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Supplemental Materials

for

Prevalence and Persistence of Misconceptions in Tree Thinking

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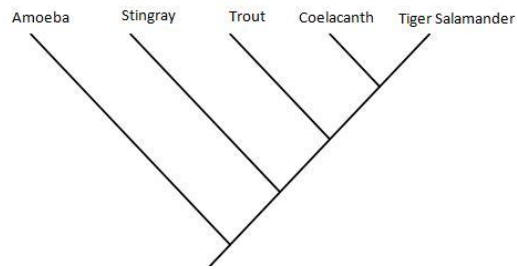
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Appendix 1: Assessment, detailed student response table, and student quotes

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422-2582. Fax: 801-422-0090. E-mail: tykummer@yahoo.com.

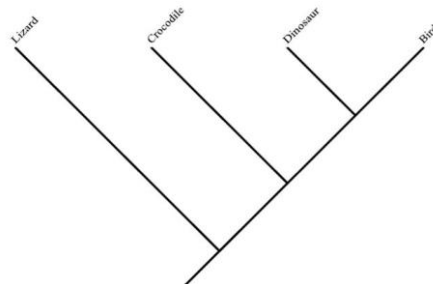Amoeba   Stingray   Trout   Coelacanth   Tiger Salamander

1. By reference to the tree above, which of the following is an accurate statement of relationships?
   a. A trout is more closely related to a stingray than to a coelacanth
   b. A trout is more closely related to a coelacanth than to a stingray
   c. A trout is equally related to a stingray and a coelacanth
   d. A trout is related to a stingray, but is not related to a coelacanth

2. Explain the reasoning you used to answer the previous question

Lizard   Crocodile   Dinosaur   Bird

3. By reference to the tree above, which of the following is an accurate statement of relationships?
   a. A crocodile is more closely related to a lizard than to a bird
   b. A crocodile is more closely related to a bird than to a lizard
   c. A crocodile is equally related to a lizard and a bird
   d. A crocodile is related to a lizard, but is not related to a bird

4. Explain the reasoning you used to answer the previous question
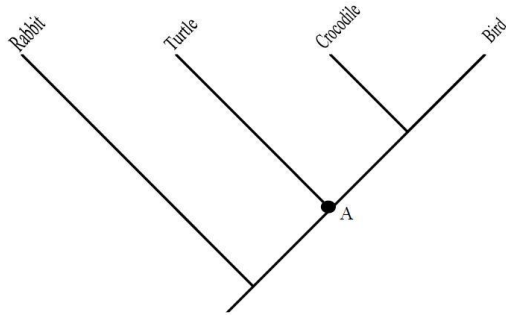
5. Given the tree above, what would you expect the common ancestor marked 'A' to look like
    a. Most like a rabbit because it is the only species that is an ancestor of A
    b. Most like a turtle because it is the most direct descendant of A
    c. Most like a crocodile because a crocodile is known to be a "living fossil"
    d. An equal mix of rabbit, turtle, crocodile, and bird features, because it is an ancestor of all of them
    e. One cannot say without a model of how traits evolved along the branches of this tree

6. Explain the reasoning you used to answer the previous question
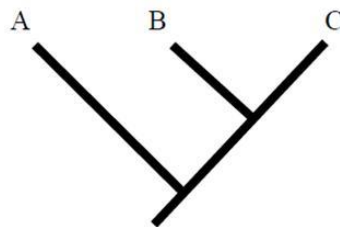
7. Which of the following is a correct interpretation of the tree shown above?
    a. "C" is descended from "B", which is descended from "A"
    b. "C" is the most advanced species
    c. "A" is the most ancient species
    d. "B" is an intermediate between "A" and "C"
    e. None of the above

8. Explain the reasoning you used to answer the previous question
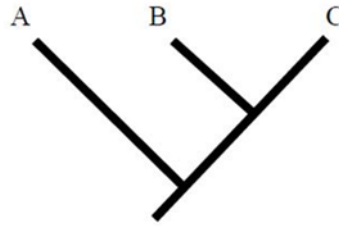
9. Referring to the above tree, which statement about common ancestry hold?
   a. A is the common ancestor of B and C
   b. The common ancestor of A and B lived after the common ancestor of A and C
   c. B and C share a more recent common ancestor than B and A
   d. Any common ancestor of C and B is also an ancestor of A
   e. None of the above

