. Line up the six pipe cleaners and twist them together about two centimeters (one inch) from the bottom. Twist all the way around twice.

3. Bend black pipe cleaner to the right and the other five to the left so they are separated as shown in illustration below.



5. Now about an inch along the group of pipe cleaners, twist them and repeat steps 3 & 4 but with the orange pipe cleaner.

6. Repeat this process three more times: first for the red pipe cleaner, then the blue, then the yellow and purple together. Your final product should look like this:



7. Take some time and twist your model around one or more branching points and draw the result. For example, if you rotated around the purple-yellow branching point, your model would look like this:



8 Use colored markers, pens, or pencils and draw at least two more "rotated" trees that you created below.

Part B: Modeling Relationships Among Animal Taxa

To understand trees, you need to understand something called common ancestry. You likely know that chimpanzees are the closest living relatives to humans. But do you know what that means? It means that if you go back far enough (more than seven million years!) you'd find a population of animals that had some traits in common with just humans, some traits in common with just chimps, and probably a lot of traits in common with both humans and chimps.

This population of animals is the common ancestor of humans and chimpanzees. If you could follow this population through time, at some point something would happen that would separate the population into two different groups. Over time, one of these groups would become more and more chimplike, and the other group would become more and more humanlike.

It turns out that you can do this, go back in time to find a common ancestor, with any two taxa (organisms, or group of organisms, singular: taxon) on the planet. That's because all life on Earth is related by common ancestry.

In this part of the activity, you will use evidence to determine patterns of relatedness among different animal groups.

Instructions:

The table below includes some important characteristics of six different groups of animals. Use the traits and your pipe cleaner to figure out which groups share the most in common by answering the questions after the table.

Table 1: Some Characteristics of Animal Groups

	Has specialized cells with nuclei	Has tissue	Has organs	Has a head	Has jointed arms and legs
Beetles	Yes	Yes	Yes	Yes	Yes
Crabs	Yes	Yes	Yes	Yes	Yes
Jellyfish	Yes	Yes	No	No	No
Snails	Yes	Yes	Yes	Yes	No
Sponges	Yes	No	No	No	No
Starfish	Yes	Yes	Yes	No	No

Evolutionary trees model relationships among taxa. Every taxon has a unique lineage, or evolutionary history. You can think of a lineage as the path back through time from the present to the beginning of all life. If you trace back any two lineages through time, eventually they will join up.

I. How many different taxa are in your pipe cleaner model, and how did you represent each of their lineages?

On a tree, lineages join at nodes. A node represents the time when one lineage split off from the other lineages on the tree.

2. How did you model nodes in your pipe cleaner tree?

The nodes on your pipe cleaner model represent the common ancestors of all the taxa "above" the node. The more recently two taxa share a common ancestor, the more recently their lineages split, and therefore the more closely related the taxa are.

3. In your pipe cleaner model, which two colored taxa are the most closely related, and how do you know?

How do you know how recently two taxa shared a common ancestor? By looking for patterns in the traits they share. When a trait evolves in a population, it is passed down to all of the lineages that descend from that population. In this way, different groups of taxa come to share traits that other taxa (that descended from a different common ancestor) lack. When a trait is shared by a very small group of taxa, it usually means that those taxa are very closely related.

Look at the tree below. When you read a tree from root to tip, if you come across a trait, that means that all of the taxa "above" that trait share it. For example, in the tree below, dogs, cats, and chipmunks share the group trait "has fur." Fur evolved in the common ancestor population of all mammals, so all mammals share it.

Dogs and cats share the group trait "specialized meat-eating teeth." This trait evolved in a common ancestor of dogs and cats, which lived more recently than the common ancestor of all mammals. Other mammals do not have this trait. So cats and dogs belong to two groups: the mammal group (because they have fur) and the dog-cat group (because they have specialized meat-eating teeth). From this evidence, we can infer that cats and dogs are more closely related to each other than to mammal taxa that doesn't have specialized meat-eating teeth, like chipmunks.



4. Complete the table below by writing in all of the taxa that have each group trait. The first group trait has been completed for you on this page.

Trait	Specialized cells with nuclei	Tissues	Organs	A Head	Jointed arms and legs
Taxa that have the trait	Beetles				
	Crabs				
	Jellyfish				
	Snails				
	Sponges				
	Starfish				

5. Based on your table, which two taxa are the most closely related? Hint: Which pair of taxa share the most traits that other organisms don't have?