10. Explain the reasoning you used to answer the previous question
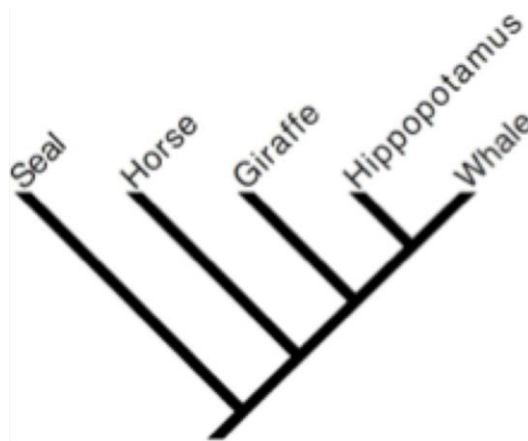
11. By reference to the tree above, which of the following is an accurate statement of relationships?
    a. A seal is more closely related to a horse than to a whale
    b. A seal is more closely related to a whale than to a horse
    c. A seal is equally related to a horse and a whale
    d. A seal is related to a whale, but is not related to a horse

12. Explain the reasoning you used to answer the previous question
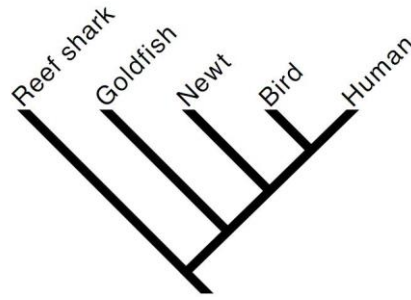
13. Assume that the tree above is correct. Which of the following is true?
    a. Reef sharks are older than newts
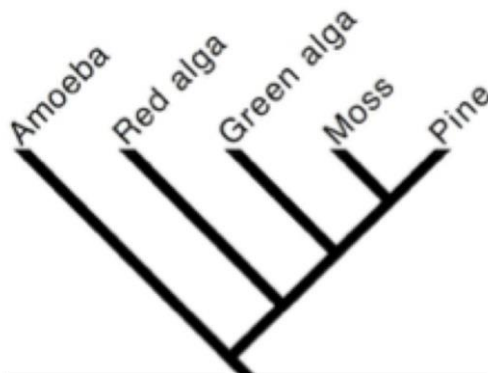   b. Reef sharks gave rise to goldfish
    c. The common ancestor of goldfish and humans lived before the common ancestor of birds and humans
    d. Reef sharks and goldfish have no common ancestor
    e. Birds came before humans

14. Explain the reasoning you used to answer the previous question

15. Looking at the tree above, five students have different interpretations. Student A says that pine is the most advanced species because it is the most recent. Student B says that the pine is the least advanced species because all the others branch off it. Student C says that all the species are equally advanced because they have all evolved the same amount of time from their common ancestor. Student D says that based on similarities, Red and Green Alga are most closely related to each other and Moss and Pines are most closely related to each other. Student E says that based on similarity, only red and green alga are closely related. Which student is correct?
    a. Student A
    b. Student B
    c. Student C

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d. Student D

e. Student E

16. Explain the reasoning you used to answer the previous question

Sharks Salmon A B Mouse Human C Lizard
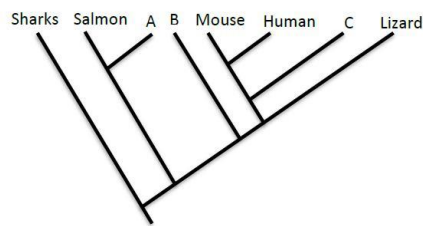
17. Looking at the tree above, where would you place a dolphin?

a. Position A

b. Position B

c. Position C

d. None

18. Explain the reasoning you used to answer the previous question

19. *Homo sapiens* evolved from *Pan troglodytes* (Chimp)

a. The above statement accurately reflects current scientific thought

b. The above statement is false because *Homo sapiens* did not evolve

c. The above statement is false because *Homo sapiens* evolved from *Homo neanderthalensis*

d. The above statement is false because *Homo sapiens* and *Pan troglodytes* each evolved from a common ancestor

20. Explain the reasoning you used to answer the previous question

Supplementary Table 1. Report of the percentage of students classified with a misconception for each question and response. M1 is Reading The Tips, M2 is Node Counting, M3 is Ladder Thinking, M4 is Similarity Equals Relatedness, M5 is Branch Length, and Other is no clear misconception.

	Intro	Evo	Intro	Evo	Intro	Evo	Intro	Evo	Intro	Evo
Question	1&2		3&4		5&6		7&8		9&10	
A (Total)	13.5	5.1	66.2	43.6	5.4	10.3	5.4		13.5	15.4
M1	9.5		55.4	18.0						
M2			2.7	15.4						
M3	2.7	2.6		2.6	5.4	10.3	5.4		12.2	12.8
M4			5.4	2.6					1.4	
M5				5.1						
Other	1.4	2.6	2.7							
B (Total)	27.0	43.6	20.3	33.3	64.9	46.2	12.2	2.6	2.7	2.6
M2	5.4		1.4							
M3	1.4		4.1	5.1	63.5	46.2	10.8	2.6	2.7	
M4	6.8		4.1							
M5		20.5		10.3						
Correct	12.2	20.5	9.5	15.4						
Other	1.4	2.6	1.4	2.6	1.4		1.4			2.6
C (Total)	59.5	51.3	13.5	23.1			28.4	53.9	44.6	71.8
M1	41.9	15.4		2.6						
M2	12.2	28.2	10.8	20.5						
M3							25.7	51.3	1.4	
M4	1.4								1.4	
M5	1.4									
Correct									39.2	69.2
Other	4.0	7.7	2.70				2.7	2.6	2.7	2.6
D(Total)					1.4		16.2		23.0	2.6
M3					1.4		14.8		10.8	
M4									2.7	
Other							1.4		9.5	2.6
E (Total)					28.4	43.6	37.8	43.6	16.2	7.7
M3							4.1	2.6	6.8	
M4									5.4	
Correct					25.7	35.9	29.7	33.3		
Other					2.7	7.7	4.1	7.7	4.0	7.7
	Intro	Evo	Intro	Evo	Intro	Evo	Intro	Evo	Intro	Evo
Question	11&12		13&14		15&16		17&18		19&20	
A (Total)	66.2	61.5	27.0	23.1	14.9	28.2	2.7	5.1	35.1	48.7
M1	44.6	20.5								
M2	6.8	38.5								
M3			25.7	23.1	12.2	28.2			27.0	46.2
M4	9.5						2.7	5.1	1.4	
M5	1.4	2.5								
Other	4.0		1.4		2.7				6.8	2.6
B (Total)	13.5	10.2	10.8	5.1	5.4	7.7	35.1	43.6		

	1	2	3	4	5	6	7	8	9	10
M1					1.4					
M2	1.4	5.1								
M3	5.4	5.1	10.8	5.1	2.7	7.7	4.1	12.8		
M4	6.8				1.4		28.4	28.2		
Other							2.6	2.6		
C (Total)	16.2	28.2	47.3	69.2	37.8	30.8	58.1	48.7	2.7	2.6
M3	1.4			2.6				2.6		2.6
M4	1.4		1.4				6.8			
M5		5.1								
Correct	10.8	18.0	43.2	64.1	35.1	28.2	48.7	46.1		
Other	4.0	5.1	2.7	2.6	2.7	2.6	2.6		2.7	
D(Total)	4.1		6.8		40.5		4.1	2.6	62.2	48.7
M1					16.2					
M2					2.7					
M3	1.4		1.4							5.1
M4					18.9		2.7	2.6	1.4	
Correct									55.4	38.5
Other	2.7		5.4		2.7		1.4		5.4	5.1
E (Total)			8.1		1.4					
M3			6.8							
M4					1.4					
Other			1.4							

Supplementary Table 2. Representative quotes for each misconception. These quotes are each indicative of the types of responses categorized under each misconception during the coding process.

Reading the Tips
"A trout is one line away from both a stingray and a coelacanth so they are a similar difference away in relation."
"They are equal distances away. If the stingray were next to the coelacanth, then my statement would be false."
"The branches for a seal and a horse are closer"
"The seal and horse are closer together than the seal and whale (which are at opposite ends)."
"Horse is closer to a seal on the tree than a whale is."

Node Counting
"There are more evolutionary steps between the seal and the whale than between the seal and the horse."
"There is only one node between the seal and the whale, and there are two (if you count the bottom node, the first split) before you can get to the horse from the seal."
"The seal is only one break away from the horse while 3 from the whale."
"The bird is two steps away from crocodile while the lizard is only one step away."
"The same number of evolutionary divergences separate the two and they have a common ancestor."

Ladder Thinking
"I reasoned that since the trout was in between the coelacanth and the stingray, it seems to have evolved from the stingray while the coelacanth evolved from the trout."
"A seal is more closely related to a whale than to a horse because it branches off from the whale line, while the horse does also, it is not directly connected to the seal."
"The seal is more closely related to the whale because its species came from the whale species."
"The seal would be a descendent of the whale and so would the horse so they're related."
"The most recent should have evolved the most."

Similarity = Relatedness
"The trout has similar characteristics with the stingray but not the coelacanth."
"The trout has all the same traits as the stingray and does the coelacanth, but the coelacanth has traits that the trout does not."
"It has very few common traits with both of them."
"They share more common traits than the seal and the whale."
"The seal is a marine mammal as with the whale. Horses are land mammals."

Branch Length
"It is difficult to measure the edge lengths in this tree. It seems to me that there is equal distance for horse-seal and whale-seal paths."
"The branch length is longer between stingray and trout than it is between trout and coelacanth, so the trout is more closely related to a coelacanth than to a stingray."
"The branch is longer to the stingray. Usually the length of the lines determines the amount of relatedness one species holds to another."
"The length of the branches equates to amount of relatedness, shorter branches are more closely related. So the trout is more closely related to the Coelcanth (*sic*) because the lines are shorter, meaning there is less difference."
"The horse and the whale have the same branch lengths."