A representation of your pipe cleaner tree is shown below.



6. Look at your answer to Questions 4 and 5. Then, on the tree, fill in the two most closely related taxa and group trait that unites them.

7. Using your understanding of trees, and your table to guide you, label the rest of the taxa and group traits on the tree.

8. Two claims about your tree are below.

Claim I: Jellyfish are more closely related to sponges than to crabs because they are closer together on the tree.

Claim 2: Jellyfish are more closely related to crabs than to sponges because they share a more recent common ancestor.

a. Which claim do you support?

b. Explain your reasoning. Hint: Look back at Part A, Question 8 where you drew rotated trees. It might help you realize why one of the claims is wrong.

9. A friend sees your tree and says that it must mean that snails are more evolved than sponges. Are they right? Use the concept of lineage to justify your answer.

A Pipe-Cleaner Model of Animal Evolution

Teacher Edition Worksheet

Part A: Pipe-Cleaner Tree

Make sure that students understand what is meant by "rotating branching points" as this is a critical part of the lesson. A sampling of equivalent trees are shown below.



Part B: Modeling Relationships Among Animal Taxa

I. How many different taxa are in your pipe cleaner model, and how did you represent each of their lineages?

There were six taxa. Each taxon's lineage was represented with a different colored pipe cleaner.

2. How did you model nodes in your pipe cleaner tree?

By twisting together the pipe cleaners and then splitting one color off at a time from the others.

3. In your pipe cleaner model, which two colored taxa are the most closely related, and how do you know?

Purple and yellow. I know because they were the last two taxa to split off, so they have the most recent common ancestor.

4. Complete the table below by writing in all of the taxa that have each group trait. The first group trait has been completed for you.

**Note to teachers: Tree-building is not quite as simple a presented here. A shared-derived character, what we are calling a "group character" here, is a characteristic that has evolved in the most recent ancestral lineage of a group and was passed down to all descendant lineages. Evolutionary biologists use many different methods to build trees. An important method is called parsimony and involves grouping taxa such that the number of evolutionary changes is minimized. Instead of specialized meat-eating teeth evolving independently twice, for example, dogs and cats (and other taxa in the order Carnivora) are all grouped together such that specialized meat-eating teeth evolved just once and was passed on to all descendant lineages. In this way, subgroups of organisms can be defined by sets of shared-derived characters that only they have. You can learn much more about tree-building on the Understanding Evolution site.

Trait	Specialized cells with nuclei	Tissues	Organs	A Head	Jointed arms and legs
Taxa that have the trait	Beetles Crabs Jellyfish Snails Sponges Starfish	Beetles Crabs Jellyfish Snails Starfish	Beetles Crabs Snails Starfish	Beetles Crabs Snails	Beetles Crabs

5. Based on your table, which two taxa are the most closely related? Hint: Which pair of taxa share the most traits that other organisms don't have?

The beetle and crab

6. Look at your answer to Questions 4 and 5. Then, on the tree, fill in the two most closely related taxa and group trait that unites them.



7. Using your understanding of trees, and your table to guide you, label the rest of the taxa and group traits on the tree.



8. Two claims about your tree are below.

Claim I: Jellyfish are more closely related to sponges than to crabs because they are closer together on the tree.

Claim 2: Jellyfish are more closely related to crabs than to sponges because they share a more recent common ancestor.

a. Which claim do you support?

b. Explain your reasoning. *Hint:* Look back at Part A, Question 8 where you drew rotated trees. It might help you realize why one of the claims is wrong.

Sample answer: Closeness across the tips doesn't tell you anything about how closely related taxa are. I can rotate around any node and get jellyfish far away from sponges. However, I know from the tree that jellyfish and crabs share a more recent common ancestor (and therefore share more of their lineages and split apart more recently) than do jellyfish and sponges. That makes jellyfish and crabs more closely related to each other than either is to sponges.

9. A friend sees your tree and says that it must mean that snails are more evolved than sponges. Are they right? Use the concept of lineage to justify your answer.

Sample answer: My friend is wrong. The tree tells me that snails split off from other taxa more recently than sponges did, but their lineages are the same length because they share a common ancestor. No one living taxon can be more evolved than another.